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Inventor(s)	WRIGHT; John David

INSULATABLE, INSULATIVE FRAMEWORK APPARATUS AND METHODS OF MAKING AND USING SAME

Abstract

A building framework is disclosed herein having a first structural member, a second structural member, and a third structural member disposed between the first and second structural members, a first web member connecting the first and third structural members in a spaced apart relationship, and a second web member connecting the second and third structural members in a spaced apart relationship. The first web member is positioned relative to the second web member such that the shortest distance between the first web member and second web member is greater than or equal to 5 times the thickness of the third structural member. Additional products, systems, and methods also are disclosed.

Inventors: **WRIGHT; John David (New Haven, CT)**

Applicant: **WRIGHT; John David** (New Haven, CT)

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS [0001] This application is a continuation of U.S. application Ser. No. 17/270,352 filed Feb. 22, 2021, which is the U.S. national phase of PCT Application No. PCT/US2019/047489 filed Aug. 21, 2019, which claims the benefit of U.S. Provisional Patent Application No. 62/720,808 filed Aug. 21, 2018, the contents of which are hereby incorporated by reference in their entirety.

TECHNICAL FIELD
[0002] This disclosure relates generally to construction, and more particularly to the construction of insulating structures with structural elements.
BACKGROUND
[0003] Publication 1 “Measure Guideline: Wood Window Repair, Rehabilitation, and Replacement” by Peter Baker, Building America Report-120, Building Science Press, 2012. Retrieved from https://www.buildingscience.com/documents/bareports/ba-1203-wood-window-repair-rehabilitation-replacement/view.
[0004] Publication 2 “Heat and Mass Transfer: a practical approach-3rd edition” by Y. A. Çengel, McGraw-Hill, New York, N. Y. (2003).
[0005] Publication 3 “Acoustic Absorption in Porous Materials,” by Kuczmarski et. al., NASA/TM-2011-216995.
[0006] Publication 4 ASTM Designation C168-97 “Standard Terminology Relating to Insulating Materials” reprinted by the American

Society for Testing and Materials.

[0007] Structural elements used in the construction of walls, ceilings, floors, doors and windows are generally made from wood or other composite material. Wood conducts energy, mostly in the form of heat, in all directions. However, the conductivity along the grain of the wood is about 2.5 times greater than the conductivity in a direction across the grain. A typical wall stud allows energy to flow from the stud surface having a first panel attached to the opposing stud surface having a second panel attached. This allows energy to flow in a direct path from one panel to the other through the stud with no insulative material resisting the flow of energy. Particularly in a stud which has stud edges separated by a joining member, the joining member allows a direct path of energy between the opposing stud surfaces. In an effort to improve resistance to energy flow by placing the joining member diagonally between the stud inside and outside portions to extending the joining member length, the energy flow may actually increase since the energy flow in the direction of the wood grain is 2.5 times the flow against the grain.

[0008] There is a need for a structural member that increases the resistance to energy flow from one edge that contacts a first panel to an opposing surface that contacts a second panel. The structural member described herein provides the resistance to energy flow which improves the overall insulative properties of the structure built with these structural members.

[0009] Buildings account for approximately 30% of global energy consumption. The structural frame of a residential building framed with solid sawn lumber accounts for approximately 20% of the total inefficiency if no corrective measures are taken. This problem is called thermal bridging. Windows are a source of even greater inefficiency. For example, a calculation performed by Building Science Corporation shows that a nominal R-value of 15 (° F..Math.ft.sup.2 per BTUh) wall has an actual R-value effectively equal to 7 (° F..Math.ft.sup.2 per BTUh) producing an inefficiency of more than 50% when vinyl-frame double-pane windows with a nominal R-value of 5 (° F..Math.ft.sup.2 per BTUh) constitute just 18% of the total wall area (publication 1).

[0010] Experimental application of the present embodiments and methods using off-the-shelf parts such as common 2×4 lumber and glass produces a 2×4 wall with an actual R-value of 15 (° F..Math.ft.sup.2 per BTUh), 0% inefficiency, and full efficiency (see FIG. **36**E) relative to the nominal R-value of 15 (° F..Math.ft.sup.2 per BTUh) for the wall (see Table 5) and more impressively a window with an actual R-value of 15 (° F..Math.ft.sup.2 per BTUh), 0% inefficiency due to thermal bridging, and full efficiency (see FIG. **36**G) relative to the nominal R-value of 15 (° F..Math.ft.sup.2 per BTUh) for the wall. Retrofitting every building with windows with full energy-efficiency relative to the rest of the building envelope over the course of 20 years alone would have a significant impact on the global energy consumption of buildings.

[0011] The embodiments and methods described herein represent a powerful way to address the problem and cost effectively construct buildings that can maintain a comfortable indoor environment via passive radiative heating by the sun in winter and passive radiative cooling to the sky in summer. The industry standard for calculating the energy efficiency of buildings is based on one-dimensional models of heat transfer. Due to this fact a rather lengthy disclosure is provided in order to explain how to intuitively understand heat flow in three dimensions and how to accurately correct the standard one-dimensional heat flow models to fully capture the effects of three-dimensional heat flow and thermal bridging.

[0012] For instance, the industry standard one-dimensional models of heat flow do not allow for the funneling type of effect where heat runs in a partially lateral direction across a wall into a thermal bridge and bypasses insulation (see wall assembly **3602** in FIG. **36**B). For that reason, the effect of thermal bridging is usually underestimated. The more efficient a building the greater the impact of thermal bridging on the percentage of heat loss and heat gain. Industry standard two-dimensional models and three-dimensional models of heat transfer implemented by computer programs are inaccessible to most trades, require lengthy setup time, and yield little physical insight into the problems and solutions when actually used.

[0013] In contrast, this disclosure defines measurement paths (metric paths) that a builder can actually draw with a pencil and measure with a measuring tape (see FIGS. **1**D-**1**H, FIG. **2**AH, and FIG. **2**AI). After measuring the length of the metric path in inches (mm) for heat flow the builder can simply multiply by the R-value per inch (R.sub.SI per mm) to obtain, the structurally insulative R-value, R.sub.sval (R.sub.SIs), in imperial (metric) units. Conservatively this method can be as rigorous as a fully developed three-dimensional heat flow calculation but has the advantage of simplicity and greater physical insight into the paths of least resistance along which heat can and does actually flow in reality.

[0014] With experience, and based on this disclosure, the conscientious builder may come to appreciate that more indirect metric paths lead to larger structurally insulative R-values and more direct paths lead to smaller structurally insulative R-values. An experienced and conscientious builder may then develop an intuition about the lengths required to achieve a minimum structurally insulative R-value with common building materials such as wood without any actual measurements or calculations. The very concept of a structurally insulative R-value defined herein will help create awareness in the building industry about the problem of thermal bridging, how to accurately quantify the problem, and how to solve the problem.

[0015] The manufacturable products described herein have specified values of path lengths and indirectness built in to achieve any required minimum structurally insulative R-value and therefore do not require any calculations. After assembling the products, such as structurally insulative studs and plates (embodiments of the invention), into a structurally insulative frame (also an embodiment of the invention) using the same traditional methods as conventional stick framing, the builder has structurally insulated the building. After filling the air-sealed structural frame with insulation, the insulation contractor completes full insulation of the building against heat. A significant advantage is that the disclosed thermally and structurally insulative products also work to structurally insulate against sound and fire spread.

[0016] Non-structural insulative construction elements are generally known. Non-structural insulation has features generally including relatively high resistivity and relatively low density by comparison to the structural elements. It is problematic when the structural elements used to construct a structure allow energy in the form of heat, fire, electricity, radiation, sound, and vibration to bypass the insulation. It would be useful to provide sufficient strength to the structural element and provide sufficient space for insulation within the structural element yet reduce the flow of energy through the structural elements themselves in order to improve the performance of an insulating barrier or collection of insulating barriers that incorporate the structural elements.

[0017] A preferred solution to this problem is to design and build a structurally insulative insulatable framework that has (1) sufficiently long metric paths, i.e. the shortest paths along which heat flows between warmer and colder parts of the structure (insulative aspect), (2) sufficient interior space for insulation (insulatable aspect), (3) sufficiently thick and sufficiently wide structural parts (strength aspect), (4) balanced ratio of structural insulation length to thickness of insulation layers (balance between the insulative and insulatable aspects), (5) balanced ratio between thickness of insulation layers and thickness of structural parts (balance between insulatable and strength aspects).

[0018] Although developed for fire-safety and energy-efficiency in residential and commercial buildings, the present embodiments and methods have a broad range of application in other areas requiring structures that insulate not just against heat but also other forms of energy such as sound, fire, electricity, and vibration. For example application of the disclosed embodiments on a micro-structural or nano-structural level, with a sufficiently insulative gas filling the internal cavities, promise materials with high, engineered values of structurally insulative resistance and better overall resistance than that of state-of-the-art materials.

SUMMARY

[0019] Bearing in mind the problems and deficiencies of the prior art, it is therefore an object of the present invention to provide a structural member which has insulative properties.

[0020] It is another object of the present invention to provide a structural member which compliment insulative materials used with the structural member.

[0021] A further object of the invention is to provide a structural member for supporting panels on opposing sides of the structural member which resists heat transfer between the opposing panels.

[0022] It is yet another object of the present invention to provide a panel structure having spaced first and second planar panels which provide structural integrity and resistance to heat transfer.

[0023] Still other objects and advantages of the invention will in part be obvious and will in part be apparent from the specification.

[0024] The above and other objects, which will be apparent to those skilled in the art, are achieved in the present invention which is directed to a panel structure including spaced first and second planar panels and a plurality of spaced structural members connecting facing surfaces of the first and second panels. Each of the structural members includes a first frame member in contact with the first planar panel in a longitudinal direction, a second frame member in contact with the second planar panel in the longitudinal direction, the second frame member being spaced from the first frame member and substantially parallel thereto and a connecting frame member between and contacting the first and second frame members, the connecting frame member contacting the first frame member at a plurality of first locations and contacting the second frame member at a plurality of second locations, the first and second frame members having free interior-facing surfaces between the first and second locations. The connecting frame member provides no direct path of conductive heat flow, in a direction perpendicular to the longitudinal direction, between interior-facing surfaces of the first and second frame members. The structural members may be made of wood or a composite thereof. The distance between first locations and second locations is at least 2 times the distance between the first and second frame members. The connecting frame member comprises a central frame member substantially parallel to the first and second frame members and a plurality of linking members perpendicular to the central frame members in contact with the first and second frame members at the first and second locations. The connecting frame member comprises a central frame member substantially parallel to the first and second frame members and a plurality of first linking members connecting a first surface of the central frame member to the first frame member and a plurality of second linking members connecting a second surface of the central frame member opposite the first surface of the central frame member to the second frame member. None of the first linking members are directly opposite any of the second linking members. The connecting frame member comprises a central frame member substantially parallel to the first and second frame members and a plurality of linking members, each linking member secured either diagonally between the first frame member and the central frame member or diagonally between the second frame member and the central frame member. The panel structure may include secondary linking members connecting one of the spaced structural members to at least one other spaced structural member. The secondary linking members may connect one of the spaced structural members to at least one other spaced structural member wherein the secondary linking members provide no direct path of conductive heat flow, in a direction perpendicular to the longitudinal direction, between spaced structural members.

[0025] Another aspect of the present invention is directed to a method of making a panel structure, the plurality of spaced structural members have the facing surfaces of the first and second panels connected using the structural members wherein the connecting frame member provides no direct path of conductive heat flow, in a direction perpendicular to the longitudinal direction, between interior-facing surfaces of the first and second frame members.

[0026] Another aspect of the present invention is directed to a structural member which connects a first and a second panel to make a panel structure. The structural member includes a first elongated frame member, a second elongated frame member spaced from and substantially parallel to the first elongated frame member and a connecting frame member between and contacting the first and second frame members, the connecting frame member contacting the first frame member at a plurality of first locations and contacting the second frame member at a plurality of second locations, the first and second frame members having free interior-facing surfaces between the first and second locations. The connecting frame member provides no direct path of conductive heat flow, in a direction perpendicular to the longitudinal direction, between interior-facing surfaces of the first and second frame members.

[0027] Another aspect of the present invention is directed to an insulative structural member including a first elongated frame member having a first length and a second elongated frame member spaced from and substantially parallel to the first elongated frame member, the second elongated frame member having a second length substantially the same as the first length. The insulative structural member includes a central elongated frame member spaced between and parallel to the first and second frame members, the central frame member having a third length substantially the same as the first length and a plurality of first connecting members joining the first elongated member to one surface of the central frame member, the first connecting members having a connection length shorter than the first length. The insulative structural member includes a plurality of second connecting members joining the second elongated member to an opposite surface of the central frame member, the second connecting members having a connection length substantially shorter than the first length. The structural member provides no direct path of conductive heat flow, in a direction perpendicular to the first length. The connection length of the plurality of first connecting members and the plurality of second connecting members may be less than 20% of the first length of the first elongated frame member and additionally may be less than 10% of the first length of the first elongated frame member. The first, second and central elongated members each may comprise a plurality of elongated lamination members secured to adjacent elongated members, and the first and second connecting members are comprise a plurality of connecting lamination members. The connecting lamination members of the first connecting members may be interwoven with the elongated lamination members of the first and central elongated members and the connecting lamination members of the second connecting members are interwoven with the elongated lamination members of the second and central elongated members.

[0028] The first and second connecting members may be secured diagonally between the corresponding first or second elongated frame member and the central frame member. The first and second connecting members may be configured to give a first metric path between an outside surface of the first elongated frame member an opposing outside surface of the second elongated frame member with a first length L1 a first span S1 a first span-wise indirectness $I1=\{L1/S1\}-1$ greater than 100% (insulative aspect) equivalent to a first geometrical insulation factor $F1=L1/S1$ greater than 2, wherein the first metric path is shorter than any other metric path between the interior and exterior surfaces. The first and second connecting members may be configured to give a first direct path between an outside surface of the first elongated frame member an opposing outside surface of the second elongated frame member with a second span and a first cumulative distance between structural parts (a) greater than {(9%±1%) times the second span} (insulatable aspect) and (b) less than {80% times the second span} (not so insulatable that the structure becomes weak) wherein the first cumulative distance between structural parts is less than any other cumulative distance between structural parts for any other direct path between the interior and exterior surfaces. The first and second connecting members may be configured to give a first path length that is less than 85 times first cumulative distance between structural parts (balance between the insulatable and insulative aspects) wherein the structural parts include each structural member and the first and second connecting member.

[0029] Another aspect of the present invention is directed to an insulative structural panel having a front surface and back surface, the insulative structural panel comprising a pair of spaced structural members having a first length, a depth extending between the front surface and back surface, a width extending perpendicular to the depth, and spaced across in a direction of the width. Each spaced structural member comprises a first elongated frame member positioned along the back surface and extending in the direction of the spaced structural member length, a second elongated frame member positioned along the front surface spaced from and substantially parallel to the first elongated frame member, the second elongated frame member having a second length substantially the same as the first length and a central elongated frame member spaced between and parallel to the first and second frame members, the central frame member having a third length substantially the same as the first length. Each spaced structural member comprises a plurality of first connecting members joining the first elongated member to one surface of the central frame member, the first connecting members having a connection length shorter than the first length and a plurality of second connecting members joining the second elongated member to an opposite surface of the central frame member, the second connecting members having a connection length substantially shorter than the first length. The spaced structural member provides no direct path of conductive heat flow, in a direction perpendicular to the first length. The insulative structural panel includes a hardenable insulative material disposed between the front surface and the rear surface in a direction of the depth, between each of the spaced structural members in the direction of the width and substantially all of the space between the first and second frame members. The insulative structural panel may include at least one additional spaced structural member disposed parallel to the pair of spaced structural members. The insulative structural panel may include at least one additional spaced structural member perpendicular to the pair of spaced structural members. The at least one additional spaced structural member may be attached at each end to one of the pair of spaced structural member end. The insulative structural panel may include a foil radiant barrier attached to at least one of the front or rear surfaces. The hardenable insulative material may be a rigid closed-cell polyurethane foam.

[0030] Another aspect of the present invention is directed to an insulative window frame for installing a window having a perimeter. The window frame comprises a plurality of structural members joined around the perimeter of the window. Each structural member comprises a first frame member disposed along an edge of the window on one side of the window and a second frame member disposed along the edge of the window on the opposite side of the window and spaced from and substantially parallel to the first frame member. Each structural member includes a connecting window member between and contacting the first and second frame members, the connecting window member contacting the first frame member at a plurality of first locations and contacting the second frame member at a plurality of second locations, the first and second frame members having free interior-facing surfaces between the first and second locations. The connecting window member provides no direct path of conductive heat flow, in a direction perpendicular to the longitudinal direction, between the first and second frame members. The connecting window member may extend diagonally between the first frame member and the second frame member. The connecting window member may include a central frame member substantially parallel to the first and second frame members and a plurality of first linking members connecting a first surface of the central frame member to the first frame member and a plurality of second linking members connecting a second surface of the central frame member opposite the first surface of the central frame member to the second frame member.

[0031] Another aspect of the present invention is directed to an apparatus comprising first, second, and third structural members spaced apart from one another, a first brace connecting the first structural member to the second structural member, and a second brace connecting the second structural member to the third structural member. The second structural member is positioned between the first and third structural members. The first and second braces are configured to give a minimum rangewise indirectness greater than about zero +5%/−0% for the flow of energy along the shortest metric path between the first structural member and third structural member. The first and second braces are configured to make the cumulative distance between structural members greater than 20% of the apparatus depth.

[0032] Another embodiment described herein is an apparatus comprising first, second, and third structural members spaced apart from one another, a first brace connecting the first structural member to the second structural member, and a second brace connecting the second structural member to the third structural member. The second structural member is positioned between the first and third structural members. The first and second braces are configured to give a minimum rangewise indirectness greater than zero for the flow of energy along metric paths between the first structural member and third structural member. This condition means that there are no direct paths and no straight diagonal paths for the conductive flow of energy through the structural members and braces.

[0033] Another aspect of the present invention is directed to a building framework, comprising: a first elongated structural member, a second elongated structural member, and a third elongated structural member disposed between the first and second elongated structural members, a first web member connecting the first and third structural members in a spaced apart relationship, and a second web member connecting the second and third structural members in a spaced apart relationship, the second web member being closer to the first web member than any other web member disposed between the second and third structural members. The first web member is positioned relative to the second web member such that the shortest distance between the first web member and second web member is greater than or equal 5 times the thickness of the third structural member.

[0034] Another aspect of the present invention is directed to a building framework, comprising: a first elongated structural member, a second elongated structural member, and a third elongated structural member disposed between the first and second elongated structural members, a first web member connecting the first and third structural members in a spaced apart relationship, and a second web member connecting the second and third structural members in a spaced apart relationship. The first web member is positioned relative to the second web member such that the most direct metric path between the first elongated structural member and second elongated structural members establish has a minimum span-wise indirectness is greater than 100% (structural insulation factor greater than 2) for the flow of energy between any point on the first structural member and any point on the second structural member.

[0035] Another aspect of the present invention is directed to a method of making a building framework, comprising: obtaining first, second, and third structural members, obtaining a first web member configured to be positioned between the first and third structural members, and a second web member configured to be positioned between the second and third structural members, determining connecting locations for the first and second web members to ensure the most direct metric through-path establishing a maximum span-wise indirectness greater than zero for the flow of energy between any point on the first structural member and any point on the second structural member, and connecting the web members to the structural members at the determined connecting locations.

[0036] Another aspect of the present invention is directed to an insulatable building framework comprising: a first elongated structural member and a second elongated structural member in a coplanar arrangement; a first web member connecting the first and second elongated structural members; wherein either the web member is non-linear resulting in a range-wise indirectness greater than zero for the shortest metric path between the first and second structural members, or the web member is straight (linear) and has a slope substantially equal to r1/r2, wherein r1 is a thermal resistivity of an insulating material surrounding the web member and r2 is a thermal resistivity of the web member along its length. In embodiments, the web member is straight and the angle between the web member and first elongated structural member is between about 5° and about 40°. The thermal resisitivity r1 may also be a thermal resistivity of an insulating material surrounding the apparatus which may be different than the insulating material surrounding the web member.

[0037] Another aspect of the present invention is directed to a building apparatus comprising a set of structural parts, the structural parts comprising a first structural-member (a), a second structural-member (b), a third structural-member, a first web, a first web-member, a second web, and a second web-member, the second structural-member positioned between the first and third structural-members, the first web comprising the first web-member, the second web comprising the second web-member, each web-member in the first web connecting the first and second structural-members in a spaced apart relationship at a minimum distance greater than 30% times the thickness of the second structural-member, each web-member in the second web connecting the second and third structural-members in a spaced apart relationship, each web-member being made of a material with a tensile strength along the strongest axis of the material greater than about 1% of the least tensile strength of the structural-members. The structural parts are dimensioned and positioned so as to comprise at least one of (A) a most direct through-path through the structural parts at least 1.5 times longer than the span of the most direct path through the structural parts or (B) a most direct path through the structural parts at least 2 times longer than the span of the most direct path through the structural parts or (C) a most direct path through the structural parts at least 2.5 times longer than the span of the most direct path through the structural parts or (D) a most direct path through the structural parts at least 3 times longer than the span of the most direct path through the structural parts or (E) a web-member that connects a pair of structural-members in a spaced apart relationship at a minimum distance greater than 30% times the thickness of the second structural-member.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0038] The features of the invention believed to be novel and the elements characteristic of the invention are set forth with particularity in the appended claims. The Figures are for illustration purposes only and are not drawn to scale. The invention itself, however, both as to organization and method of operation, may best be understood by reference to the detailed description which follows taken in conjunction with the accompanying drawings in which:

[0039] FIG. **1**A illustrates a first embodiment of the framework configuration.

[0040] FIG. **1**B illustrates the first embodiment of the framework configuration with insulating substance.

[0041] FIGS. **1**C-**1**H illustrate energy flow paths through the structural member and web members of a framework.

[0042] FIGS. **2**AA-**2**AD illustrate embodiments with diagonal web members.

[0043] FIG. **2**AE illustrates a control with diagonal web members.

[0044] FIGS. **2**AF-**2**AG illustrate a truss with straight web members.

[0045] FIG. **2**AH illustrates preferred embodiment of a nominal 2×6 stud which can be scaled to ascertain preferred embodiments of nominal 2×3, 2×4, N×M where N and M can take on integer values.

[0046] FIG. **2**AI illustrates the metric path for the framework shown in FIG. **2**AH.

[0047] FIGS. **2**AJ-**2**AL illustrate sectional views of the embodiment shown in FIG. **2**AH.

[0048] FIGS. **2**B-**2**K schematically show various embodiments of 1D and 2D (biaxial) frameworks with more than one layer of diagonal braces.

[0049] FIGS. **2**M-**2**T schematically show various embodiments of uniaxial/1D frameworks with straight braces.

[0050] FIGS. **3**A-**3**F schematically show various web member (spacer or connector) shapes in the half-unit-cell of a framework with two chords.

[0051] FIGS. **3**G-**3**L show various web member shapes in the full-unit-cell of a framework with two chords.

[0052] FIGS. **4**A-**4**F show various web member shapes in a three chord truss.

[0053] FIGS. **5**A-**5**F schematically show various web member shapes in the half-unit-cell of a framework with three chords.

[0054] FIGS. **6**A-**6**C illustrate embodiments having three chords in one direction and three chords in another direction.

[0055] FIGS. **6**D-**6**F illustrate different structurally insulative biaxial frameworks.

[0056] FIGS. **6**G-**6**H illustrate structurally insulative, insulatable frameworks with a bend in them.

[0057] FIG. **6**I shows a structure that is not itself an embodiment of an insulatable, insulative framework but is a potential component in embodiments of a biaxial framework.

[0058] FIG. **6**J illustrates another embodiment of a structurally insulative biaxial framework.

[0059] FIG. **6**K illustrates yet another embodiment of a structurally insulative biaxial framework.

[0060] FIGS. **7**-**10** each illustrate a combination of a uniaxial framework and an internetworking web array that each constitute a biaxial framework **6**A and constitute an embodiment of an insulatable, insulative framework.

[0061] FIG. **11**A illustrates the union of four uniaxial frameworks using a first method of joinery.

[0062] FIG. **11**B illustrates the union of four uniaxial frameworks using a second method of joinery.

[0063] FIG. **11**C illustrates the union of four uniaxial frameworks using a third method of joinery.

[0064] FIG. **12**A shows a triple-pane window comprising first, second, and third biaxial frameworks that are shown and fourth biaxial framework that is not shown to better illustrate the structure.

[0065] FIG. **12**B shows the embodiment of FIG. **12**A with sheathing.

[0066] FIG. **12**C shows the opposing view of FIG. **12**A.

[0067] FIG. **12**D shows the opposing view of FIG. **12**B.

[0068] FIG. **12**E shows a frame embodiment incorporating four uniaxial frameworks.

[0069] FIG. **12**F shows the embodiment of FIG. **12**E with one of the four uniaxial frameworks removed and additionally comprising six sheets of material between the uniaxial frameworks.

[0070] FIG. **12**G shows another embodiment of a framework.

[0071] FIG. **12**H shows the embodiment of FIG. **12**G with one of the four unaxial frameworks removed and additionally comprising four sheets of material between the uniaxial frameworks.

[0072] FIG. **13**A shows structure **800** and demonstrates how uniaxial frameworks and biaxial frameworks can combine to form a frame that structurally insulates in three directions.

[0073] FIG. **13**B shows a close-up view of the south east corner of structure **800** shown in FIG. **13**A.

[0074] FIG. **14** illustrates one embodiment of a cylindrical tube framework.
[0075] FIG. **15** illustrates one embodiment of a biaxial framework that structurally insulates in the longitudinal direction of the biaxial framework.
[0076] FIG. **16** illustrates one embodiment of a triaxial framework with a front layer of three strut-like structures and a front layer of four brace-like structures.
[0077] FIG. **17**A illustrates one embodiment of an insulatable, insulative framework in the form of a building panel including.
[0078] FIG. **17**B shows the structural members and web members of the building panel of FIG. **17**A without the other parts.
[0079] FIG. **18** illustrates one embodiment of an insulatable, insulative framework as a building panel containing a lattice structure between two coverings.
[0080] FIG. **19** illustrates one embodiment of an insulatable, insulative framework as a triple-pane window with a scarf joint.
[0081] FIG. **20**A illustrates an embodiment of the framework demonstrating how to make and use a scarf joint to connect biaxial frameworks together.
[0082] FIGS. **20**B-**20**C schematically illustrate various embodiments of the type of framework depicted in FIG. **20**A.
[0083] FIG. **21** illustrates one embodiment of the framework that reduces the flow of energy along its normal axis.
[0084] FIG. **22**A illustrates one embodiment of the uniaxial/1D framework filled with insulating substance.
[0085] FIG. **22**B magnifies the dotted-line region of FIG. **22**A.
[0086] FIGS. **23**A and **23**B illustrate two types of connections between a structurally insulative stud and a structurally insulative top plate.
[0087] FIGS. **24**A and **24**B illustrate a framework comprising laminations.
[0088] FIGS. **25**A-**25**C schematically illustrate different embodiments of a joist-like framework in cross sectional views.
[0089] FIG. **25**D illustrates a joist-like framework that combines one type of web which incorporates diagonal web members and a second type of web which incorporates multiple chords connected together by blocks.
[0090] FIGS. **26**A and **26**B illustrate another embodiment of a joist-like framework with straight-through web members.
[0091] FIGS. **27**A and **27**B illustrate another embodiment of the three-chord I-beam containing two closed web-members.
[0092] FIG. **28**A illustrates one embodiment of the roof framework.
[0093] FIG. **28**B illustrates the framework in FIG. **28**A with gussets to join the framework members together.
[0094] FIG. **29** illustrates another embodiment of the framework incorporating a roof truss on an enclosure.
[0095] FIGS. **30**A-**30**D schematically illustrate various stacked and rotated embodiments of the framework with seamless connections of structural web-members and braces.
[0096] FIGS. **31**A-**31**E schematically illustrate various embodiments of the framework stacked and rotated.
[0097] FIGS. **32**A-**32**J schematically illustrate different embodiments of the framework with curves, bends, twists, bulges, and other distortions.
[0098] FIG. **33** illustrates one embodiment of the framework in radial form with surface web-member protrusions.
[0099] FIG. **34** depicts one embodiment of the three-chord framework and potential energy path.
[0100] FIGS. **35**A-**35**C depict embodiments of the framework in a rectangular frame with and without insulating substance.
[0101] FIGS. **36**A, **36**B show results of thermal imaging in side-by-side comparison testing of wall assemblies built with battens and structurally insulative studs (an embodiment of the invention) versus conventional studs with exteriorly applied rigid foam insulation.
[0102] FIGS. **36**C, **36**D show drawings of a test assembly incorporating structurally insulative studs and cross braces (embodiments of the invention).
[0103] FIG. **36**E shows results of thermal imaging in a side-by-side comparison testing of wall assemblies built with structurally insulative studs (an embodiment of the invention) versus conventional studs with exteriorly applied rigid foam insulation.
[0104] FIG. **36**F shows results of thermal imaging in a side-by-side comparison testing of wall assemblies built with structurally insulative studs (an embodiment of the invention) versus control studs with foam web members instead of wood web members.
[0105] FIG. **36**G shows a thermal photograph of interior surfaces for (1) a prototype window **2963**, (2) R−15 (° F..Math.ft.sup.2 per BTUh) insulation **2966** surrounding the prototype window, and (3) a standard double pane window **2960**.
[0106] FIG. **36**H shows a thermal photograph of exterior surfaces for (1) the prototype window **2970**, (2) R−15 (° F..Math.ft.sup.2 per BTUh) insulation **2973** surrounding the prototype window, and (3) a standard double pane window **2976**.
[0107] FIG. **36**I shows a thermal photograph like that of FIG. **36**H but showing a portion of cold sky **2983** with a temperature of −40° F. and another view of window **2980** with a different exposure level for the thermal imager.
[0108] FIG. **37** depicts one type of joint used between framework structures.
[0109] FIGS. **38**A-**38**I illustrate different embodiments of uniaxial frameworks joined together into a biaxial framework.
[0110] FIGS. **39**A-**39**B show multiple structurally insulative two chord frameworks.
[0111] FIG. **40** shows a metric path through an apparatus with irregularly shaped passages, cavities, protrusions, edges, and boundaries of the apparatus (shown with black lines).
[0112] FIGS. **41**A, **41**B, **42**A, **42**B illustrate different four chord uniaxial frameworks with different cross sectional shapes.
[0113] FIG. **43** is an exploded perspective view of a panel structure according to the present invention.
[0114] FIG. **44** is an exploded perspective view of an insulated panel structure according to the present invention.
[0115] FIG. **45** is a perspective view of a structure member according to the present invention.
[0116] FIG. **46** is a perspective view of a laminated structure member according to the present invention.
[0117] The section entitled “Definitions” provides a list of definitions to clarify the meaning of words and terminology used in this application. The remaining paragraphs in this section define terminology used to describe and illustrate directions in the next section which describes the figures in detail.

Definitions

[0118] The following definitions are generally used in the context of the specification, but the word used out of context may take the ordinary meaning.
[0119] Unless otherwise specified to the contrary, each of the following definitions holds in the stated context and the context of an insulatable, insulative framework apparatus. The definitions are given to a first level of approximation and sometimes a second level of approximation. In third and higher levels of approximation, one may need to interpret and modify the definitions below using the full specification, mathematics, physics, and linguistics in order to make everything consistent and error free. Unless otherwise stated all other meanings of the words and phrases apply outside of the stated context.
[0120] 1 by 3 (N by M): (in the context of an insulatable insulative framework) the dimensions of the framework expressed as N, the number of uniaxial frameworks constituting the framework, and M, the number of structural members in each of the N uniaxial frameworks.

[0121] areal thermal resistance: 1. the temperature difference that resists any given heat flux through a material divided by the heat flux; 2. temperature difference per unit heat flux needed to sustain one unit of heat flux; 3. R-value; 4. Rø.
[0122] bound path: 1. (in the context of a framework) any path that runs on or within the framework and that does not run through any of the cavities formed by the framework; 2. (in the context of a structure) a path that runs on or within the structure but does not run through any of the cavities formed by the structure; 3. (in the context of a structure made of structural parts) any path that runs through the structural parts of a structure and only the structural parts of the structure.
[0123] bound path of least resistance: (in the context of a specified first structural part and a specified second structural part of a structure) bound path from the first structural part to the second structural part with a path resistance wherein the path resistance is less than the path resistance of any other bound path between the first structural part and second structural part; 2. (in the context of a specified first location and a specified second location on or within a structure) bound path from the first location to the second location with a path resistance wherein the path resistance is less than the path resistance of any other bound path between the first location and second location.
[0124] BTUh: BTU per hour bundle: 1. (in the context of metric paths for an apparatus) a set of metric paths that all run through the same sequence of parts of the apparatus; 2. (in the context of metric paths for an apparatus) a set of metric paths that converge to the same point.
[0125] compressive strength: 1. (SI units) the compressive force per unit area, measured in metric units of N/m2, that a structural element can withstand without failure or plastic deformation; 2. (Imperial units) the compressive force per unit area, measured in imperial units of lbf/in2 (PSI), that a structural element can withstand without failure or plastic deformation.
[0126] cumulative distance between structural parts: (in the context of an insulatable, insulative framework) the running total of distance between pairs of structural members intersected by a direct path between the outermost structural members of the framework.
[0127] direct path: 1. (in the context of an insulatable, insulative framework apparatus) an unconstrained path of least distance that may run through any part of the insulatable, insulative framework apparatus including cavities, material within the cavities, and structural parts; 2. (in the context of a path with a specified starting point on or within an insulatable, insulative framework apparatus) an unconstrained path that may run through any part of the insulatable, insulative framework apparatus including cavities, material within the cavities, and structural parts with a value of directness greater than that of any other path starting at the specified starting point; 3. (in the context of a path with a specified starting location on or within an insulatable, insulative framework apparatus) an unconstrained path that may run through any part of the insulatable, insulative framework apparatus including cavities, material within the cavities, and structural parts with a value of directness greater than that of any other path starting at the specified starting location;
[0128] direct bound path: (in the context of a path with a specified starting location on or within an insulatable, insulative framework apparatus) a constrained path that runs through the structural parts but not through the intervening cavities of the insulatable, insulative framework apparatus with a value of directness greater than that of any other path starting at the specified starting location;
[0129] directness: (in the context of a path with a length and a span) span divided by the length.
[0130] fluxwise resistance (Rø): (in the context of a general description of areal resistance for different forms of energy) 1. the equivalent of “thermal insulation R-value,” otherwise known as areal resistance, which quantifies the stimulation per unit energy flux required for a unit of energy flux to flow through a barrier; 2. the “thermal insulation R-value” or the temperature difference (ΔT) per unit of heat flux (qø) required for a unit of heat flux to flow through a barrier, that is, Rø=ΔT/qø as derived from ΔT−qøRø or qø=ΔT/Rø (Fourier's Law for heat); 3. the “electrical insulation R-value” or squared voltage (ΔV.sup.2) per unit of electrical power (p) required for one unit of electrical power to flow through a barrier, that is R=ΔV.sup.2/p or equivalently Rø=ΔV.sup.2/pø=R/A=or=V/Rø as derived from p=ΔV.sup.2/R via p.ø=ø.Math.ΔV.sup.2/R and pø=ΔV.sup.2/(R.Math.ø−1) and pø=ΔV.sup.2/Rø; 4. R(Pa/(m3/s))=Δp(Pa)/Q where Δp is the pressure difference at either end of a channel and Q=volumetric flow rate of air in m.sup.3/s (publication 3); 5. the “acoustic R-value,”=Rø=D.Math.c/cos (o), or the squared sound pressure derived from qø=p2 cos (o)/(D c), where qø is the sound energy flux, p is the sound pressure, o is the angle between the direction of sound propagation and the normal to the surface, D is the mass density, and c is the speed of sound in the medium ((Fourier's Law for sound).
[0131] framework: 1. (in the context of an insulatable, insulative framework apparatus) a connected set of two or more structural members and one or more web members, 2. (in the context of an approximate general definition for a structure) structure comprising joined parts or conglomerated particles and intervening spaces wherein the intervening spaces are detectable at a specified resolution.
[0132] heat transfer coefficient: 1. areawise thermal conductance; 2. heat flux sustained by a temperature difference divided by the temperature difference.
[0133] horizontal: extrinsic direction x.
[0134] indirectness: 1. (in the context of a metric path) spanwise indirectness and/or rangewise indirectness.
[0135] insulatable: 1. (adj. in the context of a framework) providing space(s) for insulation inside the framework; 2. (adj. in the context of a structure) providing space(s) for insulation inside the structure; 3. able to be insulated.
[0136] insulative axis: (in the context of a framework) any intrinsic direction or intrinsic angle of the framework along which a metric path has a span and sufficiently large value of rangewise indirectness or spanwise indirectness.
[0137] insulative material: (in the context of this document) any mixture of substances that resists the flow of energy through an apparatus such as closed-cell insulation, open-cell insulation, rigid insulation, loose-fill insulation, blown-in insulation, spray-applied insulation, batt insulation, foam, expanding foam, spray foam, foamed-in-place insulation, cork, mud, straw, waddle/daub, sand, autoclaved aerated concrete, wood fiber, wood fiberboard, glass wool, cloth, ceramic composites, foils, films, fiber-mat polymers, asbestos, cellular glass board, cementitious foam, polyisocyanurate foam, polyurethane foam, polystyrene foam, extruded polystyrene foam, expanded polystyrene foam, fiberglass batts, cellulose insulation, aerogel, vermiculite, perlite, mineral wool, natural fibers, cotton, straw, hemp, plastic, wool, atmospheric pressure gas, atmospheric pressure gas with a larger molecular weight than air, low-pressure gas, noble gas, greenhouse gas, thermal insulation, electrical insulation, radiant barrier, acoustic insulation, fire-retardant insulation, fire-proof insulation, etc.
[0138] internetworking web member: a connector between first and second frameworks that is shared by the first and second frameworks (synonym of external web member).
[0139] internetworking: (in the context of a web member of a multiaxial insulatable insulative framework apparatus comprising a pair of frameworks) connecting an adjacent pair of frameworks.
[0140] intranetworking web member: a connector between structural members within a framework (synonym of internal web member).
[0141] intranetworking: (in the context of a web member of a multiaxial insulatable insulative framework apparatus) connecting the first and second structural members in an adjacent pair of structural members.
[0142] isothermal and adiabatic approximation of resistance: See for example page **148** publication 2. <. See file://Wright-truss-parallel-resistance-formula-derviation-adiabatic-approximation.mw.>
[0143] least cumulative thickness of structural parts: the least value of cumulative length of each successive line segment over which any one of the structural parts overlaps a long direct path through the structural parts as evaluated for a representative set of all long direct paths

through the structural parts, (example of a criterion that uses this definition) the least cumulative thickness of structural parts being less than 85% times the length of the longest direct path through the structural parts, least resistant bound path: See bound path of least resistance.
[0144] length-to-span ratio: 1. (in the context of a path with a span and a length) the length divided by the span of the path; 2. (in the context of a path with a span and a length) the fractional number of spans contained in the length; 3. (in the context of resistance) the factor by which a spanwise path resistance is multiplied in order to obtain the lengthwise path resistance.
[0145] length: 1. (in the context of a path) the length measured along the path; 2. (in the context of a path) the length measured along the path and not the range; 3. (in the context of a path) path length.
[0146] lengthwise path resistance: See structurally insulative resistance.
[0147] long direct path: a direct path that is longer than any other direct path that the direct path overlaps.
[0148] longest minor metric path: (in the context of a set of metric paths within a bundle) metric path with a length such that the length is greater than that of any other metric path in the bundle starting at any point on the opposite side of the most direct metric path relative to the start point of the longest metric path; (in the context of a set of metric paths) metric path with a length such that the length is greater than that of any other metric path starting at any point on the opposite side of the most direct metric path relative to the start point of the longest metric path.
[0149] longest metric path: (in the context of a set of metric paths within a bundle) a metric path with a length such that the length is greater than that of any other metric path in the bundle; (in the context of a set of metric paths) a metric path with a length such that the length is greater than that of any other metric path.
[0150] maximum rangewise indirectness: the maximum value of the rangewise indirectness for a specified set of metric paths.
[0151] maximum rangewise indirectness: the maximum value of the rangewise indirectness for the metric paths that run between any first point in a first specified space to any second point in a second specified space.
[0152] maximum rangewise indirectness: 1. (in the context of specified first and second spaces) maximum value of the rangewise indirectness for metric paths that run between any first point in the first space to any second point in the second space; 2. (in the context of a specified set of metric paths) maximum value of the rangewise indirectness for the specified set of metric paths; 3. (in the context of a most direct metric path) maximum value of rangewise indirectness for the shortest metric path that overlaps the most direct metric path.
[0153] member: one of a set, group, array, matrix, combination, pair, triplet, multiplet, tuple, or any other collection of things.
[0154] metric distance: 1. (as defined in https://en.wikipedia.org/wiki/Metric_space #Definition) for any system of roads and terrain is the distance between two locations can be defined as the length of the shortest route connecting those locations; 2. (in the context of a metric path in a framework) the length of the shortest metric path connecting two parts of the framework; 3. (in the context of a metric path in a structure) the length of the shortest metric path connecting two parts of the structure.
[0155] metric path: 1. (in the context of a first part of a framework and a second part of the framework) the shortest path between the first part and second part of the framework; 2. (in the context of a first part of a framework and a second part of the framework wherein the framework has temporary web members and/or non-structural web members) the shortest path between the first part and second part of the framework determined by excluding temporary web members and non-structural web members; 3. (provisional patent application) the shortest trajectory along which energy can flow through an object between any two specified points on or within the object; 4. (in the context of a framework made of an isotropically resistive material) bound path of least resistance; 5. (in the context of a framework made of an isotropically resistive material) least resistant bound path.
[0156] metric: (in the context of paths) relating to a binary function of a topological space that gives, for any two points in the space, a value equal to the distance between them, or equal to a value, treated as analogous to distance for the purpose of analysis, such as the metric distance.
[0157] minimum rangewise indirectness: the minimum value of the rangewise indirectness for the metric paths that run between any first point in a first space to any second point in a second space.
[0158] minimum rangewise indirectness: 1. (in the context of specified first and second spaces) minimum value of the rangewise indirectness for metric paths that run between any first point in the first space to any second point in the second space; 2. (in the context of a specified set of metric paths) minimum value of the rangewise indirectness for the specified set of metric paths; 3. (in the context of a most direct metric path) minimum value of rangewise indirectness for the shortest metric path that overlaps the most direct metric path.
[0159] most direct bound path: (in the context of a first part and second part of a framework) bound path from the first structural part to the second structural part characterized by a path length L, a span S, and a directness S/L, wherein the directness is greater than that of any other bound path between the first part and second part.
[0160] most direct path: (in the context of a path) a direct path possessing a greater value of directness than any other direct path that the direct path overlaps.
[0161] most-direct: 1. (in the context of a path) having the least value of spanwise indirectness; 2. (in the context of a path) having the greatest value of directness.
[0162] mother-web: the collection of structural parts that connect the outermost structural members in a uniaxial framework.
[0163] mother-web-minimum-span: (in the context of claim **1**) the statistical minimum value of span for the direct-path-set that intersects the mother-web.
[0164] number: 1. (in the context of the text “any number of” used in claims) any non-negative integer; 2. (in the context of the text “any number of” used in claims) any integer equal to zero or greater than zero.
[0165] panel: (in the context of a structure with metric paths and bundles) a spatial region of the structure that contains a single bundle of metric paths.
[0166] part: 1. (in the context of a framework) a structural member, a web, a web member, a web formation, a structural formation, a node, a surface, a cross-sectional slice, etc. within the framework; 2. (in the context of a structure) a structural member, a web, a web member, a web formation, a structural formation, a node, a surface, a cross-sectional slice, etc. within the structure.
[0167] path length: (in the context of a metric path with end points) the distance along a metric path between the end points determined by dividing the metric path into a representative set of path segments and cumulatively summing the segment length of all path segments in the representative set of path segments.
[0168] path of least resistance: (in the context of a specified first part of an apparatus and a specified second part of the apparatus) path from the first part through any part of the apparatus to the second part with a path resistance wherein the path resistance is less than the path resistance of any other path.
[0169] path resistance: (in the context of a path) local resistivity along the direction of the path multiplied by the differential length element and integrated over all differential length elements along the total length of the path.
[0170] path segment: (in the context of a metric path) part of the metric path created by dividing the metric path into a finite number of

pieces, each small enough to qualify as a straight line within the required accuracy for any given calculation.
[0171] r-value: 1. resistivity with overall units of (Km)/W or (° F..Math.ft)/(BTUh); 2. “small r” value.
[0172] range: (in the context of a path with two endpoints) the distance between the two endpoints of the path.
[0173] range-wise: rangewise.
[0174] rangewise directness: (in the context of a path with a path length and a range) range divided by path length.
[0175] rangewise indirectness: (in the context of a path with a path length and a range) **1**. {path length divided by the range} minus one; 2. (in the context of a most direct metric path for a framework) {metric subpath length divided by metric subpath range} minus one wherein the metric subpath is the shortest subpath between the outermost structural members touched by the most direct metric path; 3. (in the context of a most direct metric through-path for a framework) {metric subpath length divided by metric subpath range} minus one wherein the metric subpath is the shortest subpath between the outermost structural members touched by the most direct metric through-path.
[0176] rangewise number of switchbacks: the number of inflection points along a metric path divided by the range of the metric path.
[0177] rangewise path resistance: 1. (in the context of a path with a range through a material with an isotropic resistivity) the range of the path multiplied by the isotropic resistivity of the material; 2. (in the context of a path with a length and range through a material with an non-isotropic resistivity described by a resistivity tensor) an integral of the component of the differential length element in the rangewise direction of the differential length element multiplied by the component of the resistivity tensor in the rangewise direction of the differential length element obtained by integrating over the entire length of the path.
[0178] removable: (in the context of a removable web-member) a web-member that is non-essential to the structural integrity of a framework that can be completely removed, and by extension partially removed, so as to eliminate all metric-paths that run through the web-member.
[0179] representative set: 1. a subset with a large enough number of elements to achieve any required level of confidence for a calculation that depends on the number of elements in the subset such that the subset fairly represents the properties of a set that contains the subset; 2. a subset with properties that fairly represents the properties of a set that contains the subset when subjected to analysis.
[0180] resistance: (in the context of this document unless noted otherwise) areal resistance.
[0181] resistivity: 1. temperature gradient per unit of heat flux that sustains one unit of heat flux between a warmer surface and colder surface of a thermal barrier; (2) (in the context of imperial units and colloquial expression) R-value per inch; (3) (in the context of metric units and colloquial expression) R.sub.SI per m or R.sub.SI per mm; (4) (in the context of a general description for all forms of energy) the positive stimulation gradient per unit of energy flux that sustains one unit of energy flux between the higher-stimulation surface and lower-stimulation surface of an energy barrier.
[0182] resistivity multiplier: See structural insulation factor.
[0183] R.sub.sval: (uppercase “R” subscript “sval”) structurally insulative resistance.
[0184] I.sub.sval: (lowercase “r” subscript “sval”) structurally insulative resistivity.
[0185] segment length: the distance, as determined using the distance formula, between the end points of a path segment short enough to accurately approximate as a straight line, justify use of the distance formula, and achieve any required accuracy for any calculation that depends thereon.
[0186] segment resistance: (in the context of a path segment with a length and span through a material with an non-isotropic resistivity) segment length of the path segment multiplied by the resistivity of the material in the direction of the path segment.
[0187] segment span: (in the context of a metric path with a first end point and a second end point on or within two specified features) the projected length of a path segment when projected onto any intersecting line of closest approach, between the two specified features, each containing an end point for the metric path or connecting to another feature that contains an end point for the metric path.
[0188] shortest bound path: 1. (in the context of a first part and second part of a framework) any bound path from the first structural part to the second structural part characterized by a path length, wherein the path length is less than that of any other bound path between the first part and second part; 2. (in the context of a set of metric paths within a bundle) a metric path with a length such that the length is less than that of any other metric path in the bundle; 3. (in the context of a set of metric paths) a metric path with a length such that the length is less than that of any other metric path in the set of metric paths.
[0189] span-wise directness: (in the context of a metric path with a span and path length) span divided by path length.
[0190] span: (in the context of a metric path with a first end point on a first surface and a second end point on a second surface) shortest distance between the first and second surfaces as measured from the first end point or second end point when the two measurements give the same result wherein the first and second surfaces may be defined by contours of constant depth when either the first end point or second end point are not on a surface; 2. (in the context of a metric path with a first end point on a first surface and a second end point on a second surface) the distance spanned by a metric path between the first end point and the second end point determined by dividing the metric path into a representative set of path segments and then cumulatively summing the segment span for all path segments in the representative set of path segments wherein the first and second surfaces may be defined by contours of constant depth when either the first end point or second end point are not on a surface.
[0191] span-wise: spanwise.
[0192] spanwise direction: (in the context of a path between with two endpoints) the radius of an osculating.
[0193] spanwise indirectness: 1. (in the context of a path with a span and a path length) {path length divided by the span} minus one; 2. (in the context of a path with a span and a super-span length) {super-span length divided by the span} minus one; 3. (in the context of a path with a span and a length) length-to-span ratio minus one; 5. (in the context of a path with a spanwise path resistance through an isotropically resistive material) factor by which the spanwise path resistance is multiplied in order to obtain the super-span path resistance of the path; 6. (in the context of improving resistance for a structure) a multiplicative factor that quantifies the improvement in resistance for a metric path in the structure by comparison to a direct path through a solid of the same material and exterior dimensions as the structure.
[0194] spanwise number of switchbacks: the number of inflection points along a metric path divided by the span of the metric path.
[0195] spanwise path resistance: 1. (in the context of a path with a span through a material with an isotropic resistivity) the span of the path multiplied by the isotropic resistivity of the material; 2. (in the context of a path with a length and span through a material with an non-isotropic resistivity described by a resistivity tensor) the resistance along the span of a path determined by dividing the metric path into a representative set of path segments and then cumulatively summing the spanwise segment resistance for all path segments in the representative set of path segments.
[0196] spanwise resistance: spanwise path resistance.
[0197] spanwise segment resistance: (in the context of a path segment with a length and span through a material with an non-isotropic resistivity) segment span of the path segment multiplied by the resistivity of the material in the spanwise direction of the path segments.
[0198] spanresistive indirectness: (in the context of a path with a length and a span) {the path resistance divided by the spanwise path

resistance} minus one.
[0199] statistical uniformity: first statistic divided by a second statistic wherein the first statistic is the minimum value for a set of values and the second statistic is the maximum value for the set of values.
[0200] stimulation: 1. (in the context of thermal energy) temperature; 2. (in the context of electrical energy) voltage for electrical energy; 3. (in the context of acoustical energy) pressure; 4. (in the context of vibrational energy) pressure; 5. (in the context of mechanical energy) work; 6. (in the context of a general description for all forms of energy) quantity analogous to temperature in Fourier's law for all fundamental equations that can be expressed in the same form as Fourier's law; 2. temperature for heat flux grad (T)=q.sup.oR.sub.o as derived from q.sup.o=grad (T)/R.sub.o (Fourier's Law for heat); 3. squared voltage or voltage for electrical power based on choice of R.sub.o−R.sub.o′ or R.sub.o=V/R.sub.o′, ΔV.sup.2−p.sup.oR.sub.o as derived from p.sup.o=ΔV.sup.2/R.sub.o (Analogy of Fourier's Law for electricity). Note: I think that the squared voltage will actually be the square of the voltage gradient (grad.V.Math.grad.V) which is the magnitude of the electric field; 4. Square of sound pressure for acoustic power; 5. pressure for hydraulic power; 6. work for mechanical power. 7. the spatial concentration of energy particles that causes the energy particles to redistribute; 8. Level of energetic activity as function of spatial-temporal coordinates.
[0201] structural insulation factor: (in the context of a framework with a most direct metric path with a length L and span S) L/S.
[0202] structural member: 1. a structural part with the primary purpose of bearing applied structural loads; 2. a primary member of a structure, such as but not limited to a wall, wall frame, stud, portion of a stud, fabric warp, window frame, portion of a window frame, rafter, portion of a rafter, joist, portion of a joist, chord, portion of a chord; 3. (in the context of an insulatable insulative framework apparatus with exactly two structural members and exactly one web-member) a structural part that interfaces with a web member; 5. (in the context of an insulatable insulative framework apparatus that conforms to definition 1 or 2) a set of any number of structural-sub-members that each physically touch one other structural-sub-member in the set; 6. (in the context of the claims) a framework.
[0203] structural part: (in the context of an insulatable, insulative framework apparatus) a part that partially or fully constitutes the framework, possesses significant structural strength relative to other parts of the apparatus, and significantly contributes to the structural strength of the framework.
[0204] structural strength: 1. (SI units) the force per unit area, measured in metric units of N/m2, that a structural element can withstand without failure or plastic deformation; 2. (Imperial units) the force per unit area, measured in imperial units of lbf/in.sup.2 (PSI), that a structural element can withstand without failure or plastic deformation.
[0205] structural: (in the context of an approximate definition for this application) relating to or forming part of the structure of a building or other item, such as a panel, window, window frame, door frame, etc. the structural members of a window frame are not necessarily structural members for a building into which the window frame installs. Thus, “structural” is a relative term that depends on context.
[0206] structural: relating to or forming part of the structure of a building or other item, such as a panel, window, window frame, door frame, etc. The structural members of a window frame are not necessarily structural members for a building into which the window frame installs. Thus, “structural” is a relative term that depends on context.
[0207] structural: serving to form a structure. The term “structural” depends on context. A structural member of a window will not require the same strength as a structural member for a load bearing wall in a house.
[0208] structurally insulate: 1. (in the context of a framework with a most direct metric path with a length L and span S) possess a metric path with a length that is longer than its span; 2. (in the context of structural parts with an isotropic resistivity) possess a path of least resistance with a span and a structurally insulating resistance for which the structurally insulating resistance is greater than the resisitivity multiplied by the span; 3. (in the context of structural parts with an nonisotropic resistivity) possess a path of least resistance with a span and a structurally insulating resistance for which the structurally insulating resistance is greater than the spanwise resistance.
[0209] structurally insulate: 1. (in the context of a specified direction) resist the flow of energy along metric paths with a spanwise direction that significantly coincides with the specified direction; 2. (in the context of an insulatable insulative framework) resist the flow of energy along metric paths such as the most direct metric path through the framework.
[0210] structurally insulative resistance: 1. (in the context of a path with a span through a material with an isotropic resistivity) the path length of the path multiplied by the isotropic resistivity of the material; 2. (in the context of a path with a span through a material with an non-isotropic resistivity) resistance along the length of a path determined by dividing the metric path into a representative set of path segments and then cumulatively summing the segment resistance for all path segments in the representative set of path segments; 3. lengthwise path resistance; 4. R.sub.sval.
[0211] structurally insulative resistivity: 1. (in the context of a path with a span through a material with a non-isotropic resistivity) structurally insulative resistance of the path divided by spanwise resistance of the path; 2. (in the context of a path with a span through a material with an isotropic resistivity) structurally insulative resistance of the path divided by spanwise resistance of the path; 4. I.sub.sval.
[0212] structurally insulative R-value: 1. (in the context of a metric path with a path length through a material with a isototropic resistivity) structurally insulative resistance.
[0213] structure: a single body of material with cavities, such as a 3D printed house frame or means an object formed from parts such as a framework, frame, window frame, door frame, window, door, building, house, frame of a building, frame of a house, framework, a lattice, a truss, skyscraper, furniture, etc.
[0214] strut: (in the context of U.S. Provisional Patent Application No. 62/720,808) chord or an elongate structural member.
[0215] subpath length: (in the context of a subpath) arclength along the subpath.
[0216] super-range length: 1. (in the context of a path with a range and a length) the length minus the range; 2. (in the context of a path with a range and a length) the portion of the length that is above and beyond the range.
[0217] super-range resistance: (in the context of a path with a range and a length) the difference between the lengthwise path resistance and rangewise path resistance.
[0218] super-span length: 1. (in the context of a path with a span and a length) the length minus the span; 2. (in the context of a path with a span and a length) the portion of the length that is above and beyond the span.
[0219] super-span resistance: (in the context of a path with a span and a length) the difference between the lengthwise path resistance and spanwise path resistance.
[0220] tangential direction: (in the context of an insulatable, insulative framework apparatus) a term for the longitudinal direction of a framework that curves and loops back on itself to form a ring or ring-like structure.
[0221] temperature gradient: 1. (simple definition) the difference in temperature across a distance divided by the distance; 2. (physics definition) the vector derivative of a spatial temperature distribution function; 3. (in the context of this document) a placeholder for stimulation gradient which might otherwise be considered an indefinite term.
[0222] temperature: 1. (simple definition) level of thermal activity; 2. (broad definition which applies to any form of energy not just thermal

energy) level of stimulation; 3. acoustic stimulation.
[0223] tensile strength: 1. (SI units) the tensile force per unit area, measured in metric units of N/m2, that a structural element can withstand without failure or plastic deformation; 2. (Imperial units) the tensile force per unit area, measured in imperial units of lbf/in.sup.2 (PSI), that a structural element can withstand without failure or plastic deformation.
[0224] thermal areawise resistance: thermal resistance.
[0225] thermal conductance: 1. reciprocal of thermal resistance.
[0226] thermal conductance: heat flowrate sustained by a temperature difference divided by the temperature difference.
[0227] thermal conductivity: heat flux sustained by a temperature gradient divided by the temperature gradient.
[0228] thermal conductivity: the thermal gradientwise flux through a material, i. e., the thermal flux through a material in W/m2 or BTUh/ft.sup.2 generated in proportion to a specified thermal gradient across the material in K/m or ° F./inch with overall units of W/(m K) or (BTUh inch)/(ft.sup.2° F.) or BTUh/(ft° F.) and called the thermal conductivity for short.
[0229] thermal energy flux: 1. the energy per unit area per unit time characterizing the steady state number of quanta passing through the unit area in unit time. 2. the instantaneous energy per unit area per unit time characterizing the instantaneous number of quanta passing through the unit area in unit time.
[0230] thermal insulance: 1. the R-value of the material with overall units of (K m.sup.2)/W or (° F. ft.sup.2)/(BTUh); 2. (in terms of thermal resistance) the apparent areal thermal resistance of a material including the effects of conduction, convection, and radiation; 3. the reciprocal of thermal transmittance; 4. the thermally-transmitted-flux-area-wise temperature difference across a material.
[0231] thermal resistance: temperature difference per unit of heat flow rate.
[0232] thermal resistance: 1. the thermal-conductive-flux-wise temperature difference across a material; 2. The temperature difference between opposing sides of a material in K or OF needed to generate a specified thermal flux through the material in W/m2 or BTUh/ft.sup.2 with overall units of (K m.sup.2)/W or (° F..Math.ft.sup.2)/(BTUh); 3. a term used in ISO 8497:1994(E), for example; 4. a more exact term for a physical quantity that is sometimes called thermal resistance for short (publication 1); 5. a quantity similar to the R-value of a material except that it only includes the effect of conduction unlike the R-value which accounts for all modes of heat transfer including radiation and convection as well as conduction; 6. (in terms of thermal insulance) the portion of areawise thermal insulance associated with heat conduction and no other heat-transfer mode; 7. (in terms of R-value) the areawise R-value when conduction is the only heat-transfer mode.
[0233] thermal resistivity: 1. the temperature gradient per unit of heat flux that sustains one unit of heat flux between the warmer surface and colder surface of a barrier; 2. r.sub.val.
[0234] thermal resistivity: ratio of temperature gradient (in K/m or ° F./inch) across an object divided by the conductive heat flux (in W/m2 or BTUh/ft.sup.2) through the material generated by the thermal gradient with overall units of (K/m)/(W/m2) or (Km)/W or (° F..Math.ft.sup.2)/(inch BTUh) or (ft° F.)/BTUh.
[0235] through-path: 1. (in the context of a framework comprising structural members and an outermost pair of structural members) path between exterior facing surfaces of the outermost pair of structural members of the framework; 2. thrupath.
[0236] U-value: the thermal transmittance with overall units of W/(m.sup.2 K) or BTUh/(ft.sup.2° F.). vertical: extrinsic direction y.
[0237] web member: 1. (in the context of an insulatable, insulative framework apparatus) a structural part with the primary purpose of connecting other structural parts together; 2. (in the context of an insulatable, insulative framework apparatus) a connecting member; 3. (in the context of a multiaxial framework) an internetworking web member or an intranetworking web member; 4. (in the context of a web as defined herein) a member of the web.
[0238] web-members: 1. (in the context of U.S. Provisional Patent Application No. 62/720,808) webs where “webs” means “web members” in common parlance; 2. (in the present application) parts of a web where “web” means “collection of web members.”
[0239] web: (in the context of an insulatable, insulative framework apparatus) an array of one or more connecting members.
[0240] wood product: wood, finger-jointed lumber, variable-length lumber, lumber, logs, timber, paper, cardboard, corrugated cardboard, wood-fiber reinforced plastic, wood-fiber reinforced polymer, fiber board, GUTEX, medium density fiberboard (MDF), high-density fiberboard (HDF), oriented strand board, plywood, artificial wood, engineered lumber, structural composite lumber (SCL), laminated veneer lumber (LVL), cross laminated timber (CLT), cross-laminated lumber (CLL), dowel-laminated timber (DLT), dowel laminated lumber (DLL), toothpicks, nail laminated timber (NLT), nail-laminated lumber NLL), parallam, glulam, engineered strand lumber (ESL), laminated strand lumber (LSL), oriented strand lumber (OSL), parallel strand lumber (PSL), other forms of structural composite lumber, other forms of engineered lumber, other engineered wood products.

DETAILED DESCRIPTION

[0241] In describing the embodiments of the present invention, reference will be made herein to FIGS. **1**-**46** of the drawings in which like numerals refer to like features of the invention.
[0242] In a first embodiment of the present invention, a plurality of web-members or web-member-like structures are disposed between and joining together a plurality of structural members or structural-member-like structures to form a labyrinth of passages with intervening cavities. The cavities are preferably filled with one or more than one insulative filler substance or an embodiment of the disclosed apparatus to reduce the flow of energy through the cavities. In some embodiments, no insulative filler substance is used. In some embodiments, the cavities are evacuated to create a vacuum with a residual partial pressure of any magnitude. The passages and cavities preferably have shapes and proportions such that the shortest paths, through the passages between different parts of the apparatus, have a sufficiently long length in proportion to their span or range to create a multiplicative gain in resistance to the throughput of energy along targeted axes of the apparatus. Any gain in resistance relative to that of a direct-path provides a means to reduce the flow of energy through the apparatus even when made with structural materials that by comparison to the insulative filler substance generally have a higher density and lower resistivity. The cavities preferably have a geometry that balances the set of goals comprising (1) minimizing any reduction in strength of the apparatus, (2) creating space for one or more than one insulative filler substance, (3) maximizing the length of metric paths through the apparatus, (4) reducing transfer of the targeted forms of energy along direct paths through the apparatus and (5) reducing transfer of the targeted forms of energy along any path through the apparatus. The relative importance of each goal depends on the particular application. Thus, the relative importance of each goal preferably factors into the design and engineering of any given apparatus for any particular application.
[0243] When designing and engineering an apparatus, one should take care to properly assess the resistivity for the targeted forms of energy of the materials used to make the structural members and web members. Resistivity for all forms of energy is generally described by a tensor with different components that depend on the direction of energy flow relative to the axes of the material, that depend on the internal structure of the material. One should also take care to properly assess the strength of the materials used to make the structural members and web members. Strength is also generally described by a tensor with different components that depend on the orientation of the axes of the material relative to applied force. For instance wood and other materials containing fibers have strength, conductivity, and resistivity values

that depend on orientation of the fibers relative to stimuli. The strength along the fibers is greater than the strength perpendicular to the fibers. The conductivity along the fibers is also greater than the conductivity perpendicular to the fibers. The resistivity along the fibers is less than the resistivity perpendicular to the fibers. Additional benefits of the disclosed apparatus may include (1) increased surface area for greater capacitance and contact resistance, (2) a reduction in area through which energy can flow, (3) an increase in dimensional stability, (4) a reduction in weight, (5) directing mechanical forces to flow along the strong axis of employed structural materials, (6) providing space for installation of fasteners, for example nuts, bolts, floating tenons, rivets, and clinched nails, and other fasteners that require space for installation, (7) reducing the need to drill holes through framing members for installation of utilities, (8) providing space to run structural bracing, structural reinforcement cables, and tie-down cables, (9) reducing the moment arm on web-members under tension and compression, (10) reduction in labor costs, material costs, injury costs, and overall cost for construction of insulated buildings, (11) reduction in cost of manufacturing and distribution of insulative materials, (12) greater energy efficiency, (13) similar or higher strength, or (14) higher strength to weight ratio relative to a similar size structural element that has no cavities, smaller cavities, or inferior geometry.

[0244] Furthermore, the disclosed means of reducing energy transfer can preserve or even increase the cross sectional area of the passages yet still reduce energy transfer through the passages. For instance an embodiment of the apparatus can have arbitrarily large lateral dimension to achieve a targeted structural strength without compromising the thermal performance of the apparatus along its normal axis. An embodiment of the disclosed apparatus also enables the reduction of energy transfer along two, three, or any number of its axes called insulative axes. Embodiments can insulate even when web members and structural members are made from the same structural material or structural materials with similar values of resistivity. Embodiments can compensate for situations in which web-members, for reasons of structural integrity, economic cost or other practical concerns, are oriented such that the least resistive axis aligns with the path of energy flow through the structure in an undesirable direction. The material constituting the web members, do not need a significantly higher resistivity than the structural members. An embodiment can structurally insulate even when the structure constitutes a thermally unbroken framework for which the resistivity of web members is less than or equal to the resistivity of the structural members along the path of undesirable energy flow. Different embodiments of the disclosed apparatus may reduce the transmission of different forms of energy such as heat, sound, vibration, shock waves, electricity, electromagnetic energy, radiation, and fire. Thus, embodiments of the apparatus are useful for energy efficiency, temperature regulation, harnessing natural power sources, temperature control, construction, material science, energy storage, and numerous other applications. Corresponding usage, systems, and methods also are disclosed. Generally, the disclosed methods can be applied to improve the insulative value of an arbitrary structural frame or material, for instance through the selective removal of material or creating frameworks to engineer indirect metric-paths and properly size cavities within frameworks.

[0245] Statistical functions can be used to characterize properties characterizing the set of metric paths for different embodiments of the disclosed apparatuses. Spanwise indirectness, rangewise indirectness, structural insulation factor, rangewise indirectness multiplier, spanwise number of switchbacks, rangewise number of switchbacks, planarity of spanwise indirectness, and planarity of rangewise indirectness, are all examples of properties that characterize the set of metric paths for different embodiments of the disclosed apparatuses. Normalized spread, statistical uniformity, average, standard deviation, average deviation, maximum, minimum, statistical range, variance, are all statistical functions that may be applied to the properties that characterize the set of metric paths for different embodiments of the disclosed apparatuses. I anticipate use of these properties and statistical functions to further define the scope of the disclosed invention in future patent applications.

[0246] In FIGS. **1**A and **1**B and in general, any particular framework has three intrinsic directions, custom-character (lateral), custom-character (longitudinal), custom-character (normal). Intrinsic direction custom-character, the longitudinal direction, runs parallel to the length of the framework. Intrinsic direction custom-character, the normal direction, runs perpendicularly relative to the longitudinal direction and parallel to a line that runs through the center of the first, second and third chords. Intrinsic direction custom-character, the lateral direction, runs perpendicular to the normal direction and longitudinal directions. Each intrinsic direction has an associated axis that runs through the center of gravity by convention in this application unless otherwise specified. These directions apply generally to any object. If an object is part of a framework apparatus then the longitudinal direction custom-character of the part corresponds to the lengthwise direction of the part. When the object is not elongated in any direction, then the longitudinal direction corresponds to that of the framework that comprises the part unless otherwise specified. When any particular intrinsic direction of an object is ambiguous, then the intrinsic direction corresponds to that of the framework that comprises the part unless otherwise specified.

[0247] The words “horizontal,” “vertical,” and “transverse” are associated with extrinsic directions X, y, z, respectively. The extrinsic directions may be indicated in a figure with three line segments labeled x, y, z that emanate from a single point. The line segment labeled with an x indicates the positive/negative horizontal direction which are sometime referred to as right/left. The line segment labeled with an y indicates the positive/negative vertical direction which are sometimes referred to as up/down. The line segment labeled with an z indicates the positive and negative vertical direction which are sometimes described as “into the page” and “out of the page,” respectively. The words “horizontal,” “vertical,” and “transverse” do not refer to the intrinsic axes of the frameworks and do not limit their use. If no other indication exists to the contrary, then, when the text is right side up, (a) the vertical direction runs parallel to the long axis of a figure page and defines the terms up and down, (b) the horizontal direction runs parallel to the short axis of the figure page defining the terms left and right, and (c) the transverse direction runs into and out of the page defining the terms inward and outward. In the absence of further detail, the longitudinal direction of a reference object is associated with the extrinsic directional adjective used to describe it. For example “horizontal framework **10**” in reference to FIG. **1**A would indicate that the horizontal direction runs parallel to the longitudinal axis of framework **10**.

[0248] The three intrinsic directions x, y, z define intrinsic orbital directions Ocustom-character, Ocustom-character, Ocustom-character. Each intrinsic orbital direction Ocustom-character, Ocustom-character, Ocustom-character characterizes an orbital rotation around an intrinsic direction of any particular framework or object where the axis of rotation does not coincide with the axis for the particular intrinsic direction. Intrinsic angle Ocustom-character, the orbital roll angle, characterizes rotations around the longitudinal direction when the orbital roll axis and longitudinal axis are displaced as in a spiraling movement. Intrinsic angle Ocustom-character, the orbital yaw angle, characterizes rotations around the normal direction when the rotational yaw axis and normal axis are displaced as in a turn made by a car. Intrinsic angle Ocustom-character, the orbital pitch angle, characterizes rotations around the lateral direction when the orbital pitch axis and lateral axis are displaced as in a loop-the-loop movement. Each intrinsic orbital direction can be used to define positions, offsets, and differences in angle. When the axis of rotation around an intrinsic direction does coincide with the rotational axis for an intrinsic orbital direction, then the orbital rotation becomes a pure rotation called a spin. In that case each of the three intrinsic angles Ocustom-character, Ocustom-character, Ocustom-character characterize a spin rotation around an intrinsic direction of any particular framework or object because the rotational axis coincides with that of the intrinsic direction. To distinguish between orbital angles and spin angles, a slash is added to the symbol for spin angles. Intrinsic spin angle Øcustom-character, called the roll angle, characterizes spin rotations around the longitudinal direction when the orbital roll axis and longitudinal axis coincide. Intrinsic spin angle Ø custom-character, the orbital yaw angle, characterizes rotations around the normal direction when the rotational yaw axis and normal axis coincide. Intrinsic spin angle Ø![custom-character], the pitch angle, characterizes rotations around the lateral direction when the orbital pitch axis and lateral axis coincide. Each of the extrinsic directions x, y, z define extrinsic orbital angles Ox, Oy, Oz and extrinsic spin angles Øx, Øy, Øz. The extrinsic orbital angles Ox, Oy, Oz apply to orbital rotation of an object around an axis parallel to an extrinsic direction that does not intersect the object. The extrinsic spin angles Øx, Øy, Øz apply to the spin rotation of an object around an axis parallel to an extrinsic direction that does intersect the object. Pure spin rotation of an object occurs when the rotational axis coincides with the axis of the associated extrinsic or intrinsic direction. The central axis of any orbital/spin angle can be inferred by finding the center of a circle that overlaps the arc drawn in a figure to indicate the orbital/spin angle. Each orbital angle and spin angle is also useful for describing angular position, offset and differences in angular position.

[0249] Each embodiment also has related embodiments based on the orientation of materials constituting the framework. The orientation of a material within a structural member, web-member, or any part of a framework apparatus is important when the material has non-isotropic strength properties. The present specification uses the arbitrary convention that Y indicates the direction of greatest strength for a material, X indicates the direction of least strength, and Z indicates the direction transverse to the X and Y directions. In the case of a wood structural member the direction of greatest material strength often runs parallel to the longitudinal direction of the structural member. Material orbital angles O.sub.X, O.sub.Y, O.sub.Z and material spin angles Ø.sub.X, Ø.sub.Y, Ø.sub.Z can also be defined for the linear material directions X, Y, Z.

[0250] A label containing X, Y, Z, x, y, z, ![custom-character], ![custom-character], or ![custom-character], followed by a subscripted identification number indicates that the direction applies to an object labeled with the same identification number in a figure.

[0251] Such a label is often accompanied by a line or arrow to visually indicate the direction. For example the arrow labeled Y**104** in FIG. **3**A indicates the chosen direction of greatest material strength for the diagonal web-member **104**. Unless explicitly specified the illustrated or described orientation of materials is not limiting. The arrow labeled Y**105** in FIG. **3**G shows that the preferred direction of greatest material strength for web-member **105** runs in the same direction as the longitudinal direction of the web-member **105** indicated by the arrow ![custom-character]**105**. Unless explicitly noted otherwise, any indication of a material direction in a figure constitutes a preferred embodiment rather than a limitation. As a hypothetical example a lead line labeled ![custom-character]**14** in FIG. **1**A would indicate the longitudinal direction of framework **14**. If an identification number corresponds to a grouping of parts, then an X, Y, Z, x, y, z, ![custom-character], ![custom-character], or ![custom-character], followed by the identification number indicates the direction for all parts in the grouping of parts. As a hypothetical example, an arrow labeled Y**412** in FIG. **9** would indicate the direction of greatest strength for the material constituting all of the web-members in internetworking web array **412**. Any set of linear directions can be generalized to any curvilinear coordinate system such as a paraboloidal coordinate system, ellipsoidal coordinate system, spherical coordinate system, cylindrical coordinate system.

[0252] FIG. **1**A illustrates a structure **10** with four structural members or 1D (uniaxial) frameworks, including vertical structural members or vertical frameworks **12**, **14** and horizontal structural members or horizontal frameworks **16**, **18**. In embodiments of structure **10**, vertical frameworks **12**, **14** function as studs, jack studs, cripple studs, posts, or mullions while horizontal frameworks **16**, **18** function as top plates, double top plates, bottom plates, transoms, headers, sole plates, or sill plates. Vertical frameworks **12**, **14** are mounted on horizontal frameworks **16**, **18**. Horizontal framework **18** is mounted to the upper ends **20**, **22** of the vertical frameworks **12**, **14**, respectively. Horizontal framework **16** is mounted to the lower ends **24**, **26** of the vertical frameworks **12**, **14**, respectively. Each framework comprises first frame member or first chord **31**, second frame member or second chord **33** and central frame member or third (struts) chord **35**, which in the embodiment of FIG. **1**A are generally parallel to one another. For structural insulation purposes the first, second, and third chord **31**, **33**, **35**, of each horizontal framework **16** are preferably mounted to the first, second, and third chord **31**, **33**, **35** of the vertical frameworks **12**, **14**, respectively, as shown in FIG. **1**A. Each middle chord has a connecting member or web member on each side. Each connecting member or web member connects an elongated frame member or chord to an adjacent chord. For instance, framework **18** has at least a first connecting member or web-member **32** between chords **31**, **33** in the normal ![custom-character]**32** direction which in the embodiment shown is positioned at the terminal end **37** of horizontal framework **18** in the longitudinal ![custom-character]**32** direction. Framework **18** has at least a second web-member **34** between chords **33**, **35** in the normal direction which in the embodiment shown is positioned at the terminal end **39**. The embodiment shown in FIG. **1**A also has a third web member **32***b* between chords **31**, **33** in the lateral direction which is positioned longitudinally away from first web member **32**, proximal to terminal end **39**. The spacing between web members **32**, **32***b* is chosen to match the spacing between vertical frameworks **12** and **14** or vice versa in a preferred embodiment like the one shown. In the embodiment shown in FIG. **1**A there is also a fourth web-member **34***b* positioned longitudinally away from first web member **34**, proximal to terminal end **37**. In the embodiment shown in FIG. **1**A, the fourth web-member **42***b* is longitudinally positioned half way between web-members **32**, **32***b*. This preferred relative positioning of web-members **32**, **32***b*, **34** produces a preferred metric path **42** through web member **32***b* and **34***b* in framework **18**. The intra-framework spacing of web-members in vertical frameworks might not or might (shown) match that of horizontal frameworks. Another embodiment (not shown) with web-member **34***b* positioned a third of the way between web-members **32**, **32***b* would produce a greater path length and therefore greater resistance for metric path **42** but a lesser path length and therefore lesser resistance for the most direct metric path through web members **32** and **34***b*. The preferred embodiment shown in FIG. **1**A has the same relative spacing between any given pair of web members. Therefore, the most direct metric path through any given pair of web members has the same spanwise indirectness as the preferred metric path **42**. In a preferred embodiment with deeper framing members, the intra-framework spacing of web-members in the longitudinal direction of the framing members would be greater to preserve the level of spanwise indirectness. Web-members **32**, **32***b* form a first web. Web-members **34**, **34***b* form a second web. In a preferred embodiment of a framework with three structural members, two webs, and consistently spaced web members like the one shown in FIG. **1**A, the web-members in adjacent webs are longitudinally offset by half the intra-web spacing of web-members as shown.

[0253] Vertical frameworks **12**, **14** and horizontal framework **16** have configurations similar to that of horizontal framework **18**. Vertical framework **14** is attached at the terminal ends of horizontal frameworks **16**, **18** whereas vertical framework **12** is proximal to but not attached at the terminal ends of horizontal frameworks **16**, **18** to permit attachment to other frameworks and to provide an unobstructed view of the terminal ends of horizontal framework **16** in the figure. In other embodiments, vertical framework **12** would be attached at the terminal ends of horizontal frameworks **16**,**18** to form a rectangular structure. In such embodiments vertical framework **12** would be preferably rolled 180° around its longitudinal y axis such that web-member **34***b* would lie closest to the web-member at the left end of horizontal framework **16**.

[0254] Another embodiment (not shown) of the structure in FIG. **1**A, incorporates a different embodiment of vertical framework **12** having a longitudinal spacing between web-members **34**, **34***b* that differs from the on-center spacing of web-members **34**, **34***b* in horizontal framework **18**. Yet another embodiment (not shown) of the structure in FIG. **1**A, incorporates a different embodiment of horizontal framework **18** in which the longitudinal spacing of web-members **34**, **34***b* differs from the horizontal spacing of vertical frameworks **12**, **14**. An embodiment for which the longitudinal spacing of web-members **34**, **34***b* equals the horizontal spacing of vertical frameworks **12**, **14** produces larger values of spanwise indirectness for metric paths in the transverse direction z. Yet another embodiment (not shown) of the structure in FIG. **1**A, incorporates another embodiment of horizontal framework **18** in which web-members **32**, **32***b* have a greater length and extend down between structural members **31**, **33** of other embodiments of vertical frameworks **12**, **14** for which the web-members nearest ends **20**, **22** are positioned further down to accommodate. Yet another embodiment (not shown) of the structure in FIG. **1**A, incorporates another embodiment of vertical framework **12** in which the web-members nearest end **20** has a greater length and extends up between chords **31**, **33** of horizontal framework **18**. In this embodiment framework **18** is horizontally shifted enough to accommodate. One can also define the normal direction for an energy barrier with an interior surface and exterior surface comprising any number frameworks. The normal direction runs along the line of closest approach between the interior and exterior surfaces of the barrier at any given point on either surface. Frameworks are preferably oriented so that the normal direction of the framework substantially parallels the normal direction of the barrier.

[0255] FIG. **1**B illustrates the framework **10′** containing a hardenable insulative material or solid insulation. The framework **10′** includes a central (gap) cavity **44′** containing an insulating segment **46′** formed from an insulating material. Additionally, FIG. **1**B illustrates a first rectangular cavity **49′** defined by opposite-facing surfaces, i.e. inner facing surface **50′** of chord **31′** and opposing surface **52′** of chord **33′**, and opposite surfaces **54′**, **56′** of web-members **32′**, **32***b*′, respectively. Rectangular cavity **49′** contains an insulating segment **58′** formed from an insulating substance. The insulating substance used for insulting segment **58′** may be the same or different insulating substance as is used for insulating segment **46′**. Another type of rectangular cavity, i.e. rectangular cavity **62′** is defined by three surfaces, i.e. inner facing surface **51′** of chord **31′**, opposite surface **53′** of chord **33′**, and outer side surface **64′** of web member **32′**. The length of cavity **62′** extends to the edge **66′** of the framework **10′**. Rectangular cavity **62′** contains an insulating segment **63′**. The insulating substance used for insulting segment **63′** may be the same or different insulating substance as is used for insulating segment **46′** or insulating segment **58′**. All other cavities between parallel chords are similarly created as **49′** and **62′** and optionally may contain similar insulating segments formed from a single type, or different types of insulating substances. Each embodiment of an insulatable insulative framework apparatus has a first related embodiment that comprises factory-installed insulation within the cavities and a second related embodiment that comprises installer-installed insulation within the cavities. For example one such embodiment comprises the vertical members **12** and **14** shown in FIG. **1**B and rigid foam or other rigid insulation that holds the vertical frameworks **12** and **14** in the configuration shown in FIG. **1**B as a prefabricated panel **10′** so that an installer can efficiently make structural connections, that more permanently hold the configuration shown in FIG. **1**B, by fastening the horizontal frameworks **16** and **18** to the vertical frameworks **12** and **14** and other vertical frameworks perhaps in a similar type of panel. In a more specific version of this embodiment, the vertical frameworks **12** and **14** are made from a wood product and function as studs. The horizontal frameworks **16** and **18**, once attached to the prefabricated panel, function as the bottom and top plate of an insulated wall. In another such embodiment the longitudinal custom-character**14** axis of the prefabricated panel is oriented in the horizontal x direction to function as a floor panel. In another such embodiment the longitudinal custom-character**14** axis of the prefabricated panel is oriented horizontally or pitched diagonally to function as a roof panel. An embodiment of the horizontal framework **16** has factory-installed solid insulation fixed between any number of the cavities so as to eliminate the labor required to install insulation on site. An embodiment of the vertical framework **12** has factory-installed solid insulation fixed between any number of the cavities so as to eliminate the labor required to install insulation on site.

[0256] In other embodiments, the framework **10** can be positioned along any intrinsic direction to any suitable position and rotated around any intrinsic angle to any suitable orientation. The frameworks may run diagonally with respect to the horizontal, vertical, or transverse directions. In the embodiments shown in FIGS. **1**A and **1**B, the web members are shown as extending in a direction generally perpendicular to the chords, however, in different embodiments, for example that shown in FIG. **2**AA, at least one web member is pitched diagonally relative to the chords. In other embodiments, not shown, at least one web member extends (b) diagonally yawed relative to the chords.

[0257] FIG. **1**C shows representative metric path set **1**CX for framework **1**C. Each black dot represents a start point for a different metric path as typified by start points **1**CA**3**A, **1**CB**2**A, **1**CC**1**A, **1**CD**4**A, **1**CD**3**A. Each bullseye dot represents an end point of a metric path as typified by end points **1**CA**3**F, **1**CB**2**F, and **1**CC**1**F. The representative metric paths converge to a focal point as typified by focal point **1**CDXF which overlaps the end points for the metric paths with start points **1**CD**4**A and **1**CD**3**A and all other metric paths that converge to focal point **1**CDXF. Any end point that overlaps a focal point can serve as a representative of the focal point. Thus, end points **1**CA**3**F, **1**CD**2**F, **1**CC**1**F, and **1**CDXF represent focal points one, two, three, and four, respectively. Each focal point defines a bundle of metric paths that all converge on the same focal point or pass through the same focal point. Thus, focal points one, two, three, and four define bundles A, B, C, and D, respectively. For instance, all metric paths that pass through or converge to focal point **1**CDXF form bundle D. Each bundle of metric paths includes a set of special paths, i.e. the most-direct metric through-path which passes through the defining focal point in addition to the shortest metric path, most-direct metric path, longest minor metric path, and longest metric path which converge on the defining focal point.

[0258] FIG. **1**D shows examples of the special metric paths within different bundles. For instance, the longest metric path in bundle D is the path that originates at start point **1**CD**4**A and terminates at focal point **1**CDXF as shown in FIG. **1**D. The longest minor metric path in bundle C is the path that originates at start point **1**CC**3**A and terminates at focal point **1**CC**3**F as shown in FIG. **1**D. The most direct metric path in bundle B is the path that originates at start point **1**CB**2**A and terminates at focal point **1**CB**2**F as shown in FIG. **1**D. The shortest metric path in bundle A is the path that originates at start point **1**CA**1**A and terminates at focal point **1**CA**1**F as shown in FIG. **1**D. The most direct metric through-path in bundle B shown in FIG. **1**E is the path that originates at point **1**CB**5**A, runs through point **1**CB**2**F (shown in FIG. **1**C) and terminates at point **1**CB**5**G. The most direct metric through-path and most direct metric path require further explanation. If framework **1**C has well-defined outermost normally facing surfaces, then the most direct metric path in bundle B may be defined as the shortest metric path in bundle B that originates on an outermost normally facing surface. If framework **1**C does not have well-defined outermost normally facing surfaces, then a more general definition is needed. More generally the most direct metric path in bundle B is defined as a metric path in bundle B with a length L, span S, and directness L/S greater than that of any other metric path in bundle B. To show that the path originating at start point **1**CB**2**A in bundle B and terminating on point **1**CB**2**F is the most direct metric path in bundle B one must prove that no other metric path in bundle B has a greater value of directness. To do so, start by proving that the most direct metric path in bundle B has a greater value of directness than that of the shortest metric path in bundle B (shown in FIG. **1**F). The path segment of the most direct metric through-path beyond point **1**CB**1**A is identical to the shortest metric path having the same length L, same span S, and same directness D equal to L/S. Up to the point **1**CB**1**A any metric path that deviates from the shortest metric path in a direction parallel to a span-wise direction line by a positive amount ΔS will have a span equal to S+ΔS and a length equal L+ΔS such that the directness D equals (S+ΔS)/(L+ΔS). A directness D of (S+ΔS)/(L+ΔS) is greater than S/L in proportion to the magnitude of ΔS. The most-direct metric path in bundle B shown in FIG. **1**D has the greatest possible deviation ΔS in the spanwise direction and thus has the largest value of directness. Up to the point **1**CB**1**A any metric path that deviates from the shortest metric path in a direction parallel to a span-wise direction line by a positive amount ΔS and deviates in a direction perpendicular to a span-wise direction line by a positive amount Δcustom-character will have a span equal to S+ΔS and a length equal L+(ΔS.sup.2+Δcustom-character).sup.1/2 such that the directness D equals (S+ΔS)/{L+(ΔS.sup.2+Δcustom-character).sup.1/2}. A directness D equal to (S+ΔS)/{L+(ΔS.sup.2+Δcustom-character).sup.1/2} is always less than (S+ΔS)/(L+ΔS) for all positive values of ΔS and positive values of Δcustom-character. The same argument applies to any other possible combination of multiple deviations from the most direct metric path. Any number of deviations always leads to a metric path with a lesser value of directness than the most direct metric path.

[0259] Similarly the most direct metric through-path also requires further explanation. If framework **1**C has well-defined outermost normally facing surfaces, then the most direct metric through-path in bundle B may be defined as the shortest bound path in bundle B that runs between the outermost normally facing surfaces. If framework **1**C does not have well-defined outermost normally facing surfaces, then a more general definition is needed. More generally the most direct metric through-path in bundle B is defined as the most direct bound path in bundle B, i.e., a bound path in bundle B with a length L, span S, and directness L/S greater than that of any other bound path in bundle B. To show that the path originating at start point **1**CB**5**A in bundle B and terminating on point **1**CB**5**G is the most direct bound path in bundle B one must prove that no other bound path in bundle B has a greater value of directness. To do so, start by proving that the most direct metric through path in bundle B has a greater value of directness than that of the most direct metric path in bundle B (shown in FIG. **1**F). The most direct metric path and most direct metric through-path are identical up to point **1**CB**1**F having the same length L, same span S, and same directness D equal to L/S. Beyond point **1**CB**1**F any bound path that deviates from the most direct metric path in a direction parallel to a span-wise direction line by a positive amount ΔS will have a span equal to S+ΔS and a length equal L+ΔS such that the directness D equals (S+ΔS)/(L+ΔS). A directness D of (S+ΔS)/(L+ΔS) is greater than S/L in proportion to the magnitude of ΔS. The most-direct metric through-path shown in FIG. **1**D has the greatest possible deviation ΔS in the spanwise direction and thus has the largest value of directness. Beyond point **1**CB**1**A any bound path that deviates from the most direct metric path in a direction parallel to a span-wise direction line by a positive amount ΔS and deviates in a direction perpendicular to a span-wise direction line by a positive amount Δcustom-character will have a span equal to S+ΔS and a length equal L+(ΔS.sup.2+Δcustom-character).sup.1/2 such that the directness D equals (S+ΔS)/{L+(ΔS.sup.2+Δcustom-character).sup.1/2}. A directness D equal to (S+ΔS)/{L+(ΔS.sup.2+Δcustom-character).sup.1/2} is always less than (S+ΔS)/(L+ΔS) for all positive values of ΔS and positive values of Δcustom-character. The same argument applies to any other possible combination of multiple deviations from the most direct metric path. Any number of deviations always leads to a metric path with a lesser value of directness than the most direct metric path. To be completely accurate one must describe the path in FIG. **1**D as the most direct metric through-path in a normal direction in bundle B. The most direct metric through-path has the extremely powerful geometrical feature of running between the outermost surfaces of a framework in the span-wise direction of the most direct metric through-path no matter how the outermost surfaces are shaped.

[0260] The longest metric path in any given bundle is a metric path with a length such that the length is greater than that of any other metric path in the bundle. The shortest metric path in any given bundle is a metric path with a length such that the length is less than that of any other metric path in the bundle. The longest minor metric path in any given bundle is a metric path with a length such that the length is greater than that of any other metric path in the bundle starting at any point on the opposite side of the most direct metric path relative to the start point of the longest metric path. The set of locally most-direct metric paths in any specified direction is a set including each most direct metric path in the specified direction from each bundle. The set of locally shortest metric paths in a specified direction is a set including each shortest metric path in the specified direction from each bundle. The set of locally most-direct metric through-paths in a specified direction is a set including each most direct metric through-path in the specified direction from each bundle. The set of locally longest metric paths in a specified direction is a set including each longest metric path in the specified direction from each bundle. The set of locally longest minor metric paths in a specified direction is a set including each longest minor metric path in the specified direction from each bundle. Each of these sets defines a set of values for each physical property of interest such as path length. Each set of values for each physical property of interest then defines a set of statistical values for each statistical function of interest such as a statistical average. In that way the statistical average path length for the set of locally most-direct metric through-paths is available to characterize an insulatable, insulative framework apparatus. A non-limiting list of physical properties of interest include path length, span, range span-wise indirectness, range-wise indirectness, structurally insulative resistance, structurally insulative resistivity, structural insulation factor, and other physical properties. A non-limiting list of statistical functions of interest includes maximum, minimum, standard deviation, average, uniformity, count, and other statistical functions. For example the average spanwise indirectness for the locally most-direct metric paths in the normal direction of uniaxial framework **1**C means the statistical average for the set of each spanwise indirectness value for each most-direct metric path in each bundle of the framework. If no type of metric path is specified for a statistical function then the statistical function applies to all metric paths excluding the through-paths. For instance the average spanwise indirectness means the average of the set of spanwise indirectness values for the representative set of metric paths.

[0261] If no bundle is specified then (1) the term shortest metric path means a metric path with a length such that the length is less than that of any metric path in any bundle, (2) the term longest metric path means a metric path with a length such that the length is greater than that of any metric path in any bundle, (3) the term longest minor metric path means a metric path with a length such that the length is less than that of any minor metric path in any bundle, (4) the term most-direct metric path means a metric path with a directness such that the directness is greater than that of any metric path in any bundle, (5) the term most-direct metric through-path means a bound path with a directness such that the directness is less than that of any bound path in any bundle. For example, FIG. **1**G shows the shortest metric path in the normal direction for framework **1**C. As another example, FIG. **1**H shows the most-direct metric through-path for framework **1**C.

[0262] FIG. **2**AA shows a framework with three structural members and diagonally pitched web members. The pitch angles shown are substantially less than ±45° relative to the chords, i.e. 15°. The diagonal web members in FIG. **2**AA could have alternating pitch angles of ±45° relative to the chords. The diagonal web members in different layers create a chevron pattern. Another embodiment (not shown) has web members with a diagonal pitch and a diagonal yaw relative to the structural members.

[0263] FIG. **2**AB shows three parallel chords with a single row of diagonal braces positioned between each set of adjacent chords. This framework has diagonal braces/web-members with a constant intra-layer brace/web spacing and the maximum characteristic offset between braces/web-members, with the same pitch-angle sign, in different layers.

[0264] FIG. **2**AC shows framework **1900** with a single open web of straight diagonal web members interconnecting two parallel chords. The web members for this type of embodiment have a characteristic pitch angle Øy.sub.1900 relative to the bottom chord of less than 40°. The characteristic pitch angle Øy.sub.1900 for the embodiment shown in FIG. **2**AC is 15° with alternating positive and negative signs. U.S. Pat. No. 3,452,502, the contents of which is hereby incorporated by reference in its entirety, discloses a method of joining two diagonal web-members with each other and a chord of a truss using finger joints. Embodiments of diagonal-web trusses described herein include this type of finger joint as well as any other type of woodworking joint.

[0265] FIG. **2**AD shows truss **1900′**, the same as truss **1900**, except with a single straight diagonal web member **1902** interconnecting two chords **1901**, **1903** at a separation distance Δz.sub.19013. Straight diagonal web member **1902** has a pitch angle Øy.sub.19012 relative to chord **1901** of 15°. Straight diagonal web member **1902** has a thickness Δcustom-character equal to half the separation distance Δz.sub.19013. The pitch angle Øy.sub.19012, thickness Δcustom-character, and separation distance Δz.sub.19013 determine the shortest path through the structure from chord **1901** to chord **1903** which is shortest metric path **1904**. Shortest metric path **1904** has a 29° pitch angle Øy.sub.19014 relative to chord **1901**, a span S.sub.1904 equal to the separation distance Δz.sub.19013, and a length L.sub.1904 equal to 2 times the separation distance Δz.sub.19013. The structural insulation factor F.sub.1904 for shortest metric path **1904** equals L.sub.1904 divided by S.sub.1904, that is 2. If straight diagonal web member **1902** is made from a material with an isotropic resistivity r.sub.1902 then the structurally insulative resistivity r.sub.s1902 equals the resistivity r.sub.1902 multiplied by the structural insulation factor which in this case is 2:11902. The physical quantity of span-wise indirectness, I, specifies the improvement in resistivity afforded by the structural insulation factor, i.e., {2:r.sub.1902−r.sub.1902}/r.sub.1902 which also yields the definition {r(L/S)−r}/r which simplifies to I={L/S-**1**}. Herein the span-wise indirectness is expressed as a percentage by convention. For the embodiment shown in FIG. **2**AD the span-wise indirectness equals {2:r.sub.1902−r.sub.1902}/r.sub.1902. Thus, truss **1900′** has a span-wise indirectness of 100% which corresponds to a 100% improvement in structurally insulative resistivity for an isotropically resistive material. For any span-wise indirectness I and isotropic resistivity r, the structurally insulative resistivity is {I+1} r. In an embodiment preferred for strength, the strong axis of the material that constitutes web member Y.sub.1902 is oriented parallel to the longitudinal custom-character.sub.1902 direction of web member **1902**. In another embodiment preferred for resistance, the strong axis of the material that constitutes web member Y.sub.1902 is oriented perpendicularly or substantially non-parallel to the longitudinal custom-character direction of web member **1902**. These variations in orientation of the strong axis of a material relative to the axis of the structural part it constitutes apply to all embodiments.

[0266] For comparison with framework **1900**, FIG. **2**AE shows a control in the form of truss **2000** with two chords **2001**, **2003** at a separation distance Δz.sub.20013 interconnected by a straight diagonal web member. Straight diagonal web member **2002** has a pitch angle Øy.sub.20012 relative to chord **2001** of 45°. Straight diagonal web member **2002** has a thickness Δcustom-character equal to half the separation distance Δz.sub.20013. The pitch angle Øy.sub.20012, thickness Δcustom-character, and separation distance Δz.sub.20013 determine the shortest path through the structure from chord **2001** to chord **2003** which is shortest metric path **2004**. Shortest metric path **2004** has a pitch angle Øy.sub.20014 relative to chord **2001** of 75°, a span S.sub.2004 equal to the separation distance Δz.sub.20013, and a length L.sub.2004 equal to 1.04 times the separation distance Δz.sub.20013. The structural insulation factor F.sub.2004 for shortest metric path **2004** equals L.sub.2004 divided by S.sub.2004, that is 1.04. If truss **2000** is made from a material with an isotropic resistivity r then the structurally insulative resistivity equals the resistivity r multiplied by the structural insulation factor which in this case is 1.04r.

[0267] For comparison, truss **2005** shown in FIG. **2**AF incorporates chords **2006** and **2008** with a separation distance Δz.sub.20068 interconnected by a straight direct web member **2007** with a pitch angle Øy.sub.20067 relative to chord **2006** of 90°. These quantities determine that the shortest metric path **2009** between chords **2006** and **2008** has a length L.sub.2009 and span S.sub.2009 equal to the separation distance Δz.sub.20068 and a structural insulation factor L/S equal to 1. If truss **2005** is made of the same material as truss **2000** with isotropic resistivity r, then the structurally insulative resistivity equals the resistivity r multiplied by the structural insulation factor which equals r. Thus, truss **2000** offers an improvement of {1.04r−r}/r, that is 4%, over truss **2005**. Span-wise indirectness quantifies this improvement as {length/span}−1. For instance, shortest metric path **2004** has a span-wise indirectness I.sub.2004 equal to {L.sub.2004/S.sub.2004}−1, that is 4%, so the geometry of truss **2004** offers an improvement of 4% to the structurally insulative resistivity.

[0268] FIG. **2**AG shows a truss **2000′** with chords **2001′** and **2003′**, straight-through web member **2002′**, and metric path **2004′** between chords **2001′** and **2003′**. Metric path **2004′** runs straight through web member **2002′**.

[0269] The straight-diagonal-web-member two-chord trusses in FIG. **2**AC and FIG. **2**AD compensate for the effects described for truss **2005** by (1) making the most direct metric path length between the chords a greater percentage of the inter-chord length of the diagonal web member, (2) lessening the linear density of material along the longitudinal direction of the chords, (3) still allowing for an increase in lateral extent of material in comprising the truss, (4) increasing the least angle between the shortest metric path and the local span-wise direction, (5) providing a greater area for the web member to interface with the chords which strengthens the joint, and (6) increasing the length L of the most direct metric path relative to its span S thereby increasing the structural insulation factor L/S and (a) increasing the resistance R=rL along the most direct metric path where r is the resistivity approximately parallel to custom-character or equivalently (b) increasing the structurally insulative resistivity of the web member, r.sub.sval=r.sub.val.Math.L/S. Table 1A summarizes useful formulae and Table 1B summarizes the symbols and terminology. Mcustom-character, associated with an angle relative to the span of a metric path, in the table corresponds to the span-wise slope of a tangent line (change in normal direction divided by change in longitudinal direction or change in lateral direction divided by change in longitudinal direction) to any straight subpath of the most direct metric path or shortest metric path. Mø, associated with an angle relative to the chords, in the table corresponds to the slope of a tangent line (change in longitudinal direction divided by change in normal direction or change in longitudinal direction divided by change in lateral direction) to any straight subpath of the most direct metric path or shortest metric path.

TABLE-US-00001 TABLE 1A R.sub.sval = r.sub.val .Math. L, (1) R.sub.val = r.sub.val .Math. S (2) F = R.sub.sval/R.sub.val = L/S (3) I = R.sub.sval/R.sub.val − 1 = L/S − 1 = (L − S)/S (4) MΘ = [(L.sup.2 − S.sup.2).sup.1/2]/S (5) MΘ = [(L/S).sup.2 − 1].sup.1/2, = [F.sup.2 − 1].sup.1/2 = (6) (I.sup.2 + 2 .Math. I).sup.1/2 F = L/S = I + 1 = (M.sup.2 + 1).sup.1/2, (7) I = (M.sup.2 + 1).sup.1/2 − 1, (8) ΔR.sub.sval = R.sub.sval − R.sub.val = r.sub.val .Math. (L − S) = (9) r.sub.val .Math. I .Math. S = r.sub.val .Math. (F − 1) .Math. S r.sub.sval = R.sub.sval/S = r.sub.val .Math. L/S = r.sub.val .Math. F = r.sub.val .Math. (I + 1) (10) Δr.sub.sval = ΔR.sub.val/S = r.sub.val .Math. (L − S)/S = r.sub.val .Math. (F − 1) = r.sub.val .Math. I (11) F = L/S = R.sub.sval/R.sub.val = r.sub.sval/r.sub.val.Math., (12) r.sub.dir = r.sub.target or R.sub.dir = R.sub.target (13) r.sub.sval = r.sub.target or R.sub.sval = R.sub.target (14) MΘ = [(r.sub.sval/r.sub.val).sup.2 − 1].sup.1/2 = (15) [(r.sub.target/r.sub.val).sup.2 − 1].sup.1/2 MΘ ≈ r.sub.target/r.sub.val, for r.sub.target/r.sub.val >> 1. (16) Mø = 1/MΘ (17)

TABLE-US-00002 TABLE 1B S span of the metric path L length along the metric path R.sub.val areal resistance R.sub.Sl areal resistance (metric units) R.sub.sval structurally insulative resistance R.sub.Sls structurally insulative resistance (metric units) r.sub.sval structurally insulative resistivity r.sub.val direct resistivity F structural insulation factor I span-wise indirectness M custom-character metric path slope relative to the span-wise direction Mø metric path slope relative to a structural member

[0270] FIG. **2**AH shows uniaxial framework **1000** which possesses three chords **1001**, **1003**, **1005** and two webs **1002**, **1004** like uniaxial framework **12** in FIG. **1**A. Webs **1002**, **1004** each comprise at least one web member **1002*a***, **1004*a***, respectively. Webs **1002**, **1004** comprise terminal web members **1002**N and **1004**N which could be the same as web members **1002*a***, **1004*a*** in a framework with only one web member in each of webs **1002*a***, **1004*a***. For the embodiment shown in FIG. **1**A, web **1002** incorporates web members **1002*a***, **1002*b***, **1002**N and web **1004** incorporates web members **1004*a***, **1004**N. For the embodiment shown in FIG. **1**A, web **1002** incorporates floating tenons **1002*a*′**, **1002*b*′**, **1002**N′ and web **1004** incorporates floating tenons **1004*a*′**, **1004**N′. The two wavy lines **1009** indicate the possibility for additional length of chords **1001**, **1003**, **1005**, additional web members, and additional floating tenons. Table 2 shows preferred values for the key dimensional parameters. Preferred dimensional parameters for any other embodiment can be obtained by multiplying these parameters by a scaling factor. For instance multiplication by a scaling factor of 2 produces the preferred dimensional parameters of an 11 inch (˜280 mm) deep framework.

TABLE-US-00003 TABLE 2 Imperial Units SI Units Dim. Preferred Preferred Param. Value Range Value Range Δ custom-character .sub.1000 5.5 in 5-7 in 148 mm 123-175 mm Δ custom-character .sub.1002 24 or 16 in 12-36 in 600 mm 300-900 mm Δ custom-character .sub.10024′ 12 or 8 in 6-24 in 300 mm 150-450 mm Δ custom-character .sub.1004a 2.4 or 1.5 in 0.75-3 in 61 or 48 mm 19-75 mm Δ custom-character .sub.1001 ¾ or 1.1 in 0.5-2.5 in 19 or 30 mm 12-61 mm Δ custom-character .sub.1002 1¼ or 1.1 in 0.5-2.5 in 36 or 30 mm 12-61 mm Δ custom-character .sub.1003 1⅛ or 1.1 in 0.5-2.5 in 36 or 30 mm 12-61 mm Δ custom-character .sub.1004 1.25 or 1.1 in 0.5-2.5 in 36 or 30 mm 12-61 mm Δ custom-character .sub.1005 1.125 or 1.1 in 0.5-2.5 in 36 or 30 mm 12-61 mm Δ custom-character .sub.10050 3.0625 or 0 in 0-6 in 0 mm 0-150 mm Δ custom-character .sub.1005′ 92.625 or 96 in or 72-288 in 2400 mm 1800-7200 mm 104.625 or 108 in

[0271] FIG. **2**B is a control schematically showing a chord **230** with no web members and can be described by code 1. FIGS. **2**C-**2**I schematically show various embodiments of 1D (uniaxial) frameworks with each pair of chords connected by a web of diagonally pitched web members.

[0272] FIG. **2**C shows a chord having a vertical row of pitched diagonally extending web members **236** connected thereto, and can be described by code 1a.

[0273] FIG. **2**D shows an embodiment similar to that of FIG. **2**C except that the direction of the diagonal braces is reversed. This embodiment is described by code 1b.

[0274] FIG. **2**E show three parallel chords with a single row of diagonal braces positioned between each set of adjacent chords. In FIG. **2**E, horizontally spaced diagonal braces extend in different directions from one another. This embodiment shows constant intra-layer web-member spacing and a characteristic offset of zero between braces/web-members, with the same pitch-angle sign, in different webs and can be described by code 1a1a1. Horizontally spaced diagonal braces are substantially parallel to one another.

[0275] FIG. **2**F shows 2 chords and two sets of diagonal braces, one set to the right of each chord. This framework is a code 1a1a framework which is the same as FIG. **2**E except with one peripheral chord omitted.

[0276] FIG. **2**G is similar to FIG. **2**E except that the braces spaced in the vertical direction from one another have a different alternating pattern. This is a code 1a1a1 framework with diagonal web members sloping one way in the first half of the framework and then the opposite way along the second half of the framework along longitudinal axis.

[0277] FIG. **2**H is similar to FIG. **2**E except all of the diagonal braces are parallel to one another. This code 1a1a1 framework has diagonal web members sloping one and only one way. For any framework of this type one can omit one or both of the peripheral struts/chords. For some embodiments of the framework in FIGS. **2**C-**2**I some or all adjacent web members in the same horizontal layer touch one another like the embodiments shown in FIGS. **2**A and **2**B. For other embodiments of the framework in FIGS. **2**C-**2**I (not shown), some or all adjacent web members in the same horizontal layer do not touch one another as in the embodiments shown in FIGS. **3**C, **3**F. Some embodiments incorporate half-unit-cells and an odd number of web members per horizontal layer of web members. The number of web members per horizontal layer of web members ranges between one and any positive integer.

[0278] FIG. **2**I shows four chords with diagonal braces therebetween. Horizontally spaced braces are parallel to one another. Vertically spaced braces alternate in their diagonal direction. This can be described as a code 1a1a1a1 framework with two units cells, 4 struts/chords, and 3 layers of diagonal braces/web-members with a constant intra-layer brace/web spacing and an interlayer characteristic offset of zero between same-polarity web members.

[0279] FIG. **2**J shows four chords with diagonal braces there between. Horizontally spaced braces alternate in their diagonal direction. Vertically spaced braces also alternate in their diagonal direction. This can be described as a code 1a1b1a1 framework with two units cells, 4 struts/chords, and 3 layers of diagonal braces/web-members with a constant intra-layer brace/web spacing and a maximum interlayer characteristic offset between same-polarity braces/web-members. FIG. **2**K shows five chord with diagonal braces therebetween. This is a code 1a1b1a1b1 framework with two units cells, 5 struts/chords, and 4 layers of diagonal braces/web-members with a constant intra-layer brace/web spacing and a maximum interlayer characteristic offset between same-polarity braces/web-members.

[0280] FIGS. **2**M-**2**T schematically show various embodiments of uniaxial/1D frameworks with straight braces. The framework in each figures shows 1.5 unit-cells with each pair of chords connected by a web containing two web-members.

[0281] FIG. **2**M shows 1 chord **330** with two straight web members **336** attached thereto. This framework is a control described with code 1a.

[0282] FIG. **2**N shows 1 chord with two straight web members attached at lower vertical locations than the embodiment of FIG. **2**B, but with substantially the same spacing from one another as in the embodiment of FIG. **2**B. This framework is a control described with code 1a.

[0283] FIG. **2**O shows three chords with two straight web members between each set of adjacent chords. The pair of web members between the first and second chords is vertically higher than the pair of web members between the second and third chords. This framework has a code of 1a1b1.

[0284] FIG. **2**P depicts four chords with two straight web members between each set of adjacent chords. The pair of web members between the first and second chords is at the same vertical height as the pair of web members between and third and fourth chords, following a pattern of code 1a1b1a1.

[0285] FIG. **2**Q shows four chords with two straight web members between each set of adjacent chords. Each pair of web members is at a different vertical height than the other pairs of web members, following a pattern of code 1a1b1c1.

[0286] FIG. **2**R depicts five chords and four pairs of straight members. The vertical height of the first and third pairs of web members is the same. The vertical height of the second and fourth pairs of web members is the same. This arrangement follows the pattern of code 1a1b1a1b1.

[0287] FIG. **2**S shows three chords in a pattern of code a1b1a1b with no chord on the left, showing that a web can be left unconnected on one side so as to create an extra layer of insulatable cavities when connected to another object.

[0288] FIG. **2**T shows four chords in a pattern of code 1a1b1o in which o indicates a web of horizontally extending web members running into and/or out of the page. In this case, the web members do not connect two chords in the normal direction but function to connect a chord in one framework (shown) to a laterally disposed chord in one or more than one other framework (not shown).

[0289] For the most direct metric path in the normal and/or lateral direction of a framework that defines a span, a path length, a range, a rangewise indirectness, a spanwise indirectness, and a greatest web member thickness parallel to the span, (1) the ratio of the path length to the maximum web member thickness is less than a certain amount, (2) the maximum web thickness is greater than a certain percentage of the span, and (3) the framework has at least one of (A) a rangewise indirectness greater than 0% and spanwise indirectness greater than x or rangewise indirectness equal to zero and spanwise indirectness greater than y in a preferred embodiment of the framework for any application.

[0290] FIGS. **3**A-**3**F show six non-limiting examples of web shapes in a half-unit-cell of framework **129**. Each web shape is shown between two adjacent chords. The vertical lines in each of FIGS. **3**A-**3**F schematically show chords as shown by labeled chords **130** and **132** in FIG. **3**A. The dotted lines **104**, **106**, **108**, **110** and **112** between adjacent chords schematically show webs **104**, **106**, **108**, **110**, and **112** between chords **130** and **132**. Web **104** shown in FIG. **3**A is straight and runs diagonally between the chords **130** and **132**. A preferred embodiment of a framework apparatus to have no thermal bridging upon installation in an insulated, wood-frame building with a resistivity of approximately r.sub.1 for the wall cavity insulation, comprises the FIG. **3**A truss made from a material with a resistivity of approximately r.sub.2 along the longitudinal direction of the diagonal web member **140**, wherein the diagonal web member **104** has a slope (Δy/Δx) substantially equal to r.sub.1 divided by r.sub.2, the x and y directions are shown in the FIG. **3**A, and the resistivities have thermal units of ° F..Math.sqft per BTUh per inch as a non-limiting example.

[0291] The web shown in FIG. **3**B incorporates a third chord **131** and two webs **105** and **107** which function together as a web-like structural member **106**. Web **108** shown in FIG. **3**C is similar to web-like structural member **106** in that web members **105** and **107** are present in both web **108** and **106** and web member **131′** connects web member **105** and **107** as does structural member **131**. However, web member **131′** is not a structural member like structural member **131**. Thus, web **108** is not a web-like structural member because web **108** does not include a structural member. Instead the structural-member like segment **131′** does not run the entire longitudinal length of the half-unit-cell delimited by black circles in FIG. **3**C. Each embodiment with a half-unit-cell shape like that of web **106** has a related embodiment with a shape like that of web **104**, **108**, **110**, **112** and all other implicit web shapes. Each closed circle **102** in FIGS. **3**A-**3**F represents an interface between a key pair of structural parts. Each closed circle **102** in FIGS. **3**A-**3**F appears in a corresponding figure in the grouping of FIGS. **4**A-**4**F to illustrate the process of replicating a half-unit-cell to create a new framework. Generally any half-unit-cell with three structural members can be replaced by a half-unit-cell with two structural members and vice versa in embodiments where the shape of the web for the replacement half-unit-cell has an advantage. The same method applies to half-unit-cells with more than three structural members. Generally the spanwise indirectness can be preserved for such replacements although. Frameworks with a non-zero rangewise indirectness generally provide a higher spanwise indirectness than frameworks with zero rangewise indirectness for any given span of the most direct metric path along any targeted direction.

[0292] FIGS. **3**G-**3**L show various web member shapes. FIGS. **4**A-**4**F show six non-limiting examples of web shapes in the half-unit-cell of a framework. The web shapes are shown between adjacent chords in a framework that includes at least 3 chords.

[0293] For instance the FIG. **4**A framework has three chords labeled **130′**, **132′**, and **132″**. By comparison to the FIG. **3**A framework, the FIG. **4**A framework has an additional chord, chord **132″**.

[0294] The FIG. **4**B framework has 5 chords labeled as **130′**, **131′**, **132′**, **131″**, and **132″**. Chord **132″** is analogous to chord **132** in the sense that chord **132″** is the last chord to the right in the figure and is the last chord in the structural-member-array comprising chords **130′**, **131′**, **132′**, **131″**, and **132″** just as chord **132** is the last chord to the right in FIG. **3**A and is the last chord in the structural-member-array comprising chords **130**, and **132**. Chord **132″** has two labels **130″** and **132″**. In the FIG. **4**B embodiment, chord **130″** is the same as chord **132″**. In another embodiment (not shown) chord **130″** is attached to chord **132″** and they are different objects joined together. Each closed circle **102′** represents the interface of a key pair of structural parts which is translated to the right and transformed into each open circle **100′** to illustrate the process of replicating a half-unit-cell to create a new framework. The vertical lines schematically show chords as illustrated by chords **130′**, **132′** and **132″** in FIG. **4**A. The dotted lines **104′**, **106′**, **108′**, **110′** and **112′** between adjacent chords **132′** and **132″** schematically show web members between chords **132′** and **132″**.

[0295] FIGS. **5**A-**5**F show six non-limiting examples of web shapes in the full-unit-cell of a framework. Dashed lines **114′**, **116′**, **118′**, **120′** and **122′** represent a vertical reflection of the dashed lines **104′**, **106′**, **108′**, **110′** and **112′** in FIGS. **4**A-**4**F. Dashed lines **104″**, **106″**, **108″**, **110″** and **112″** between adjacent chords **130′** and **132′** schematically show web members between chords **130′** and **132′** analogous to dashed lines **104**, **106**, **108**, **110** and **112** in FIG. **3**A-**3**F. Dashed lines **114″**, **116″**, **118″**, **120″** and **122″** represent a vertical reflection of the dashed lines **114′**, **116′**, **118′**, **120′** and **122′**. Each of FIGS. **5**A-**5**F illustrates how to create a new framework by combining each framework of FIGS. **4**A-**4**F, respectively, with a vertical reflection of each framework of FIGS. **4**A-**4**F, respectively.

[0296] FIG. **6**A shows a biaxial framework **610** comprises multiple pieces of material, i.e. structural parts, including a 3 by 3 matrix of chords, 2 by 3 matrix of internetworking webs, and a 2 by 3 matrix of intranetworking webs, wherein each internetworking web comprises a plurality of internetworking web members formed separately from the chords and each intranetworking web comprises a plurality of intranetworking web members formed separately from the chords. The internetworking web members and intranetworking web members are arranged so that biaxial framework **610** structurally insulates in any direction perpendicular to the chords. In other embodiments the interworking web members and/or intranetworking web members are formed as part of the structural members. These structural parts can be conceptually grouped into frameworks, intranetworking webs (webs within a framework) and into internetworking webs (webs between frameworks) in more than one way as typified by the following example of a first conceptual grouping. A first layer **411** is framework **411**. A second layer **412** is an internetworking web array **412**. A third layer **413** is framework **413** which is a replica of framework **411**. A fourth layer **414** is a internetworking web array **414** containing internetworking web-members that are offset relative to those of internetworking web array **412**. A fifth layer **415** is framework **415** which is a replica of framework **411**. Each of the internetworking web arrays **412** and **414** comprise substantially perpendicular intranetworking web members. In other embodiments (not shown) the internetworking webs arrays **412** and **414** and the biaxial framework **610** comprise diagonal intranetworking web-members have diagonal intranetworking web-members in either pitch angle, yaw angle, or both the pitch and yaw angle. Each of the frameworks **411**, **413** and **415** comprise first and second intranetworking webs and first, second, and third chords. Each of the frameworks **411**, **413** and **415** has substantially perpendicular intranetworking webs. In other embodiments (not shown) the uniaxial frameworks **411**, **413** **415** and biaxial framework **610** have diagonal intranetworking web-members in either pitch angle, yaw angle, or both pitch and yaw angles. In other embodiments (not shown) these frameworks have diagonal web-members such that the biaxial framework **610** also has diagonal web members. Frameworks **411**, **413** and **415** align in a side-by-side arrangement such that the first chords of the framework align with each other, the second chords of the framework align with each other, and the third chords of the framework align with each other in a first non-limiting configuration.

[0297] Framework **411** is individually illustrated in FIG. **7**. Internetworking web array **412** is illustrated in FIG. **8** with framework **411** included to clarify the spatial web-to-framework relationship. Frameworks **413** and **415** are replicas of the Framework **411** illustrated in FIG. **7**. Internetworking web array **414** is illustrated in FIG. **10** with framework **411** included to clarify the spatial web-to-framework relationship. Relative to a solid piece of the same material with the same dimensions, biaxial framework **410** reduces the flow of energy along its normal axis z, into and out of the page along a diagonal line z sloping downwardly from left to right on the page, and also reduces the flow of energy along its lateral axis x, up and down the page in the direction shown by line y. This reduction in energy flow stems from the geometrical relationship between the structural parts and the metric paths produced by that geometrical relationship. The metric paths for biaxial framework **410** are substantially the same as the metric paths for biaxial framework **410**, illustrated in FIG. **6**D. A preferred embodiment of a framework apparatus, (not shown) for installation in an insulated building, comprises biaxial framework **410** and an insulating material that fills the cavities of biaxial framework **410**.

[0298] A preferred embodiment of a framework apparatus, (not shown) for installation in an insulated, wood-frame building with 2×4 walls and an R-value of 13° F..Math.sqft per BTUh for the wall cavity insulation, comprises biaxial framework **410** made from a wood product to have a normal dimension of 3.5″, wherein the cavities of biaxial framework **410** hold an insulating material with a thermal resistivity greater than about 2.6° F.-sqft per BTUh per inch to achieve minimum code compliance for R5ci, that is an R-value of 5° F.-sqft per BTUh of continuous insulation over the structural members.

[0299] A preferred embodiment of a framework apparatus, (not shown) for installation in an insulated, wood-frame building with 2×4 walls and an R-value of 13° F..Math.sqft per BTUh for the wall cavity insulation, comprises biaxial framework **410** made from a wood product to have a normal dimension of 3.5″ and a normal dimension totaling 1.5″ for the two cavities, wherein the cavities of biaxial framework **410** have a total normal dimension of 1.5″, hold an insulating material with a thermal resistivity greater than about 5.8° F..Math.sqft per BTUh per inch, and achieve minimum code compliance for R10ci, that is an R-value of 10° F..Math.sqft per BTUh of continuous insulation over the structural members.

[0300] Biaxial framework **410** has cavities that are similar in width to the width of the chord-like features. A convention itself is a choice and other choices are possible. By convention I will take the normal direction of an orthogonal biaxial framework, such as biaxial framework **410**, to parallel the direction of a line that orthogonally intersects the plane of each component uniaxial framework. This same convention in the context of a manufacturing process that produces uniaxial frameworks in a first step and then joins uniaxial frameworks together into biaxial frameworks in a second step, implies that the normal axis of biaxial frameworks produced in the second step is perpendicular to the normal axis of the uniaxial frameworks produced in the first step.

[0301] FIG. **6**B illustrates such a manufacturing process whereby two internetworking webs longitudinally oriented along the horizontal direction x are positioned in the two spaces between three uniaxial frameworks which are also longitudinally oriented along the horizontal direction x to form biaxial framework **410** by pressing everything together along the vertical direction y. FIG. **6**B also illustrates an exploded view for biaxial framework **410**′ which is a replica of biaxial framework **410** but is constructed via a second conceptual grouping of the structural parts. This conceptual grouping contrasts with the conceptual grouping illustrated by FIGS. **7**-**10**. Biaxial framework **410**′ comprises three uniaxial frameworks **421**, **423**, **425**. The pair of frameworks **421**, **423** are interconnected by internetworking web array **422**. Internetworking web array **422** incorporates three internetworking webs **422***a*, **422***b*, **422***c* each of which three internetworking web members as typified by internetworking web members **422***a***1**, **422***a***2**, **422***a***3** shown in FIG. **6**B.

[0302] FIG. **6**C shows a biaxial framework with a 3 by 3 matrix of chords and 7 web members separately formed along each chord, including a peripheral internetworking web of peripheral internetworking web members on the front and back of the biaxial framework. The peripheral internetworking web members on the front and/or back of the biaxial framework create a standoff and a layer of cavities between itself and another connected framework apparatus or connected object.

[0303] FIG. **6**D shows a biaxial framework **409**. Framework **409** has the same shape, size, and cavity structure as biaxial framework **610** shown in FIG. **6**A. The features of framework **610** are modeled with reference to the structural parts of biaxial framework **410** so as to possess a 3 by 3 matrix of chord-like features and a 2 by 2 matrix of web-like features which are analogous to the chords, internetworking webs, and intranetworking webs of framework **610**. These features can be conceptually grouped into framework-like features, internetworking web-like features, and intranetworking web-like features which respectively correspond to the frameworks, internetworking webs, and intranetworking webs described for biaxial framework **610** in the description of FIG. **6**A. Biaxial framework **409** reduces the flow of energy along its normal axis custom-character, into and out of the page along a diagonal line z sloping downwardly from left to right on the page, and also reduces the flow of energy along its lateral axis custom-character, up and down the page in the direction shown by line y. Framework **409** is a biaxial framework because it reduces the flow of energy along two axes. FIG. **6**D shows two most-direct metric through-paths for two different bundles of metric paths with spans in the normal direction to structurally insulate against energy flow from the first chord-like feature to the third chord-like feature analogous to chords **421***a* and **421***e* of framework **410**′. FIG. **6**D shows two most-direct metric through-paths for two different bundles of metric paths with spans in the lateral direction for energy flow from the first framework-like feature to the third framework-like feature. The first and third framework-like features of framework **409** are analogous to the first uniaxial framework **421** and third uniaxial framework **425** of biaxial framework **410**′. These metric paths for biaxial framework **409** are similar to the metric paths for biaxial framework **410** and **410**′ because frameworks **409** and **410** have the same shape and size. The path length of all of these metric paths is calculated as the cumulative length of all path segments between the start point, intermediate points, and end point which are shown as circles along each of the paths.

[0304] FIG. **6**E shows an embodiment of a biaxial framework wherein the internetworking web members, running between structural members in the vertical y direction, are offset in the longitudinal direction custom-character relative to the intranetworking web members. The intranetworking web members being the web members that run between structural members the transverse z direction. This configuration is advantageous for manufacturing frameworks wherein the structural members are finger jointed together because the joints internetworking web-members fall at different locations than the intranetworking web-members.

[0305] FIG. **6**H shows uniaxial framework **415** and **425** without the other structural parts in order to reveal the structure.

[0306] FIG. **6**I conceptually illustrates the transformation of uniaxial framework **415** or **425** into solid **415**′ or **425**′, respectively which is a useful process for other disclosed embodiments. Solids **415**′ and **425**′ are controls used to illustrate the process and represent part of an embodiment for which uniaxial framework **415** or uniaxial framework **425** is replaced by solid **415**′ or solid **425**′ in framework **410** or **410**′, respectively.

[0307] Other embodiments of the frameworks shown in FIGS. **6**A-**6**K have (1) web members with circular, hexagonal, octagonal, polygonal, Nsp-pointed star where Nsp is an integer, or other shaped cross sections, (2) Niw internetworking webs per internetworking web array where Niw is an integer.

[0308] FIGS. **7**-**10** show non-limiting examples of frameworks and internetworking webs that can be used to build the biaxial frameworks of FIG. **6**A and FIG. **6**C. FIG. **7** shows a uniaxial framework **411** which is the first part of the biaxial framework **610** shown in FIG. **6**A according to the first conceptual grouping. Uniaxial framework **411** includes 4 intranetworking web members **438**, **440**, **442** and **444** that form the first intranetworking web between the first chord **430** and the second chord **432**. Uniaxial framework **411** also includes three intranetworking web members **446**, **448**, **450** that form a second intranetworking web between the second chord **432** and the third chord **434**. Intranetworking web members **446**, **448**, **450** are longitudinally offset from the 4 intranetworking web members **438**, **440**, **442** and **444** by a distance equal to half the distance between intranetworking web members **438** and **440**. FIG. **8** shows uniaxial framework **411** for reference and internetworking web array **412** which is the second part of the biaxial framework **610** shown in FIG. **6**A according to the first conceptual grouping. Internetworking web array **412** comprises 18 internetworking web members extending in the transverse z direction. Internetworking web array **412** connects uniaxial framework **411** to uniaxial framework **413**. The combination of uniaxial framework **411** and internetworking web array **412** also constitutes an embodiment of a uniaxial framework with a peripheral web array. FIG. **9** shows internetworking web **412***a* which typifies all three of the internetworking webs in the internetworking web array **412**. Each of the three internetworking webs incorporates six internetworking web members typified by the web members of internetworking web **412***a*. the web members of internetworking web **412***a* correspond to the branches of the lead line for internetworking web **412***a*. FIG. **10** shows internetworking web array **414** which is the fourth part of the biaxial framework **610** shown in FIG. **6**A according to the first conceptual grouping. Internetworking web array **414** connects uniaxial framework **413** to uniaxial framework **415**. FIG. **8** shows uniaxial framework **413** for reference. The combination of uniaxial framework **413** and internetworking web array **414** also constitutes an embodiment of a uniaxial framework with a peripheral web. Internetworking web array **414** comprises 18 internetworking web members that all extend in the same direction transverse to the plane of uniaxial framework **413** outwardly from the page along a diagonal line sloping downwardly from left to right on the page. Pressing together framework **411**, internetworking web array **412**, framework **413**, internetworking web array **414**, and framework **415** produces framework **410** shown in FIG. **6**A. Pressing together internetworking web array **412**, framework **411**, internetworking web array **412**, framework **413**, internetworking web array **414**, framework **415** and internetworking web array **414** produces the biaxial framework in FIG. **6**C.

[0309] FIG. **12**A discloses a triaxial window frame **700** comprising four biaxial frameworks **710**, **720**, **730**, **740** similar to that shown in FIG. **6**A. Triaxial window frame **700** structurally insulates in the horizontal x**12**, vertical y**12**, and transverse z**12** directions, that is, a direction parallel to the plane of the frame, shown as x**12** with FIG. **12**A, and in a direction perpendicular to the plane of the frame, shown as y**12** in FIG. **12**A. In summary the triaxial window frame **700** structurally insulates in any direction perpendicular to any of the component biaxial frameworks. The embodiment shown in FIG. **12**A includes first, second, and third sheets **751**, **753**, **755** of material within the inner perimeter of window frame **700**. Each of first sheet **751**, second sheet **753** and third sheet **755** may be rigid sheets such as glass, acrylic, plexiglass, polycarbonate, polymer, crystalline solid, sapphire, diamond or a non-rigid sheet of optically transparent material such as window film, insulating window film, acetate, polyester. In embodiments using non-rigid material, the non-rigid material is preferably stretched across one of the sub-frames **701**, **703**, and **705** and possibly shrunk with application of heat so as to be taut and free of creases. In other embodiments (not shown) each of the sub-frames **701**, **703**, and **705** holds more than one sheet of material. In some embodiments like the one shown in FIG. **12**A sheets **751**, **753**, **755** and any other sheets comprise an optically transparent material or an optically transparent but light-diffusive material. In variations of the prior embodiments, the sheets have a coating such as a security film, UV protection film, low-emissivity coating on any of the front and/or back surfaces of any additional sheets as well as on the front and/or back surfaces **751′**, **751″**, **753′**, **753″**, **755′**, **755″** shown in FIG. **12**D of sheets **751**, **753**, and **755**, respectively. In a preferred embodiment for maximum durability and strength the sheets **751**, **753**, **755** and any other additional sheets are made of a rigid material. In a preferred embodiment for durability with reduced weight, the outermost sheets are made of a rigid material, i.e. sheets **751** and **755** in embodiment **700** illustrated in FIG. **12**A. The window frame **700** shown in FIG. **12**A can function as a picture window or a window sash as non-limiting examples. The window frame **700** comprises four biaxial frameworks, including first framework **710**, second framework **720** (not shown and only labeled here in the text for reference), third framework **730**, and fourth frameworks **740**. First framework **710** and second framework **720** are oriented vertically and joined together by third framework **730** and fourth framework **740** which are oriented horizontally. The first and second panes **751**, **753** are positioned next to each other forming a cavity that can be filled with a gas, preferably an insulative gas. The second and third panes **753**, **755** are positioned next to each other forming a cavity that can also be filled with a gas, preferably an insulative gas. The second vertical framework has been removed to show the internal part of the window frame **700**. Each framework is a 3 by 3 framework formed by joining 3 uniaxial/1D frameworks, each of which comprises an array of 3 chords. For instance framework **710** comprises three uniaxial frameworks, i.e., uniaxial frameworks **711**, **713**, and **715** which each respectively comprise an array of 3 chords, {**711′**, **711″**, **711′″**}, {**713′**, **713″**, **713′″**}, and {**715′**, **715″**, **715′″**} which are labeled here in the text but not in FIG. **12**A to preserve visual clarity of the illustration. To illustrate the composition of a uniaxial framework FIG. **12**A shows the array of chords {**721′**, **721″**, **721′″**} which constitute uniaxial framework **721**. Uniaxial frameworks **711**, **713**, and **715** are connected by internetworking webs **712** and **714**, not labeled to avoid clutter but exemplified in the FIG. **12**A by internetworking web members **712′** and **714′**, to form biaxial framework **710**. Each component biaxial framework **710**, **720**, **730**, **740** structurally insulates along its own normal direction custom-character and its own lateral direction custom-character. In the illustrated embodiment, the ends of the frameworks are cut on a diagonal and joined together with miter joints in the corners. Each chord to chord joint can be a miter joint, spline joint, butt joint, biscuit joint, mortise-tenon joint, half-lap joint, bridle joint, dado rabbet joint, dovetail joint, finger joint, or any other known type of joint. The component frameworks are joined such that chord in like chord layers are joined together. Then energy will flow around the corners instead of running out the end of any chord in any given component framework. In contrast, solid window frames present thermal bridges in all three spatial directions. In this embodiment, the corners have thermal bridges in that the web members in an adjacent layer are not offset. One of the two web members at each corner, like the one labeled **714′** in the upper left corner of window frame **700**, is a temporary web member that is added to preserve the form of the frame during shipping and then removed during installation to remove the thermal bridge and improve energy efficiency. This configuration can be further modified by adding to the front or back side a 4th 1D framework that has 3 chords, and a fourth pane of glass. Frame **699**, another embodiment of window frame **700** not shown but labeled here in the text for reference, has no panes of glass and forms a frame for an opening that structurally insulates in all directions x**12**, y**12**, z**12**. Such an opening frame can install in a larger framework such as the wall framework **827** shown in FIG. **13**A. Such an opening frame could function as a door frame, portal frame, sash for a window, casement for an operable window, conduit for a penetration, tunnel through a wall, utility chase, two-way flange for mounting insulated shafts on either side, the structural frame of a building, etc. Such an opening frame could comprise three frameworks as shown in FIG. **12**A but turned such that the longitudinal direction custom-character**720** of framework **720** aligns with the vertical axis custom-character**710**.

[0310] FIG. **12**B shows the embodiment of FIG. **12**A with side molding or sheathing **760** around the outer perimeter of the window frame **700** which can also apply to frame **699**. The sheathing **760** is preferably an insulating material. Sheathing **760** can also be a veneer or film for example as a means of sealing the sides against the infiltration or exfiltration of gas from inside the cavities of frame **760**. Some variants of frame **699** and **700** have sheathing on the inner perimeter **760′**. Other embodiment have no sheathing on (A) the outer perimeter, (B) the inner perimeter, and/or both A and B. In other embodiments the cavities between the structural parts of frame **699** and **700** are filled with material. This material is preferably insulating. When the insulating material is a gas then the cavities between the sheets **751**, **753**, **755** and any additional sheets can be filled along with the cavities between structural parts of the framework. When the outer perimeter of the framework does not have sheathing or the sheathing does not prevent the infiltration or exfiltration of gas then the fill material can provide a means of sealing against the infiltration/exfiltration of gas through the cavities. Sealant can be applied to seal around the edges of sheets **751**, **753**, and **755** and any additional sheets. Sheets can interface with a normal face of a structural member near the edge of the sheet as illustrated by interface **759** shown in FIG. **12**C. Structural member **735′** has a groove at interface **759** which provides a seat on which sheet **755** sits. The groove also provides a bed for sealant when sealant is applied before seating sheet **755**. Any structural member with a groove like structural member **735′** can have no groove like structural member **733′** as shown at interface **757** in FIG. **13**C. For this type of interface

the sheet and/or sealant rests on the inner lateral face of structural member **733**′. A groove can be created for interface **757** without removing material by adding a spacer to the inner lateral face of structural member **733**′. Frame **699** and **700** could have muntins. Non-structural or structural, insulative muntins can be incorporated using the same methods described for window frame **700**. Frame **359** in FIG. **36**C incorporates a structurally insulative muntin in the form of uniaxial framework **360**′ that runs horizontally. In some embodiments the four framework **710**, **720**, **730**, and **740** form a four way cross. The described method of joinery can also be used to construct elbows, tees, four-way crosses, planar grids, six-way crosses, and spatial grids (not shown). At interface **755** a single structural member in one uniaxial framework joins with a pair of structural members in another uniaxial framework. Any of the front facing uniaxial frameworks and any of the back facing frameworks in frame **700** can be solid as illustrated by the transformation of framework **425** shown in FIG. **6**H into solid **425**′ shown in FIG. **6**I. Although the resulting embodiment no longer structurally insulates directly through the solid portions, the interior uniaxial frameworks still structurally insulate the remainder of frame **700**.
[0311] Biaxial frameworks **710**, **720**, **730**, and **740** may also have molding or sheathing on the outward front normal surfaces. The sheathing could be like that of the side sheathing. The sheathing is visible when installed and could be for decoration. In a preferred embodiment for excellent insulative performance the sheathing is an insulative material. In embodiments, the side molding **760** includes two vertical components **761**, **763** and two horizontal components **762**, **764**. In embodiments the front molding **765** is formed around all four sides of the front side **700**′ of the window frame **700**, and the back molding **765**′ (FIG. **12**D) is formed around all four sides of the back side **700**″ of the window frame **700**. FIGS. **12**C and **12**D show the window frame **700** from the opposite side. FIG. **12**D shows an embodiment of frame **700** with sheathing.
[0312] FIG. **12**E discloses frame **780**, a uniaxial variant of triaxial frame **700**, that structurally insulates in the normal custom-character direction coinciding with the transverse z direction in the figure. The framework **780** comprises three thin frames **781**, **783**, and **785** that are stacked in the transverse z direction. The first thin frame **781** is a combination of structural-members **781**′, **781**″, **781**‴, and **781**″″. Embodiments of frame **780** can have any of the variations mentioned for opening frame **699**. For instance frame **780** can incorporate sheathing. By discretizing any full rotation around an intrinsic angle into N discrete angles, which are not necessarily evenly spaced, one can conceptually create a framework in the shape of an N-sided polygon or any portion of an N-sided polygon. For example a four-step rotation in orbital pitch angle structural member **781**′ produces the elements **781**″, **781**‴, and **781**″″ and the whole frame **781** as a single part rather than a collection of four parts in FIG. **12**E. For example four-step rotation in orbital yaw angle of the structural parts **781**′, **782**′, **783**′, **784**′, **785**′ produces a functional equivalent of whole framework **780** as a single part rather than a collection of 20 parts. One can build the same window framework **780** by applying a four-step rotation in orbital yaw angle of the structural members **781**′, **783**′, and **785**′, placing web-members **782**′, **782**″, **782**‴, **782**″″ between reference frames **781** and **783** with an even spacing being preferred, and then placing the web-members **784**′, **784**″, **784**‴, **784**″″ between reference frames **783** and **785** so that they are offset from web-members **782**′, **782**″, **782**″, **782**″″ with a preference toward orbital yaw angles half way between those of web-members **782**′, **782**″, **782**‴, **782**″″. Additional constraints such as structural integrity at the joints and aesthetic design can alter the preferred oribtal yaw angle of the web members. Another embodiment of framework **780** has an octagonal shape produced by eight-step rotation of structural parts **781**′, **782**′, **783**′, **784**′, **785**′. This same conceptual process applies to any embodiment not just framework **780**. One can start with a biaxial framework like biaxial framework **730**. For instance, four-step rotation in orbital yaw angle of biaxial framework **730** produces multi-axial framework **700**. The mitered end conditions of the structural members in framework **730** give a different aesthetic than the un-mitered ends of the structural members of framework **780**. Given a particular embodiment one can infer how many discrete steps in angle are used for rotation. A number N steps can be applied to rotation of structural members and a different number M steps can be applied to rotation of web members. An offset is applied to web-members in one of two adjacent webs.
[0313] FIG. **12**F discloses window frame **780**′ with first, second, third, fourth, fifth, and sixth sheets **791**, **792**, **793**, **794**, and **795** of material within the inner perimeter of window frame **780**. Each sheet noticeably reduces the convective transfer of heat between the outermost sheets which are sheets **791** and **796** for the embodiment shown in FIG. **12**F. Any sheet incorporated into window frame **780**′ or window frame **700** could be a number of thinner sheets pressed together. Other embodiments have fewer than six sheets. For instance window **2963**, built for testing, has five sheets in the form of glass panes. Other embodiments have more than six sheets, more than three structural members, and more than two webs of web members. Embodiments of window frame **780**′ can have any of the variations mentioned for window frame **700**. For instance, window frame **780**′ can also serve as a window sash, a casement for a casement window, and the like. Any variations mentioned here also apply to windows **700** and **840**′. In embodiments of windows **700**, **780**′, and **840**′ the space between each pair of sheets is filled with an insulative gas. In embodiments of windows **700**, **780**′, and **840**′ preferred for energy efficiency, the space between each pair of sheets is filled with an insulative gas with molecular weight greater than that of air in order to slow the convective flow of heat between the sheets **751**, **753**, **755**, **791**, **792**, **793**, **794**, **795**, **796**, **851**, **852**, **853**, **854**. In embodiments of windows **700**, **780**′, and **840**′ preferred for reducing convection and reducing radiative heat loss and radiative heat gain through the window, the space between each pair of sheets is filled with a greenhouse gas with a molecular weight greater than that of air. The greenhouse gas being for example carbon dioxide, methane, or any other gas that absorbs solar radiation. The greenhouse gas works to absorb incoming radiation and then reradiate the energy into all directions with approximately 50% of the incident radiation being reradiated backward to some extent relative to the incident direction. In the heating season the greenhouse gas works to prevent heat loss from the building in which the window is installed by absorbing and reradiating incident radiation back into the building. In the cooling season the greenhouse gas works to actively reject infrared and visible radiation produced by the sun and surrounding objects. Any other gas with a large molecular weight and/or absorption line in the visible or infrared spectrum could be used instead. Experimental window **2963** shown in FIG. **36**G was filled with carbon dioxide gas using dry ice and the process of sublimation accelerated to generate the carbon dioxide gas. Experimental window **2963** used window frame **708**′. A greenhouse gas can also serve as a filler for an other embodiment of the present invention. Furthermore, a greenhouse gas could also be used to fill apparatuses that do that do not incorporate an insulatable, insulative framework such as an insulating glass unit, a window, a wall cavity, or other type of air-sealed framework.
[0314] FIGS. **11**A, **11**B and **11**C each illustrate an embodiment incorporating four uniaxial frameworks and a different method of joining the four uniaxial frameworks together into a rectangular frame. FIG. **11**B illustrates a method of joining the four uniaxial frameworks by joining each structural member in one framework to another structural member in a like layer of another framework. Instead of joining single structural members one can join a pair of structural members in one framework to a single structural member in another framework as illustrated by interface **755** in FIG. **11**A. The method of joinery illustrated by FIGS. **11**A and **11**B creates a unified structure with the same the structural insulation factor as the component frameworks as measured along the most direct metric path in a direction perpendicular to the structural members. FIG. **11**B illustrates an embodiment of joining uniaxial frameworks. The method of joinery illustrated by FIG. **11**B creates a unified structure with a lesser structural insulation factor than that of the component frameworks, as measured along the most direct metric path in a direction perpendicular to the structural members. However, this method of joinery might be preferred for expediency as a non-limiting example.

[0315] FIGS. **12**G and **12**H disclose a structurally insulative frame **840** and structurally insulative window **840**′ each of which incorporates four uniaxial frameworks **831**, **832**, **833**, **834**. Each of the uniaxial frameworks **831**, **832**, **833**, **834** incorporates two chords **841** and **843** interconnected by a web of diagonal web members typified by diagonal web member **842**. These web members could have any pitch angle between 0° and ±90° relative to one of the chords **841**. The web members shown have a pitch angle of 15° with an alternating positive and negative sign. In other embodiments (not shown) the web members **842** are dowels with polygonal or circular cross sections. Retainers, typified by retainer **844**, provide a brace to retain diagonal web members **842** that terminate at the ends of a framework **831**, **832**, **833**, or **834**. In some embodiments structurally insulative frame **840** is spun 90° around its central axis running in the transverse z direction of the figure such that the bottom framework **833** would support frameworks **832** and **834**. In that configuration frameworks **832** and **834** can function as studs and frameworks **831** and **833** can function as a top plate and bottom plate or vice versa. In the current configuration frameworks **831** and **833** can function as studs and frameworks **832** and **834** can function as cross braces. FIG. **12**H shows a cutaway view with uniaxial framework **831** omitted to more clearly reveal the edges of glass panes **851**, **852**, **853**, and **854** which are incorporated into frame **840** to create structurally insulative window **840**′. All of the variations mentioned for windows **700** and **780**′ apply to window **840**′.
[0316] FIG. **13**A shows a structure **800** that structurally insulates in three directions. More particularly, this figure show how uniaxial/1D frameworks and biaxial/2D frameworks can combine to form a frame that structurally insulates in three directions in this case (1) upward and downward through the foundation framework in the vertical y**13** direction (2) inward and outward through the foundation framework along the north/south axis, transverse z**13** axis, and (3) inward and outward through the foundation framework along the west/east axis, horizontal x**13** axis. Four frameworks, exemplified by biaxial framework **825** in FIG. **13**A, joined together at right angles create a framework that serves as an insulatable, insulation foundation for building walls. FIG. **13**A also discloses a means of constructing a wall with uniaxial/1D frameworks that serve as studs, exemplified by uniaxial framework **812**, and uniaxial/1D frameworks that serve as top plates, exemplified by uniaxial framework **816**, and bottom plates, exemplified by uniaxial framework **818**. The embodiment of stud-like uniaxial framework **812**, illustrated in FIG. **13**A, and constituting each stud, has web members that are (1) the same thickness and width as the structural members and (2) spaced along the longitudinal direction custom-character**812** with the same spacing as the web members of top-plate-like uniaxial framework **816**. Stud-like uniaxial framework **812** derives strength from the fact that the web members are short with respect to their span in the normal direction custom-character**812** so that applied forces have a short lever arm on which to work. Note that any biaxial framework can benefit from the joinery method shown in FIGS. **11**A and **11**B. Any number of floating tenons, between a web-member and adjacent structural members can strength the framework against shear forces acting along the longitudinal direction. Note that the corners of the foundation framework might appear to have thermal bridges in that the braces in an adjacent layers are not offset. However, unlike the framework in FIGS. **12**A-**12**D, this framework has only one edge that is exposed to the indoor environment. An entire face of the framework is not exposed to the indoor environment as for the window frame in FIGS. **12**A-**12**D. Thus, the web members in an adjacent layer that are not offset do not constitute a thermal bridge. They represent a purely mechanical bridge that strengthens the corner. FIG. **6**H shows uniaxial frameworks **415** and **425** that constitute the outermost uniaxial framework components for biaxial framework **410**. Biaxial framework **810** has a uniaxial framework **815** with its normal custom-character axis oriented along the vertical y direction analogous to framework **415** and has a uniaxial framework **825** analogous to framework **425** with its normal custom-character axis oriented along the transverse z direction. In an embodiment (not shown) vertical uniaxial framework **815** is a solid board with the same envelope dimensions as framework **815** in order to provide additional strength and function as a rim joist for mounting other structures like a deck. In an embodiment (not shown) horizontal uniaxial framework **825** is a solid board with the same envelope dimensions as framework **815** in order to provide additional strength and function as a sole plate to fasten down to a sill plate, j-bolts, or similar means of connecting framework **810** with any additional portion of the foundation which might include a masonry wall, concrete wall, concrete slab, pier system, solid timber frame, as non-limiting examples. In an embodiment (not shown) both vertical uniaxial framework **815** and horizontal uniaxial framework **825** are solid boards configured as in the prior two embodiments in analogy to FIGS. **1**A and **1**B which show frameworks **415** and **425** as solid boards with the same envelope dimensions as frameworks **415** and **425**.
[0317] In FIG. **13**A, the lower portion **805** of the structure **800** is formed from a total of four biaxial framework segments, like biaxial framework **810**, connected to form a rectangle, that resist heat flow in the directions that are not parallel to the length of the chords. Each of the four biaxial framework segments include three uniaxial frameworks and three structural members per uniaxial framework for a total of nine structural members. In the south east corner of lower portion of foundation **800** lower portion **805** Another embodiment includes uniaxial frameworks typified by uniaxial framework **820** running in the horizontal direction between two opposing biaxial frameworks of lower portion **805** which function as structurally insulative joists in embodiments of structure **800**. The vertical portion **827** of the structure **800** is formed from seven 1 by 3 uniaxial framework segments **812** that resist heat flow in the direction z**13**, which is perpendicular to the plane of the framework portion **827** and function as studs in embodiments of structure **800**. These seven segments **812** are connected across their bottom terminal ends to uniaxial framework **818**, which serves as a bottom plate for the wall, and are connected at the top to uniaxial framework **816**, which serves as a top plate, across their top terminal ends. In one embodiment of a building method the entire vertical portion **827** is assembled lying down on a horizontal surface and then stood up into position as often done in conventional stick framing. The reduction in weight afforded by the cavity structure of each framework in the vertical portion **827** has the advantage of (a) reducing strain and injury on workers, (b) easing the process of raising the vertical portion **827** into position, and (c) enabling larger wall sections to be constructed when the total weight of vertical portion **827** is comparable to that of a conventional wall frame. In another embodiment (not shown) sheathing, wrap, or other surface defining means is applied to the interior and exterior surfaces of the structure **800** to create fully enclosed cavities which are filled with an insulating material to block convective flow of gas trapped within the enclosed cavities caused by temperature differences across the wall or heat from a fire and block the conductive flow of energy through the enclosed cavities including those of the framework members. The three chords of each uniaxial framework segments **812** enhance structural reliability, for instance, by (1) avoiding sudden failure if any one of the three chords is compromised by fire, chemicals, projectile, shockwave, earthquake, hurricane, or other attack and (2) increasing the time until failure under sustained conditions of attack in the aforementioned scenarios relative to two-chord embodiments. Another advantage is that the binary connections between each web member and each structural member mean that the structure is determinate for a structural engineering analysis. Another embodiment includes a web or horizontal web members that connect adjacent uniaxial framework segments **812** into a lattice similar to the one shown in FIG. **35**A. This embodiment may further increase the time until failure during a fire especially when insulated with a fire resistant insulative fill material such as mineral wool or borated cellulose insulation such that fire burns along the most direct metric path.
[0318] FIG. **13**B shows a close-up view of the south east corner of structure **800** shown in FIG. **13**A. This framework is a smaller biaxial framework which is inserted into the larger biaxial framework **825** to strengthen the corner.
[0319] FIG. **14** shows a cylindrical tube-shaped triaxial structure **910** that includes first, second and third circular frameworks **913**, **915**, **917** of concentric, coaxial first, second and third circular chords **930**, **932** and **934**, with each circular framework being vertically spaced from the others along a common vertical axis and being parallel to the others. The circular structural members and web member between them are

integrally formed. In other embodiments the web members and circular structural members separate sets of structural parts joined together. This configuration structurally insulates along (a) the axial direction of the cylindrical framework and (b) the radial direction which encompasses both the horizontal and transverse directions. In summary the triaxial structure **910** structurally insulates along any perpendicular to the chords. This is a variation of FIG. **6**A. The configuration can be modified to include (a) fewer concentric chords, or (b) additional concentric chords, and/or (c) fewer vertically spaced circular frameworks, and/or (d) additional vertically spaced chord sets. In the embodiment shown in FIG. **14**, the concentric chords have a spacing that is similar to the thickness of the individual chords, however, other embodiments (not shown) have smaller relative spacing and larger spacing relative to the thickness of the individual chords. The spacing between first and second chords can be the same as, or different from, the spacing between third and fourth chords as a non-limiting example. In the embodiment shown in FIG. **14**, the distance between vertically spaced chord sets is about 4-5 times the thickness of the individual chords to provide a substantially non-zero span-wise indirectness in the vertical direction and to better illustrate the internal structure of the circular frameworks. However, smaller or larger spacing can be used. Smaller spacing yields greater span-wise indirectness and greater values of structural insulation factors in the vertical direction as well as the radial direction. In the embodiment shown in FIG. **14**, the horizontally extending web members **936** are spaced such that there are four horizontally extending web members between adjacent pairs on concentric chords at a given height. The appropriate spacing between web members can be inferred by scaling the dimensional parameters in Table 2 and then using them as arc lengths for around the circumference of a circular structural member. The arclength spacing can also be calculated using the equations in Table 2 and working backwards from the targeted structural insulation factor, F.sub.target, corrected for the effects of non-isotropic resistivity along metric paths in the targeted direction to solve for the spacing which relates to the length along the metric path. For example, referring to the metric path diagrammed in FIG. **2**AI for the three-chord framework shown in FIG. **2**AH, the spacing Δcustom-character approximately equals L−{Δcustom-character**1001**+Δcustom-character**1002**+Δcustom-character**1004**+Δcustom-character**1005**} where L equals F.sub.target.Math.S. In this case the spacing the spacing Δcustom-character corresponds to an arclength rather than a linear length. To understand this idea wrap uniaxial framework **1000**, shown in FIG. **2**AH, into a circle. Alternatively imagine cutting one of the circular structural members and straightening it out. Finally, one can rework the equations in table 2 for arclength and do the calculation directly in cylindrical coordinates. Similar ideas hold for calculating the spacing of web members in the vertical directions (axial direction). In the embodiment shown in FIG. **14**, the vertically extending web members **938** are spaced such that there are four vertically extending web members between adjacent sets of the outermost chords and four vertically extending web members between adjacent sets of the innermost chords. In other embodiments there also are vertically extending web members positioned between adjacent intermediate chords in analogy to the biaxial framework shown in FIG. **6**E. In other embodiments there are vertically extending web members positioned between only adjacent intermediate chords in analogy to the biaxial framework shown in FIG. **6**J. The embodiment of framework **910** shown in FIG. **14** corresponds to bending a slightly longer embodiment of the biaxial framework shown in FIG. **6**K with additional web members around an orbital pitch axis such that the ends of the biaxial framework wrap around and join with each other end to end. Other embodiments of triaxial frameworks can be created by bending any biaxial framework like those shown in FIGS. **6**A-**6**K in the orbital yaw axis, orbital pitch axis or any other orbital axis that allows the structural members to wrap around and join end to end. Framework **910** in FIG. **14** represents an embodiment of ˜20-step rotation in orbital pitch angle of the structural members and 4-step rotation in orbital pitch angle of the web members. An offset of 45° is applied to rotation in orbital pitch angle for the outermost web of each uniaxial framework. This figure practically illustrates continuous rotation of infinitely short structural members but does not exactly illustrate continuous rotational extrusion of a cross section of structural members because the 3D CAD software is not capable of modeling continuous curves, that is, non-discretized curves. Continuous rotation along a first spin axis of a spin-symmetric array of structural-member cross sections creates concentric structural shells. These structural shells can be structurally insulated by discrete-step rotation, around the same spin axis but in orbital angle, of web-member cross sections with web-members in adjacent webs having a different angular offset. Further continuous spin rotation of the structural member array along an orthogonal spin direction creates completely closed concentric structural cells. These structural shells can be structurally insulated by discrete orbital rotation, along the orthogonal spin direction, of web-member cross sections with web-members in adjacent webs having a different offset in orbital angle. All internetworking web members could be solid cylinders but are shown here to (a) reveal the internal structural (b) structurally insulate along the axial direction and (c) create a triaxial framework.

[0320] FIG. **15** shows an embodiment of a multiscale, biaxial framework **1500**. In this embodiment, the chords **1501**, **1503** and **1505** are each made from a stack of frameworks **1510**, and each web member **1502** is made from a stack of frameworks **1512**. More specifically, in the illustrated embodiment, each chord is made from a stack containing about 50-60 frameworks, and each web member is made from a stack containing about 5 frameworks. Larger or smaller number of frameworks can be used in the stacks depending on the desired size and strength of multiscale, biaxial framework **1500**. Multiscale, biaxial framework **1500** structurally insulates in the longitudinal direction (the vertical y direction in FIG. **15**) and the normal direction (the horizontal x direction in FIG. **15**). In the version shown in FIG. **15**, the frameworks in the chord stack extend horizontally and the frameworks in the web member stack extend vertically.

[0321] FIG. **16** shows triaxial framework **1600** made from three aligned frameworks **1601**, **1602** and **1603**. The web members **1602** are staggered relative to web members **1604**. In both sets of web members **1602** and **1604** each web member extends across two out of the three aligned frameworks. Triaxial framework **1600** is a multiscale framework made with web members and chords that are small frameworks in and of themselves. One can create an embodiment with any arbitrary number of scales by making the structural parts at any given scale into small frameworks in and of themselves. Likewise one can create an embodiment with any arbitrary number of scales by making the structural parts into a larger structurally insulative framework. Triaxial framework **1600** structurally insulates in all three directions, i.e. the longitudinal direction along the long axis of the framework (transverse z direction in the figure), normal direction (horizontal x direction in the figure), and lateral direction (vertical y direction in the figure). This framework reduces energy flow in the vertical direction with a similar geometry to that of the framework disclosed in FIG. **17**. The front layer of three strut-like structures and front layer of four web members **1602** constitutes a single layer biaxial framework that suppresses energy flow along the transverse z direction in the picture and the vertical y direction in FIG. **16**. In another embodiment shown in FIG. 26 of U.S. Provisional Patent Application No. 62/720,808 the general cross sectional shape of the chords is square rather than rectangular.

[0322] FIG. **17**A illustrates an embodiment of a laterally extended framework of structural formations as a building panel **1206** with vertical stud-like frameworks **1210**. Framework panel **1206** also includes a rigid, planar solid board **1270**, and horizontal strapping **1272**. Insulatable framework panel **1206** structurally insulates along the transverse z**17** direction perpendicular to the plane of the board **1270**. Framework panel **1206** contains three structural formations **1270**, **1211**, and **1212**. Structural formation **1270** is the board **1270**. Structural formations **1211**, **1212** each incorporate three chords that are not directly connected and are spaced apart in the horizontal x direction as shown in FIG. **17**B. The branches of the lead line labeled **1211** correspond to individual chords in the structural formation **1211**. The branches of the lead line labeled **1212** correspond to individual chords in the structural formation **1212**. Each pair of structural formations is interconnected by one of the web formations **1214**, **1213**. Each of web formations **1213**, **1214** contains 3 webs. Each of the 3 webs in each of the web formations **1213**, **1214** contains six web members. Each of the three branches of the line labeled **1213** in FIG. **17**B points to the first web member in each of the three webs that constitute web formation **1213**. Each of the three branches of the line labeled **1214** in FIG. **17**B points to the first web member in each of the three webs that constitute web formation **1214**. In other embodiments (not shown) each chord is an array of structural members such as a group of veneer strips laminated together. In other embodiments (not shown) each structural formation is an array of structural formations such as a multiplicity of framework panels connected together either using the present methods or not using the present methods. As a non-limiting example, using the present methods to connect such an array of framework panels can provide protection against the lateral spread of fire between structurally connected framework panels that form an insulatable, insulative wall framework apparatus.

[0323] FIG. **18** illustrates an embodiment of an insulatable, insulative building panel **1800** comprising a lattice framework **1812** between two sheets **1815**, **1817** which serve as sheathing to contain insulating material as well as block convective and radiative transfer in the normal z direction (vertical y direction in the figure). Different embodiments of sheets **1815**, **1817** are rigid while others are flexible. Different embodiments of the two sheets **1815**, **1817** are structural while others are non-structural. Different embodiments of the two sheets **1815**, **1817** are transparent while others are semi-opaque or opaque. Two layers of structural members **1836** run in the transverse z direction in the figure. Structural members **1836** in different layers are offset in the horizontal x direction of the figure. Web members **1834** in different layers are offset in the transverse z direction of the figure. Two layers of web members **1834** run in the horizontal x direction in the figure and join with the structural members to create the lattice framework **1812**. Framework **1812** structurally insulates along its own normal custom-character**1800** axis parallel to the vertical y direction. To conductively flow from the bottom sheet **1815** into a structural member **1836** and then to the top sheet **1817** along the vertical y direction, energy must additionally flow in the transverse z direction, then in the horizontal x direction, and then again in the transverse z direction along the way. To conductively flow from the bottom sheet **1815** into a web member **1834** and then to the top sheet **1817** along the vertical y direction, energy must additionally flow in the horizontal x direction, then in the transverse z direction, and then again in the horizontal x direction along the way. The top layer of sheathing **1817** is partially cut away in order to better show the underlying structure. One layer of sheathing or both layers of sheathing could be omitted.

[0324] FIG. **19** illustrates one embodiment of the framework as an insulative panel **1900** comprising three or more sheets **1912**, **1914**, and **1916** of material with two or more layers of spacer ribs **1918** staggered relative to those of the adjacent layer. In some embodiments of panel **1900** the sheets are made of transparent material and together function as a triple-pane window **1900** with a scarf joint. The illustration shows one sheet of material offset from the other. This design allows multiple panels to scarf-join together and maintain their full insulative capability. The illustration shows a transparent material that allows one to better see the structure.

[0325] FIG. **20**A illustrates on embodiment of the framework demonstrating how to make and use a scarf joint to longitudinally connect together biaxial frameworks **1612**, shown separately in FIG. **20**B, and **1614**, shown separately in FIG. **20**C. In the embodiment shown, each framework has nominal exterior dimensions of 4 inch by 8 inch (100 mm×200 mm) along the non-longitudinal axes. This figure also illustrates the required configuration for the ends of the chords. In some cases, these frameworks are made of wood. A worker can glue these frameworks together in the field. The protruding blocks, typified by block **1616** in FIG. **20**C, lock the two frameworks together along their normal and lateral axes. Holes drilled through overlapping pieces of the frameworks filled with pins made from wood dowels or any other material can further secure the two frameworks together along their longitudinal axes. Nails or screws driven through overlapping pieces of the frameworks could serve the same the purpose. This same method also works for uniaxial frameworks. FIG. **20**A also illustrates this concept. For instance the foreground set of chords and web-members **1622**, **1624** for halves **1612** and **1614**, respectively, constitute uniaxial frameworks and shows how they can be scarf joined. FIGS. 32 and 34 in U.S. Provisional Patent Application No. 62/720,808 show other embodiments of scarf joined biaxial frameworks.

[0326] FIG. **21** shows an elevation view of a uniaxial framework **1712** that structurally insulates along its normal axis (into and out of the page along a diagonal sloping downward from left to right on the page) and most-direct metric through-paths **1721** and **1723** from two different bundles of metric paths with a span in the normal direction.

[0327] FIG. **22**A illustrates one embodiment of a vertically extending uniaxial framework filled with insulating material. The framework has protrusions which provide space, typified by cavities **5***a* and **5***b*, for insulation between the nearest chord-like feature and the interior facing surface of any cooperative object attached to the protrusions. One example protrusion contains the points labeled **5***c* and **5***d* in FIG. **2**A. The points **5***c* and **5***d* are the starting points for two most-direct metric through-paths from two different bundles of metric paths with a span in the normal direction. The protrusions also significantly increase the length of the two most-direct metric through-paths shown relative to what they would be in the absence of protrusions.

[0328] FIG. **22**B magnifies the dotted-line region of FIG. **22**A and shows intermediate points **6***b*, **6***a′* as well as end point **5***c′* for the path beginning at **5***c*. FIG. **22**B also shows intermediate points **7***b*, **7***a′* as well as end point **5***d′* for the path beginning at **5***d*. The path length of each path is calculated as the cumulative length of all path segments between the start point, intermediate points, and end point.

[0329] FIGS. **23**A and **23**B show two different configurations of a stud and plate joined together with a screw and a nail. In FIG. **23**A the web member **2304** of plate-like framework **2314** extends into the cavity created by a pair of structural members in stud-like framework **2311** lying down as it would be when framing a wall for instance. FIG. **23**A shows a screw driven through the pair of structural members and web member **2304**. However, a dowel, nail, or any other appropriate fastener could be used instead of the screw. This type of connection is preferred for strength over the other connection show in FIG. **23**A in which a nail is driven through chord **2301** of the plate-like framework **2314** into the adjacent chord of stud-like framework **2311**. Web member **2302** is shown with a dotted line to indicate that it is not in the same plane as web member **2304**. This convention is used in other figures as well. Thus, the web members **2302** and **2304** are offset and provide no direct path for conductive energy flow between chords **2305** and **2301** through chord **2303** of framework **2300**. Furthermore, the greater the offset between web members **2302** and **2304** the more indirect the most-direct metric path through them becomes making the structural insulation factor larger. In FIG. **23**B web member **2314** of framework **23**B extends into a cavity created by chords **2305** and **2303** of framework **2300**. Then frameworks **2300** and **2310** are secured together with a screw driven through chords **2305** and **2303** and web member **2314**.

[0330] FIGS. **24**A and **24**B illustrate a uniaxial framework **2400** comprising laminations **2410**, **2411**, **2412**, and **2413**. Framework **2400** is rotated in FIG. **24**B relative to that in FIG. **24**A to show the opposite side as indicated by the axis label custom-character**2400**. Laminations **2410** and **2412** build to form chords. Laminations **2412** run the entire length of framework **2400**. Additional laminations like laminations **2412** could be added to make an I-beam cross section and strengthen the overall framework. Laminations **2410** run between web-member-like laminations **2411**. Web-member-like laminations **2413** run between chord-like laminations **2412**. In order to manufacture framework **2400**, one could assemble the laminations into a form with the orientation of the framework in FIG. **21**. Then the laminations could be pressed together. Heat could be applied conductively through the form and faces of the press. Heat could also be applied via radiative heating with microwaves or other suitable form of radiation. Other embodiments use laminations characteristic of oriented strand lumber, cross laminated timber, parallel strand lumber, or laminated strand lumber. The laminations **2410**, **2411**, **2412**, and **2413** shown in

FIG. **24** are characteristic of laminated veneer lumber. The laminations could be prepressed with or without heat before being fully pressed together into final form. Frameworks can also be glued together in the configuration shown in FIG. 6 of U.S. Provisional Patent Application No. 62/720,808. Frameworks can be manufacture by creating a wide framework as shown in FIG. 6 of U.S. Provisional Patent Application No. 62/720,808 and then cutting the wide framework into more narrow frameworks.

[0331] FIGS. **25**A-**25**D schematically illustrate different embodiments and views of a structurally insulative joist framework **2512** with and without straight-through, web-member braces. This set of figures shows a structure that is trimmable, insulatable, and insulative with a portion that has two structural members and diagonal web members. A preferred embodiment, shown in FIG. **25**D, for framing a barrier insulated along its entire length has no straight-thru braces.

[0332] FIGS. **26**A and **26**B show a different embodiment of a structurally insulative joist framework with straight-through braces/web-members. FIG. **26**A illustrates a joist-like framework with two parts that are each similar to the joist-like framework of FIG. **25**D and a third part with two chords connected by straight-through web members that create a rectangular opening in the center of the joist-like framework. FIG. **26**B illustrates a joist-like framework incorporating multiple chords connected together by blocks that could incorporate straight-through web members. The structure of FIG. **25**D may be preferred when the joist need only be structurally insulative at its ends. In that case the straight-thru web members do not degrade thermal performance and provide space for running utilities for example. The end views of FIGS. **25**A, **25**B, and **25**C show different possible profiles of (a) nominal 2 inch by 2 inch top and bottom chords (c) nominal 2 inch by 4 inch top and bottom chords (e) nominal 2 inch by 3 inch top and bottom chords, for the apparatuses in the lengthwise view of FIG. **25**D.

[0333] FIG. **27**A shows a side view of a framework pre-form **2211** that includes three parallel chords **2230**, **2232** and **2234** with a first continuous web member **2237** extending along the length of the structure pre-form **2211** between first and second chords **2230**, **2232**, and a second continuous web member **2239** extending along the length of the structure pre-form **2211** between second and third chords **2232**, **2234**. FIG. **27**B illustrates an end view of the structure, showing that the web members **2237**, **2239** are thinner than the chords. Openings can be cut in the web members **2237** and **2239** to create indirect paths in the vertical direction on the page between the first chord **2230** and the third chord **2234** in order to form the finished structure.

[0334] FIG. **28**A illustrates an end view of one embodiment of a roof frame **2306**. Each end of the roof frame **2306** includes a pair of slanted beams **2353**, **2354** that are joined in an upside-down V configuration to form the peak of the gable. A vertical support **2357** provides reinforcement to the beams **2353**, **2354** by carrying some of the load of the roofing material. The main horizontal tie **2310** is formed from first, second and third chords **2331**, **2333**, **2335**, respectively, with web members **2332** positioned between the first and second chords **2331**, **2333**, and web members **2334** positioned between the second and third chords **2333**, **2335**. Vertical small frameworks **2313** and **2315** support opposite end of the main horizontal support **2310**. Each of the vertical frameworks is made from three chords and two web members. Diagonal beams **2355** and **2356** provide reinforcement to the center of the main horizontal tie beam **2310**. The roof framework has a main horizontal apparatus that incorporates three structural members. Each structural member has a horizontal tie member and a vertical heel member. The three structural members are connected together by two intervening webs. Each of the webs has a plurality of braces. Instead of joining structural members and braces one could cut openings into a single heel in order to create the same indirect paths of the three braced heels. In this embodiment, the various truss members are jointed together with metal truss plates that can be stamped to form an array of integrated nails.

[0335] FIG. **28**B illustrates a roof frame **2306**′ similar to that of FIG. **28**A with gussets **2386**, **2388**, **2390**, **2392**, **2394** and **2396** to join the framework members together. The gussets can be glued, nailed, or attached in another suitable manner. The gussets do not modify the minimum rangewise indirectness of the main horizontal tie member. The broken line **2397** shows a “W” shaped web that could substitute for the single vertical support that rises to the peak of the gable.

[0336] FIG. **29** illustrates an end view of a structure **2410** that includes a roof frame **2306**″ similar to that of FIG. **28**A mounted on an enclosure **2411**, such as a building. The two illustrated frameworks **2412**, **2414**, **2416** and **2418** can be uniaxial frameworks each comprising a 3 by 1 matrix of structural members or a biaxial framework comprising a 3 by 3 matrix of structural members, or can have other dimensions depending on the building size and load requirements. The illustrated embodiment shows 3 by 1 frameworks for ease of understanding. In the construction of a building, the opposite end of the building would have a similar structure, and there would be four horizontal frameworks connecting the two opposite end of the building frame. Two transversely oriented top-plate-like uniaxial frameworks **2413** and **2415** sit on top of each wall and tie together the stud-like frameworks at their top ends. A transversely oriented bottom-plate-like and sole-plate-like uniaxial frameworks sit at the base of each wall and tie together the stud-like frameworks at their bottom ends. Uniaxial framework **2416** is a floor-joist-like framework.

[0337] FIGS. **30**A-**30**E schematically illustrate various stacked and rotated embodiments of the framework where the structural members and web members are seamlessly connected so that they become an integrated unit with structural-member-like features and web-member-like features without joints. FIG. **30**A shows a first unit **2522** decorated with vertical stripes for the purpose of illustration. FIG. **30**B shows a second unit **2524**. The second unit **2524** is that same as the first unit **2522** except that it has been rotated by 180° around its longitudinal axis and decorated with horizontal stripes for the purpose of illustration. FIG. **30**C shows the first unit **2522** stacked on the second unit **2524** and a third unit **2526**, which is identical to the second unit **2524**. The second unit **2524** is underneath and to the left while the third unit **2526** is underneath and to the right. The first unit **2522** is drawn with a transparent background to illustrate the positional relationship of the first unit with the second and third unit. The left half **2527** of the closed cavity **2528** in the first unit **2522** lines up with the right open cavity **2532** of the second unit **2524**. The right half **2531** of the closed cavity **2528** in the first unit **2522** lines up with the left open cavity **2535** of the third unit **2526**. The right half **2533** of the closed cavity **2534** in the second unit **2524** lines up with the open cavity **2535** on the left side of the third unit **2526**. The left half **2536** of the closed cavity **2537** of the third unit **2526** lines up with the open cavity **2538** on the right side of the first unit **2522**. This feature means that the first unit **2522** can form a “running bond” with copies of itself as shown FIG. **30**D. Running bonds are important for strength in a wall assembly. In FIG. **30**D the inner edges **2550**, **2552** of the lower units **2551**, **2553**, respectively, are offset essentially half way between the inner edge **2554** of the upper unit **2556** in a “running bond” configuration. The gaps between the units provide space for a substance to bond the units together. Embodiments of frameworks **2522**, **2524**, **2612**, and **2614** take the form of bricks, masonry units, and blocks. Embodiments of frameworks **2522**, **2524**, **2612**, and **2614** could be made from any material but ceramics, concrete, adobe, and rammed earth are commonly used materials for bricks, masonry units, and blocks. FIG. **31**D shows a brick-like framework with a structurally non-insulating cavity **2563**. Cavity **2563** can be considered as structurally non-insulating cavities because no metric path intersects cavity **2563**. Structurally non-insulating web members and structural members are also possible when no metric path intersects them. Cavity **2563** does contribute somewhat to the insulatable aspect of the brick. Embodiments preferred for their insulatable aspects may have structurally non-insulating cavities. Embodiments preferred for their strength have few to zero structurally non-insulating cavities. Features **2564** and **2565** are ineffective features because the presence of features **2564**, **2565** do not change the insulation characteristics of the overall structure by more than 10%. The analog of these ineffective features in the case of a framework made of structural parts would be ineffective web members and structural members whose presence does not change the insulation characteristics of

the overall structure by more than 10%.
[0338] FIGS. **31**A-**31**E schematically illustrate various embodiments of the framework stacked and rotated. These figures show embodiments where the chords and web members are seamlessly connected so that they become an integrated unit with structural-member-like features and brace-like web members without joints. FIG. **31**A shows a first set **2611** of two side by side staggered units **2612** (shown with horizontal stripes). FIG. **31**B shows a second set **2613** of two side by side stagger units **2614**. The second unit is a copy of the first unit except rotated by 180° around its longitudinal axis and decorated with vertical stripes for the purpose of illustration. FIG. **31**C shows the first set **2611** stacked partially on top of the second set **2613**. This arrangement gives the same functionality as a “running bond” with the look of a “stack bond” front either side of the wall. FIG. **31**D shows how the forward half of the first unit (outlined with a bold line) in the foreground looks like it is “stack bonded.” FIG. **31**E illustrates a brick-like framework with cavities.
[0339] FIGS. **32**A-**32**J schematically illustrate different embodiments of the framework with curves, bends, twists, bulges, and other distortions. Each figure shows a 5 chord configuration (although each may be formed as a one-piece component rather than by connecting 5 separate chords with individual web members). FIG. **32**A shows an S-shaped framework **2612** with a generally uniform thickness along its length. FIG. **32**B shows a framework **2614** that is wider in the middle than on the ends. Additional width can be occupied by making cavities of varying width, and/or by using chords of non-uniform width. FIG. **32**C depicts a straight framework **2618** with a generally uniform thickness and diagonally extending web members **2636**. The structure of FIG. **32**D is similar to that of FIG. **32**C except that the pattern of web members **2638** is different. The framework **2622** of FIG. **32**E has wider web members **2640** than the web members of FIG. **32**D. FIGS. **32**F, **32**G and **32**H show frameworks **2624**, **2626** and **2628** with non-uniform thicknesses along their length. The framework **2630** of FIG. **32**I has curved longitudinal ends **2642**, **2644**.
[0340] FIG. **33** illustrates one embodiment of a framework **2712** in radial form with web members **2736** and surface web member protrusions **2737**. By removing one or more of the protrusions, one can create other embodiments of the disclosed apparatus.
[0341] FIG. **34** shows a photo of one embodiment of a three-chord framework, framework **2812**, and the most direct metric path **2819** between the outermost chords of framework **2812**.
[0342] FIGS. **35**A-**35**C depict embodiments of the framework in a rectangular frame with and without insulating substance in accordance with Example 5. FIG. **35**A shows an insulative panel **2910** made from five frameworks **2912**, **2914**, **2916**, **2918** and **2920**. The vertical frameworks **2912** and **2914** and combination with the horizontal frameworks **2916** and **2918** form a box-type structure.
[0343] Vertical framework **2920** acts as a single central stud. The cross braces **2926**, **2928** and **2930** create a stand-off mentioned in the previous paragraph.
[0344] FIG. **36**A shows a conventional stud wall **3602** and an insulative stud wall **3601** corresponding to an embodiment described herein in accordance with Example 6. The conventional stud wall **3602** has a continuous layer of foam on the exterior with an R-value of 2.5 (° F..Math.ft.sup.2 hr/BTU) and an estimated total nominal R-value of 20 (° F..Math.ft.sup.2 hr/BTU). Table 3 shows the values used in the estimate. The estimated total nominal R-value of the conventional stud wall **3602** does not include the effects of thermal bridging.
TABLE-US-00004 TABLE 3 Nominal normal r.sub.val R.sub.val Control Stud thickness ° F. sqft/ ° F. sqft/ Wall 3602 inch (BTUh inch) BTUh stud cavity (true 4 3.7 14.80 4-inch studs) furring cavity 0 0.00 foam 0.5 5 2.50 siding 0.81 sheathing 0.55 drywall 0.5 0.9 0.45 interior air film 0.68 exterior air film 0.17 Total 19.96
TABLE-US-00005 TABLE 4 normal r.sub.val R.sub.val Insulative Stud thickness ° F. sqft/ ° F. sqft/ Panel 3601 inch (BTUh inch) BTUh insulative stud 3.5 3.7 12.95 cavity furring cavity 1.36 3.7 5.03 foam 0 0.00 siding 0.00 sheathing 1.10 drywall 0 0.9 0.00 interior air film 0.68 exterior air film 0.17 Total 19.93
TABLE-US-00006 TABLE 5 normal r.sub.val R.sub.val Insulative Stud thickness ° F. sqft/ ° F. sqft/ Panel 359 inch (BTUh inch) BTUh insulative stud 3.5 3.7 12.95 cavity furring 0 0.00 foam 0 0.00 siding 0 0.00 sheathing 1.10 drywall 0 0.00 interior air film 0.68 exterior air film 0.17 Total 14.90
[0345] FIG. **36**B shows a thermal image of stud walls **3601** and **3602**. When the image was taken, the outdoor temperature was 34° F. and the indoor temperature was 72° F. The low temperature on insulative stud wall panel **3601** was 68° F. whereas the low temperature on the conventional stud wall **3602** was 57° F.
[0346] FIG. **36**C shows an embodiment of a rectangular uniaxial framework **359** lying down as it might be built while platform framing, for example, with its longitudinal custom-character.sub.359 direction aligned with the transverse z axis of the figure page. This embodiment of framework **359** has two uniaxially structurally insulating stud-like frameworks **370**, **370′** and three uniaxially structurally insulating cross-brace-like frameworks **361**, **361′**, **361″**. Each of the cross-brace-like frameworks has two webs with two web members in a first web, as typified by web member **362**, **362′**, and one web member in a second web as typified by web member **364**. The web members in each of web interconnects a pair of structural members as exemplified by the connection of structural members **361** and **362** by web members **362**, **362′** and the connection of structural members **362** and **363** by web member **364** in cross-brace-like framework **360**. Stud-like framework **370′** has three structural members **371**, **373**, and **375**. Structural members **371** and **373** are connected by web members **372**, **372′**, **372″** while structural members **373** and **375** are connected by web member **374**, **374′**, **374″**. In an example, each of the web members is 1.5 inches by 1.5 inches in the longitudinal y and lateral x directions and 0.7 inches deep in the normal direction. Each of the structural members is 0.7 inches deep in the normal direction. The web members within a web are spaced by 13.75 inches in all of the stud-like frameworks and all of the brace-like frameworks. Web members in adjacent webs are offset by 6.125 inches relative to each other. Each of stud-like frameworks **370**, **370′** is 32 inches in longitudinal length, 1.5 inches in lateral width, and 3.5 inches in normal depth. Each of cross-brace-like frameworks **360**, **360′**, **360″** is 16.75 inches in longitudinal length, 1.5 inches in lateral width, and 3.5 inches in normal depth. Thus, uniaxial framework **359** is 19.75 inches (Δcustom-character.sub.359) by 32 inches (Δcustom-character.sub.359) by 3.5 inches (Δcustom-character.sub.359). These key parameters determine that the most direct metric path between the outermost structural members of any framework has a length of about 0.7+0.7+6.125+0.7+0.7 inches or 8.925 inches, a span of 3.5 inches, a span-wise indirectness of 155%, and a structural insulation factor of 2.55. The longest direct metric path between the outermost structural members of any framework has a length of about 0.7+0.7+12.25+0.7+0.7 inches or 15.05 inches, a span of 3.5 inches, a span-wise indirectness of 330%, and a structural insulation factor of 4.3. The average span-wise indirectness is 242% and average structural insulation factor is 3.42. The average structural insulation factor satisfies an average condition for zero thermal bridging which is that the average structural insulation factor equal the ratio of the resistivities for the insulating material in the inter-stud-like framework cavities and the structural material. The insulating material used in the test was cellulose insulation within a resistivity of 3.7° F..Math.sqft/(BTUh inch) {25.6 Km/W}. The structural material was wood with a resisitivity of 1° F..Math.sqft/(BTUh inch) {6.9 Km/W}. The average structural insulation factor of 3.42 which is within 10% **3.7**, i.e. the ratio of the resistivities for the insulating material in the inter-stud-like framework cavities and the structural material. This embodiment was built as a prototype for thermal testing. Another embodiment of this framework has sheets of transparent material similar to the transformation of frame-like framework **780** into window framework **780′** illustrated by FIGS. **12**E, **12**F.
[0347] FIG. **36**D shows framework **359** with cuboidal pieces of rigid foam insulation, exemplified by pieces **3661**, **3662**, **3671**, **3761**, **3762**,

3771, **3772**, and **3773**, inserted into each of the intra-framework cavities defined by the structural members and web members. The resistivity of the rigid foam insulation was 6.6° F..Math.ft.sup.2/(BTUh inch) for a total R-value of 12° F..Math.sqft/BTUh over the 1.4 cumulative distance of the cavities and including the 2.1 inches of wood with a total R-value of 2.1° F..Math.sqft/BTUh which is also within 10% of the target R-value of 13° F..Math.sqft/BTUh. In other embodiments pieces of any rigid insulation are used in place of pieces **3661**, **3662**, **3671**, **3761**, **3762**, **3771**, **3772**, and **3773** both extending beyond the outermost lateral facing surfaces as shown and not extending past the outermost lateral facing surfaces of the framework. Pieces of insulation that do extend past the outermost lateral facing surfaces of the framework help to block direct paths of heat flow along the outermost lateral facing surfaces of the framework. The inter-stud-like-framework cavities between frameworks **370** and **370**′ and between frameworks **360**, **360**′, and **360**″ were filled with cellulose insulation enclosed by two pieces of sheathing on opposing sides of the resulting insulated panel.

[0348] FIGS. **36**E and **36**F show the results of thermal imaging. Table 3 summarizes the parameters of conventional stud wall **3795** and the parameters of insulative stud-wall module **359**. FIG. **36**E shows that the conventional stud wall **3602** shows thermal bridging in that the regions of the wall over the studs **3759** are cold relative to the surrounding portions of wall. The insulative stud wall module **37491** show no thermal bridging in that the regions of the wall over the stud-like frameworks and cross-brace-like frameworks is the same temperature as the surrounding portions of wall. Conventional stud wall **3602** has a higher nominal R-value than the insulative stud wall module **37491**. Therefore a second type of control experiment was performed to compare the insulative stud wall module **37491** to replica insulative stud wall module **38001** which was exactly the same as module except with solid foam for the webs and no structural web members. FIG. **36**G shows that the two modules perform equally well in that they both have the same even temperature profile across their interior surfaces. The slightly darker border **38002** around the replica insulative stud wall module **38001** corresponds to a region where the surrounding insulation was tucked under the sheathing at the edge of insulative stud wall module **37491** creating a border region of slightly lesser R-value.

[0349] FIGS. **36**G-**36**I show the results of testing for a prototype window as one embodiment. The prototype window has a significantly warmer temperature than the standard double pane window. The outdoor temperature was 27° F. on that day. Radiative cooling to the cold sky made surrounding buildings and surfaces colder than the ambient air temperature. The prototype picture window **2963** has a frame like the one illustrated in FIG. **12**E and five panes of uncoated glass. The energy efficiency is equivalent to that of the surrounding insulation **2966** with an R-value of 15.6 (° F..Math.ft.sup.2 hr/BTU) as explained in the next few paragraphs. Window **2963** keeps the warm side warm, as shown in FIG. **36**G, and the cool side cool, as shown in FIG. **36**H. The performance of the window can be improved by (1) filling the window with an insulative gas and/or (2) applying a low emissivity coating to one or more panes of glass, especially the exterior one. FIG. **36**G shows that convective heat flow between the window panes makes the top of the window slightly warmer than the bottom and makes the bottom of the window cooler than the top. The bottom of the window sustains a temperature difference of 75° F. (from 64° F. down to −11° F.) which equals the temperature difference of 75° F. (from 66° F. down to −9° F.) sustained by the foam insulation **266**. Thus, the R-value at the bottom of window **2963** equals that of the foam insulation **266**. The top of window **2963** sustains a temperature difference of 77° F. (from 66° F. down to −11° F.) that exceeds the temperature difference of 75° F. sustained by the surrounding foam insulation **266**. The surrounding insulation (four layers of 0.7-inch-thick XPS foam board) has an R-value per inch of 5.6 (° F..Math.ft.sup.2 hr/BTU) per inch, a thickness of 2.8 inches, and a total R-value of 15.6 (° F..Math.ft.sup.2 hr/BTU) at a mean temperature of 25° F. The actual R-value is higher because air films between the 4 layers of XPS foamboard increase the effective R-value per inch of each layer of foam.

[0350] FIG. **36**H shows that the exterior surface of the window **2970** is colder than that of the insulation because glass has a higher emissivity (**0.92**) than insulation (**0.6**). Therefore a window pane has a relatively high rate of radiative cooling to the sky. FIG. **36**I shows that the sky **2983** has an extremely cold temperature of −40° F. Notice that the surfaces of the building can cool below the ambient air temperature (27° F. on the day the images were acquired) via to the same effect of radiative cooling to the cold sky. This effect is similar to the surfaces of a building heating above the ambient air temperature due to radiative heating by the sun.

[0351] FIG. **37** depicts one type of joint used between framework structures, namely a finger joint. Other suitable types of joints are described below.

[0352] FIG. **38**A-**38**C illustrate different a non-limiting example of a technique for joining frameworks together.

[0353] FIG. **38**D shows a structure **3210**′ that can be made in the general manner described above in the preceding paragraph with first frameworks **3240**′, second frameworks **3242**′ and third frameworks **3244**′. FIG. **38**E shows a structure **3210**″ that can be made in the general manner described above with first frameworks **3240**″, second frameworks **3242**″ and third frameworks **3244**″. FIG. **38**F shows a structure **3210**‴ that can be made in the general manner described above with first frameworks **3240**‴, second frameworks **3242**‴ and third frameworks **3244**″.

[0354] FIG. **39**A shows three embodiments of frameworks **3930**, **3940** and **3950** with two chords each, exemplified by first chord **3930** and second chord **3932**, and with diagonal web members exemplified by diagonal web member **3932** as well as modifiable, terminal straight-direct web members **3934**, **3944**, **3954**. Non-limiting examples of dimensions for chord thickness, chord width, web member width, web member angle, etc. are shown.

[0355] FIG. **39**B shows frameworks **3930**, **3940** and **3950** with the modifiable, terminal straight-direct web members **3934**, **3944**, **3954** modified into retaining members **3934**′, **3944**′, **3954**′. Other embodiments of frameworks **3930**, **3940**, **3950** have fewer, possibly zero, removable web members. Other embodiments of frameworks **3930**, **3940**, **3950** have more than two removable web members and do not have retaining members.

[0356] FIG. **40** shows a metric path through an apparatus with irregularly shaped passages, cavities, protrusions, edges, and boundaries of the apparatus (shown with black lines). The line **4107** is an approximation to the metric path from point A to point B created with 10 path segments that are each straight lines. The approximate length of the metric path from point A to point B is the sum of the lengths of all 10 path segments. The range of this metric path is the direct distance between points A and B. The span must be calculated using the method described in the definition of span due to the irregularity of the boundaries. Circle **4110** drawn with a dotted line exemplifies one of many circles drawn for the purposing of determining the line of closest approach between a first point, point C for this example, on the uppermost boundary of the apparatus and the lowermost boundary on the apparatus. Circle **4110** is centered on the uppermost boundary and drawn to osculate with the lowermost boundary such that no other circle that osculates with the lowermost boundary has a smaller radius. Circle **4110** is an osculating circle of least radius. The dotted line segment **4108** is the line of closest approach between the point C on the uppermost boundary and the lowermost boundary. The line of closet approach runs from point C, the center of circle **4110** i.e. the osculating circle of least radius, to point D, i.e. the point where the osculating circle of least radius touches the lowermost boundary. The line of closest approach serves as a direction line for the purpose of determining the span according to the definition. The method illustrated by FIG. **41** is only one of more than one method for determining the lines of closest approach between opposing surfaces of an object. The method of determining the lines of closest approach between opposing surfaces for all possible choices of point C on one of the opposing surfaces, or a representative set thereof, also serves to map out the set of direct paths between opposing surfaces of an object. The method of determining a line of closest approach in three dimensions uses an osculating sphere of least radius centered at point C and drawing a line from the center of the osculating sphere of least radius to the point at which the osculating sphere of least radius touches the opposing boundary. In general a three dimensional is required unless an object has planar structure that can be exploited to perform a two dimensional analysis.

[0357] FIGS. **41**A, **41**B, **42**A, **42**B shows different embodiments of an apparatus with a single framework with a uniform shape or I-beam shape. FIG. **41**A shows a 93.5″ long, 11″ deep, framework with two 1.5″ wide, 2.5″ thick flanges, three 3.5″ wide webs offset by 12″ and 1.25″ thick web members spaced by 32″ that can serve as joist, stud, rafter, or similar building component. FIG. **41**B shows a cross section of the framework in FIG. **41**A with an I-beam shape created by a 2.5″ wide top flange and bottom flange and 1.5″ wide chords and web members in between. FIG. **42**A shows the framework in FIG. **41**A wherein the web-members in each different web are offset from web members in all other webs. FIG. **42**B shows a cross section of the framework in FIG. **41**A with a 2.5″ wide chords and web-members.

Additional Features

[0358] One can combine frameworks in many different ways which basically follow the same pattern as timber framing joinery techniques. One can use scarf joints, finger joints, finger-scarfing joints, mortise and tenon joints, miter joints, concealed miter joints, dovetail joints, Japanese-type joints, simple lap joints to name a few. The joint patterns can be applied in the longitudinal, normal, and lateral directions to lock the frameworks together. Fasteners such as truss plates, mending plates, cables, chain, rope, string, lashing, straps, ties, collars, screws, nails, and dowels can be used to secure frameworks to each other and other structural components. The open architecture of the frameworks allows for rivets, rivnuts, clinched nails, nuts, and bolts to be used to similar effect and provides an advantage over solid framing members to use these types of fasteners. One can angle fasteners depending on the application. One can add features such as actuators, adhesive, apertures, bearings, bushings, buttons, clasps, conduit, cords, cranks, detachable frames, dials, electrical wire, electronic elements, film, flanges, flashing, gaskets, guides, handles, hanging mechanisms, hardware characteristic of doors, hardware characteristic of windows, hinges, holes, hoses, indentations, indicators, insulative mullions, kick plates, knobs, lights, locks, lubricant, metal pieces, mirrors, molding, mullions, o-rings, o-rings, pipes, pockets, protrusions, rabbets, retractable cords, retractors, screens, sealant, seals, sensors, shades, sheathing, solvents, springs, transparent materials, trim, tubing, valves, weather stripping, wheels, and wire. Another example is adding a concave curvature to the outermost chords of a wall truss to flatten the seams between drywall pieces that fall over a stud-like framework. Another example is cutting the frameworks into smaller pieces to produce battens, furring strips, and backer boards for floating drywall pieces that do not fall over stud-like framework. Another example is applying adhesives, fire-retardants, and other coatings to frameworks, low-emissivity coatings (particularly window panes). Radiant barrier can be applied in the intra-framework, inter-framework cavities, surfaces of a framework. The ideas of cross-laminated timber, dowel-laminated timber, nail-laminated timber, structural-composite lumber, laminated-veneer lumber, laminated-strand lumber, oriented-strand lumber can be applied to many of the present embodiments. One can exploit differences in moisture content when using dowels or floating tenons to make intra-framework and inter-framework connections. One can mill, plane, route, and cut to customize the shape of manufactured frameworks. One can customize the frameworks on-site by cutting a piece off one framework and fastening it to another. The references cited teach many ideas that can combine with the present embodiments to produce a wide array of other embodiments. Generally any variation described herein for one framework can be applied to any other framework.

Universal Possibilities

[0359] The custom-character, custom-character, and custom-character axes of a framework can have any arbitrary alignment with respect to a set of fixed reference axes x, y, and z. A framework can have any arbitrary yaw, pitch, or roll and any arbitrary orbital yaw, orbital pitch, or orbital roll. For instance a structurally insulative stud is an embodiment of an insulative, insulatable framework with its custom-character axis oriented parallel to the vertical y direction defined by gravity. Whereas the same framework oriented with its custom-character axis perpendicular to the vertical y direction defined by gravity becomes a top plate or bottom plate. Rolling the framework 90° transforms the framework into a joist. Embodiments can be joined with one another. The strongest axis Y of a material that constitutes of a web member can run parallel to the longitudinal custom-character direction of web member, often enhancing strength, or substantially non-parallel or even perpendicular to the longitudinal direction of a web member, often enhancing insulative resistance. In summary the strongest axis Y of a material can align in any direction relative to the longitudinal direction of a web member or any other structural part. Structural members can be flanged. The lateral width of structural members can be greater than that of web members or vice versa. All key geometric parameters for any given structural part can be customized relative to all other structural parts. Key geometric parameters are lateral width, normal depth, longitudinal length, surface qualities, joint structure, shape, twistedness, cuppedness, bowedness, crookedness, kinkiness, smoothness, roundness, squareness, curviness, flatness, planarity, density of wood can be higher in certain places. Physical parameters such as density can be customized for any given structural part. For instance one part could have a higher density or moisture content. Higher density material at joints between structural parts represents one way of increasing strength of the joint and the overall structure by extension. The structurally insulative resistance of any material can be enhanced by selectively removing linkages between adjacent elongate structural members. A chemical compound can be engineered to selectively bind at specific sites and/or resist binding at other sites such that a material naturally assembles into an embodiment of the present invention.

[0360] The disclosed embodiments can be manufactured with available methods of manufacturing and future methods of manufacturing. The disclosed embodiments can be manufactured with currently available materials and materials developed in the future. A non-limiting non-exhaustive list of materials includes: metal, ceramics, carbon compounds, carbon nanotubes, graphene, graphite, wood fiber, nanomaterial, nanocrystals, wood, artificial wood, composite materials, wood/plastic composite material, wood-based materials, FRP, fiber-reinforced plastic (FRP), plastic, carbon fiber, kevlar, fiberglass, structural composite, composite plastic, ceramic, glass, polymer, autoclaved aerated concrete, concrete, stone, brick, compressed earth, mineral, glass, crystalline material, elemental material, colloidal material, transparent material, textile, nanomaterials, biomaterials, composite material, metal, alloy of metals, semiconductor material, structural material, rigid insulation, foam, elements, minerals, chemicals, chemical compounds, insulation.

[0361] The disclosed embodiments can be engineered and manufactured for all forms of energy. A non-limiting list of methods for manufacturing insulatable, insulative framework apparatuses includes: 3D printing, 3D printing with pumped concrete, additive manufacturing, carpentry, carving, casting, chemical deposition, CNC machining, coating, cutting, directed extrusion, dowel lamination, electron beam forming, etching, extrusion, fastening parts with nails, fastening parts with screws, fastening parts together with truss plates, forging, forming, friction welding, future industrial process, future manufacturing process, gluing, joinery, joining, lamination with adhesive, lamination, laser ablation, laser etching, lashing, machining, masonry, microwave heated pressing, milling, molding, nail lamination, permanently clamping and gluing, plasma cutting, plating, pottery, preheated prepressing, pressing, pultrusion, robotic assembly, routing, screw lamination, selective removal of pre-existing material to form a new material with greater structural insulation factor, self-assembly, sintering, soldering, sputtering, stamping, steam-injection pressing, subtractive manufacturing, temporarily clamping and gluing, turning, water-jet cutting, weaving, and welding.

Parameters and Ranges

[0362] In embodiments, when the apparatus is a building element selected from the group consisting of: a stud, joist, rafter, jack, header, window buck, door buck, window, door, the minimum rangewise indirectness between the interior face and the exterior face of the building element is non-zero. The global minimum spanwise indirectness between the interior face and the exterior face of the building element is greater than 0%. This means that the apparatus provides no direct path for the conductive flow of energy between the interior face and exterior face of the building. The uniformity of global indirectness between the first feature and the second feature has a value of about 0.074 to about 0.962, or about 0.222 to about 0.814, or about 0.370 to about 0.666.

[0363] In embodiments, when the apparatus is a building element selected from the group consisting of: a stud, joist, rafter, jack, header, window buck, door buck, window, and door, the minimum rangewise indirectness between the first feature and the second feature is non-zero. The global minimum path resistance between the first feature and the second feature has a value of about 3.5 to about 72° F..Math.ft.sup.2 per BTUh per inch, or about 4.5 to about 22° F..Math.ft.sup.2 per BTUh per inch, or about 5.0 to about 12° F..Math.ft.sup.2 per BTUh per inch.

[0364] In embodiments, when the building element is a roof truss with a global minimum spanwise indirectness greater than 0 (0%) between the top surface of a layer of insulation on the floor of an attic created by the roof truss and the bottom chord of the truss, the maximum and minimum indirectness have values of: about equal to about 200% of being equal, or about 10% to about 150% of being equal, or about 25% to about 100% of being equal, or about 50% to about 75% of being equal.

METHODS

[0365] Method 1 (designing/building an insulative, insulatable framework apparatus) [0366] 1. Optimize the length of the most direct metric path, i.e., the most direct path through the structural material alone excluding the surrounding space and non-structural material. [0367] 2. Optimize the cumulative distance between structural members encountered along the most direct metric path. [0368] 3. Iterate on 1 and 2 by adjusting the number of structural parts and geometry of structural parts until achieving satisfactory results.

[0369] Note: the identity of the most direct metric path and longest direct path can change during the process wherein the criteria for optimization are: [0370] 1. strength of the framework apparatus [0371] 2. least resistance Ra along any path through the framework apparatus, wherein Ra is the lesser of values R1 and R2 as defined in the definitions below. [0372] 3. optional constraints like: structural strength, cost effectiveness, level of thermal bridging, resistance along the most direct metric path, resistance along the longest direct path, resistance along the shortest direct path, resistance along the shortest or longest direct path in the same bundle as the most direct metric path, level of structural redundancy (for resistance to fire, corrosive chemicals, earthquake, hurricane, wild fire, ballistics, military attack, etc) and adjusting geometry includes but is not limited to: [0373] 1. modifying the relative position of structural parts [0374] 2. modifying the dimensions of structural parts [0375] 3. modifying the cross sectional shape of structural parts (circular, rectangular, trapezoidal, triangular) [0376] 4. modifying the cross sectional shape of cavities (circular, ellipsoidal, rounded-corner rectangular, rectangular, stadium-shaped, trapezoidal, triangular)

[0377] Method 2 (designing/building insulated barriers such as frameworks, panels, walls, roofs, floors, etc)

[0378] Same as method 1 with one additional criterion [0379] 4. targeted resistance R.sub.o for the whole barrier

[0380] Method 3 same as method 2 wherein the targeted resistance R.sub.o is the resistance Rb along the longest direct path through the non-intervening material within the barrier

[0381] Method 4 is the same as method 2 wherein the targeted resistance is a minimum required value of Rci

[0382] Method 5

[0383] To achieve a code-minimum R-value [1] for a two-chord truss, three-chord truss, or any N-chord truss

[00001]

1. $r2 = (\mathrm{Rci} + R\mathrm{std} - \mathrm{Rextra}) / L2 \Leftrightarrow L2 = (\mathrm{Rc}i + R\mathrm{std} - \mathrm{Rextra}) / r2 \Leftrightarrow M = \mathrm{sqrt}(((Rci + R\mathrm{std} - \mathrm{Rextra}) / r2 / S)^{\wedge}2 - 1) \Leftrightarrow$ x = forthcomingformu

2. $r1 = (Rn + R\mathrm{ci} - \mathrm{Rextra}) / L1 \Leftrightarrow L1 = (Rn + R\mathrm{ci} - \mathrm{Rextra}) / r2$

[0384] Method 6

[0385] To practically eliminate thermal bridging for a two-chord truss with diagonal webs: [0386] 1. the slope of diagonal web-members in a truss should approximately equal r2/rb.

[00002]2. $r1 > \mathrm{rb} > r2$

[0387] Method 7

[0388] To practically eliminate thermal bridging for a three-chord truss with diagonal webs: [0389] 1. the slope of the shortest line segment through a middle chord of a three-chord framework between web-members attached to opposite sides of the middle chord should approximately equal r2/rb

[00003]2. $r1 > rb > r2$

[0390] Variations on Methods 1-7 [0391] 1. Instead of the most direct metric path use the most medial metric path, i.e., the most medial metric path within the same bundle as the most direct metric path. [0392] 2. Instead of the most direct metric path use the longest metric path, i.e., the longest metric path within the same bundle as the most direct metric path. [0393] 3. Instead of the most direct metric path length use the most direct metric path resistance. 4. Instead of the most direct metric path length use the most medial metric path resistance. [0394] 5. Instead of the most direct metric path length use the longest metric path resistance. [0395] 6. Instead of cumulative distance between structural members encountered along the most direct metric path use the cumulative thickness of structural material crossed by the longest direct path [0396] 7. Instead of cumulative distance between structural members encountered along the most direct metric path use the cumulative web member thickness for web members encountered along the most direct metric path. [0397] 7. Instead of cumulative distance between structural members encountered along the most direct metric path use the cumulative web member thickness for web members encountered along the metric path of interest. [0398] 8. Instead of cumulative distance between structural members encountered along the most direct metric path use the longest direct path resistance [0399] 9. Similar variations changing the metrics.

Definitions Related to Methods 1-7

[0400] Ra: the lesser of values R1 and R2. [0401] R1: resistance along the longest direct path through the structural material of the framework and any intervening material. [0402] R2: resistance along the longest direct path through the structural material alone. [0403] Rb: (in the context of a direct path through a framework apparatus installed in a barrier) resistance along the longest direct path through the non-intervening material within the barrier (barrier-cavity insulation) [0404] Rn: 1. R-value of non-continuous insulation required by the ICC building code such as “13” in the “13+5” standard or “20” in the “20±5” standard [**2**]. [0405] Rci: 1. the R-value of continuous insulation required by the ICC building code such as “+5” in the “13+5” standard or “+10” in the “13+10” standard [**2**]. [0406] Rextra: 1. Rtotal-Ra, 2. the R-value of extra material, outside the framework, intersected by the longest direct path between the outer surface and inner surface of a barrier that overlaps the most direct metric path. [0407] Rtotal: 1. R-value along the longest direct path between the outer surface an inner surface of a barrier that overlaps the most direct metric path. [0408] code-minimum R-value: 1. Rn+Rci where Rn is 13 and Rci is 10 in the 13+10 standard for example. [0409] Rstd: 1. standard R-value associated with the relevant framing member for a code-minimum R-value such as 3.5° F..Math.ft.sup.2/BTUh associated with a 3.5″ deep wood stud associated with the 13+5 standard [**2**], 2. rstd multiplied by depth of the relevant framing member associated with a code-minimum standard such as a 3.5″ deep wood stud associated with the 13+5 standard [**2**]. [0410] rstd: 1. standard thermal resistivity value associated with the relevant framing member for a code-minimum standard such as 1° F..Math.ft.sup.2 per BTUh per inch associated with a 2×4 wood stud associated with the 13+5 standard [**2**]. [0411] r1: R1 divided by L1. [0412] r2: R2 divided by L2. [0413] ra: ra divided by La. [0414] rb: Rb divided by Lb. [0415] L1: path length of the longest direct path through the structural material of the framework and any intervening material. [0416] L2: path length of the most direct metric path. [0417] La: path length of the path associated with Ra. [0418] Lb: path length of the longest direct path through the non-intervening material within the barrier (barrier-cavity insulation). [0419] M: slope of diagonal web-members in a two-chord truss. [0420] cumulative distance between structural members: 1. (in the context of a metric path) the sum of distances between each pair of structural members as measured along the metric path. [0421] directness: (in the context of a metric path with a length and a span) span divided by length. [0422] direct path: 1. path through the structural material of a framework and any intervening material with a directness value of 1. [0423] most direct metric path: 1. path through the structural material of the framework that has the least value of directness, 2. path through the structural material of the framework that has the least span-to-length ratio. [0424] most direct metric path: 1. most direct path through the structural material of a framework bypassing any intervening material, 2. path through the structural material of a framework bypassing any intervening material with the least value of directness. [0425] most direct path: 1. path through the structural material of the framework and any intervening material that has the least value of directness. [0426] longest direct path: longest direct path through the structural material of a framework and any intervening material. [0427] resistance: 1. areal thermal resistance, 2. R-value measured in Imperial units of ° F..Math.ft.sup.2 per BTUh and metric units Kelvin by square meter per Watt, 3. areal resistance associated with any form of energy transfer. [0428] resolution: 1. (in the context of a metric path) span of the metric path divided by the path length of the subpath through the structural part with the least length measured along the metric path. [0429] path: 1. (in the context of a specified resolution) path as determined to the specified resolution, 2. (in the context of a resolution that is not explicitly specified) path as determined to a resolution of 1000, 3. (in the context of a resolution that is not explicitly specified but inferable by context) path as determined to a resolution inferred by context. [0430] span-to-length ratio: (in the context of a path with a span and a path length) the path length divided by the span. [0431] Δx: (in the context of a three-chord truss with web members) spacing between web-members attached to opposite sides of the middle chord.

[0432] [2] https://codes.iccsafe.org/content/iecc2018/chapter-4-re-residential-energy-efficiency?site_type=public

[0433] Method 8 is a method of making and/or using an apparatus with an improved value of minimum spanwise indirectness for at least one metric path between a first feature and second feature relative to a building component of prior art. The method involves reducing thermal bridging by increasing rangewise indirectness, controlling thermal bridging by controlling rangewise indirectness, increasing spanwise indirectness, and/or controlling spanwise indirectness. In embodiments, the method involves increasing spanwise indirectness along metric paths and equalizing the spanwise indirectness along metric subpaths. In some cases, the method comprises controlling spanwise indirectness along metric paths and equalizing the spanwise indirectness along metric subpaths.

[0434] Method 9 is a method of manufacturing an apparatus described herein by pultrusion and intermittent insertion and removal of at least one barrier during the pultrusion process in order to create the cavities. In some cases, the apparatus is manufactured by extrusion and intermittent insertion and removal of at least one barrier during the extrusion process in order to create the cavities.

[0435] Method 10 is a method of building a house with crisscrossing furring strips and the apparatus described herein so as to produce a nonzero spanwise indirectness between the inside and outside of the house.

[0436] Method 11 is a method of designing buildings by calculating indirectness for the minimized paths and minimized subpaths through the frame of the building;

[0437] Method 12 is a method of manufacturing an apparatus described herein wherein structural members with cooperative finger joints join to form the whole apparatus. In embodiments, structural members with cooperative finger joints join to form the whole apparatus wherein the finger joints are cut with a saw; and/or structural members with cooperative finger joints join to form the whole apparatus wherein the finger joints are stamped with a stamping tool with the shape of the negative space of the finger joints. Strands of lumber are arranged into a mat with the shape of the apparatus and then pressed into a structural component, and/or veneers of lumber are pressed into a mat with the shape of the apparatus and then pressed into a structural component.

[0438] Method 13 is a method of calculating spanwise indirectness for one or more metric paths through a building frame.

[0439] Method 14 is a method of calculating rangewise indirectness for one or more metric paths through a building frame.

[0440] Method 15 is a method of simultaneously maximizing the adiabatic one-dimensional model of effective resistance in combination with maximizing the spanwise indirectness calculated using the methods described herein.

[0441] Method 16 is a method of simultaneously maximizing the adiabatic one-dimensional model of effective resistance in combination with maximizing the rangewise indirectness calculated using the methods described herein.

ADDITIONAL EMBODIMENTS DISCLOSED HEREIN

[0442] Embodiment A is an apparatus comprising: a matrix of structure arrays (the structure matrix), a matrix of web arrays (the web matrix), the structure matrix comprising one or more structure arrays (the structure arrays) and the web matrix comprising one or more web arrays (the web arrays). Each of the web arrays comprises one or more webs (the webs), each of the structure arrays comprising three or more structural members (the structural members), and each of the webs comprising one or more web members (the web members). Every two sequential structural members in every structure array forming a doublet array of first and second structural members and an intervening cavity. Every three sequential structural members in every structure array forming a triplet array of first, second, and third structural members. The web matrix is configured to give a non-zero rangewise indirectness for the flow of energy between the first and third structural members of at least one triplet array containing only structural members from the first structure array of the structure matrix. In embodiments, the web matrix is configured to give a non-zero rangewise indirectness for the flow of energy between the first and third structural members of at least one triplet array containing only structural members from the first structure array of the structure matrix.

[0443] Embodiment B is an apparatus comprising: a framework array, a structure matrix, and a web matrix. The framework array comprising one or more frameworks, and each of the frameworks comprising one or more structure arrays. The structure matrix comprising one or more structure arrays (the structure arrays), the web matrix comprising one or more web arrays (the web arrays), and each of the web arrays comprising one or more webs (the webs). Each of the structure arrays comprises three or more structural members (the structural members), and each of the webs comprising one or more web members (the web members). Every two sequential structural members in every structure array form a doublet array and an intervening cavity of first and second structural members, and every three sequential structural members in every structure array forming a triplet array of first, second, and third structural members.

[0444] In some cases, the web matrix is configured to give a non-zero rangewise indirectness for the flow of energy between the first and third structural members of at least one triplet array containing only structural members from the first structure array of the structure matrix. In embodiments, the web matrix is configured to give a non-zero rangewise indirectness for the flow of energy between the first and third structural members of at least one triplet array containing a structural member from two different structural arrays. This embodiment includes a structural member array, the first array, a web array, the second array, the cardinality of the first array being three or more, the cardinality of the second array being two or more, each web array comprising one or more web members, the first array structural members being spaced apart, every two adjacent structural members in the first array forming an adjacent pair, every first-array structural member adjacent to any adjacent pair forming an adjacent trio, every adjacent pair forming an intervening cavity, with each web contributing an increase in the rangewise indirectness.

Embodiment C—(See FIGS. **38**A, **38**B, **38**C, **38**D, **38**E, **38**F) Inherently Biaxial Framework Apparatus; Three Structural Members Minimum in at Least 1 Framework

[0445] Embodiment C is an apparatus comprising an structural parts and a matrix of intraframework cavities, each intraframework cavity defined by a pair of structural parts, the structural parts comprising an array (**1**) of frameworks, the array of frameworks comprising at least one framework (**1***a*), each framework comprising an array of structural members (**2**) and an array of webs (**3**), —the array of structural members within each framework comprising one or more than one structural member (**2***a*), and the array of structural members within at least one framework comprising three or more structural members. There is a similar embodiment wherein at least one framework comprises two or more structural members. Every two adjacent structural members within every framework forms a structural-member pair (**4**) of first and second structural members, and every two adjacent frameworks forms a framework pair (**5**) of first and second frameworks. Every three adjacent structural members within a framework forms a structural-member trio of first, second, and third structural members, and every three adjacent frameworks forms a framework trio of first, second, and third frameworks. Every array of webs comprises one intranetworking web (**3***a*) for each structural-member pair and one internetworking web (**3***b*) for each framework pair. Each intranetworking web for a specified structural-member pair comprises one or more intranetworking-web members. The intranetworking-web members connect the first and second structural members within the specified structural-member pair. Each internetworking web for a specified framework pair comprises one or more internetworking-web members, the internetworking-web members connecting the first and second frameworks of the specified framework pair. The intranetworking webs are configured to give a minimum rangewise indirectness within a statistical range of values for the flow of energy between the first and third structural members of one or more than one structural-member trio, the statistical range of values being selected from the group consisting of: greater than zero and 50%, greater than 50% but less than 100%, greater than 100% but less than 120%, greater than 120% but less than 140%, greater than 140% but less than 160%, greater than 160% but less than 180%, greater than 180% but less than 200%, greater than 200% but less than 250%, greater than 250% but less than 300%, greater than 300% but less than 400%, greater than 400% but less than 500%, greater than 500%.

[0446] In other embodiments the internetworking webs are configured to give a minimum rangewise indirectness within a statistical range of values for the flow of energy between the first and third frameworks of one or more than one framework trio, the statistical range of values being selected from the group consisting of: greater than zero and 50%, greater than 50% but less than 100%, greater than 100% but less than 120%, greater than 120% but less than 140%, greater than 140% but less than 160%, greater than 160% but less than 180%, greater than 180% but less than 200%, greater than 200% but less than 250%, greater than 250% but less than 300%, greater than 300% but less than 400%, greater than 400% but less than 500%, greater than 500%.

Embodiment D—Sandwich 2D Framework Apparatus—See FIG. **6**F

[0447] Embodiment D is an apparatus comprising an array (**1**) of frameworks and a matrix of cavities, the matrix of cavities being formed by the array of frameworks in and of themselves ipso facto, the array of frameworks comprising one or more than one framework (**1***a*), each framework comprising an array of structural members (**2**) and an array of webs (**3**), the array of structural members within each framework comprising one or more than one structural member (**2***a*). The array of structural members within at least one framework comprise three or more structural members, every two adjacent structural members within every framework forming a structural-member pair (**4**) of first and second structural members, and every two adjacent frameworks forming a framework pair (**5**) of first and second frameworks. Every three adjacent structural members within a framework form a structural-member trio of first, second, and third structural members, and every three adjacent frameworks form a framework trio of first, second, and third frameworks. Every array of webs comprises one intranetworking web (**3***a*) for each structural-member pair. Each web for a specified structural-member pair comprises one or more networking-web members. Each networking-web member connects the first and second structural members within the specified structural-member pair, and each networking-web member connects the first and second frameworks of the specified framework pair. The array of webs is configured to give a maximum rangewise indirectness within a statistical range of values for the flow of energy between the first and third structural members of one or more than one structural-member trio. In embodiments, the statistical range of values is as described above in Embodiment C.

Embodiment E—Lattice 2D Framework Apparatus—See FIG. **17**B

[0448] Embodiment E is an apparatus comprising an array (**1**) of frameworks and a matrix of cavities. The matrix of cavities is formed by the array of frameworks in and of themselves ipso facto. The array of frameworks comprises one or more than one framework (**1***a*). Each framework comprises an array of structural formations and an array of webs (**3**), the array of structural formations within each framework comprising one or more structural formations. The array of structural formations within at least one framework comprises three or more structural formations, with each structural formation comprising one or more than one array of structural members (**2***a*). Each array of structural members comprises one or more than one structural member. Every two adjacent structural formations within every framework form a structural-formation pair (**4**) of first and second structural formations, and every two adjacent frameworks forming a framework pair (**5**) of first and second frameworks. Every three adjacent structural formations within a framework form a structural-member trio of first, second, and third structural formations, and every three adjacent frameworks forming a framework trio of first, second, and third frameworks. Every array of webs comprises one intranetworking web (**3***a*) for each structural-formation pair and one internetworking web (**3***b*) for each framework pair. Each intranetworking web for a specified structural-formation pair comprises one or more intranetworking-web members, with the intranetworking-web members connecting all structural members in the first and second structural formations within the specified structural-formation pair. Each internetworking web for a specified framework pair comprises one or more internetworking-web members. The internetworking-web members connect the first and second frameworks of the specified framework pair. The intranetworking webs are configured to give a maximum rangewise indirectness within a statistical range of values for the flow of energy through one or more than one structural-formation trio between any structural member in the first structural formation and any structural member in the third structural formation. In embodiments, the statistical range of values is as described above in Embodiment C.

[0449] In Embodiments C, D, E and F with three or more frameworks in the array of frameworks, the internetworking webs can be configured to give a maximum rangewise indirectness within a statistical range of values for the flow of energy between the first and third frameworks of one or more than one framework trio, the statistical range of values being selected from the group consisting of: greater than 0% but less than 1%, greater than 1% but less than 10%, greater than 10% but less than 20%, greater than 20% but less than 40%, greater than 40% but less than 60%, greater than 60% but less than 80%, greater than 80% but less than 100%, greater than 100% but less than 120%, greater than 120% but less than 140%, greater than 140% but less than 160%, greater than 160% but less than 180%, greater than

180% but less than 200%, greater than 200% but less than 250%, greater than 250% but less than 300%, greater than 300% but less than 400%, greater than 400% but less than 500%, greater than 500%.

[0450] In Embodiments C, D, E and F with three or more frameworks in the array of frameworks, the internetworking webs can be configured to give a minimum rangewise indirectness within a statistical range of values for the flow of energy between the first and third frameworks of one or more than one framework trio, the statistical range of values being selected from the group consisting of: greater than 0% but less than 1%, greater than 1% but less than 10%, greater than 10% but less than 20%, greater than 20% but less than 40%, greater than 40% but less than 60%, greater than 60% but less than 80%, greater than 80% but less than 100%, greater than 100% but less than 120%, greater than 120% but less than 140%, greater than 140% but less than 160%, greater than 160% but less than 180%, greater than 180% but less than 200%, greater than 200% but less than 250%, greater than 250% but less than 300%, greater than 300% but less than 400%, greater than 400% but less than 500%, greater than 500%

[0451] In Embodiments C, D, E and F with one framework in the array of frameworks, the intranetworking web of the framework being configured to give a maximum rangewise indirectness within a statistical range of values for the flow of energy between the first and third structural members of one or more than one structural-member trio, the statistical range of values being selected from the group consisting of: greater than 0% but less than 1%, greater than 1% but less than 10%, greater than 10% but less than 20%, greater than 20% but less than 40%, greater than 40% but less than 60%, greater than 60% but less than 80%, greater than 80% but less than 100%, greater than 100% but less than 120%, greater than 120% but less than 140%, greater than 140% but less than 160%, greater than 160% but less than 180%, greater than 180% but less than 200%, greater than 200% but less than 250%, greater than 250% but less than 300%, greater than 300% but less than 400%, greater than 400% but less than 500%, greater than 500%.

[0452] In embodiments C, D, E and F with one framework in the array of frameworks, the intranetworking web of the framework being configured to give a minimum rangewise indirectness within a statistical range of values for the flow of energy between the first and third structural members of one or more than one structural-member trio, the statistical range of values being selected from the group consisting of: greater than 0% but less than 1%, greater than 1% but less than 10%, greater than 10% but less than 20%, greater than 20% but less than 40%, greater than 40% but less than 60%, greater than 60% but less than 80%, greater than 80% but less than 100%, greater than 100% but less than 120%, greater than 120% but less than 140%, greater than 140% but less than 160%, greater than 160% but less than 180%, greater than 180% but less than 200%, greater than 200% but less than 250%, greater than 250% but less than 300%, greater than 300% but less than 400%, greater than 400% but less than 500%, greater than 500%.

[0453] In embodiments C, D, E and F with one framework in the array of frameworks, the intranetworking web of the framework being configured to give a maximum spanwise indirectness within a statistical range of values for the flow of energy between the first and third structural members of one or more than one structural-member trio, the statistical range of values being selected from the group consisting of: greater than 0% but less than 1%, greater than 1% but less than 10%, greater than 10% but less than 20%, greater than 20% but less than 40%, greater than 40% but less than 60%, greater than 60% but less than 80%, greater than 80% but less than 100%, greater than 100% but less than 120%, greater than 120% but less than 140%, greater than 140% but less than 160%, greater than 160% but less than 180%, greater than 180% but less than 200%, greater than 200% but less than 250%, greater than 250% but less than 300%, greater than 300% but less than 400%, greater than 400% but less than 500%, greater than 500%.

[0454] In embodiments C, D, E and F with one framework in the array of frameworks, the intranetworking web of the framework being configured to give a minimum spanwise indirectness within a statistical range of values for the flow of energy between the first and third structural members of one or more than one structural-member trio, the statistical range of values being selected from the group consisting of: greater than 0% but less than 1%, greater than 1% but less than 10%, greater than 10% but less than 20%, greater than 20% but less than 40%, greater than 40% but less than 60%, greater than 60% but less than 80%, greater than 80% but less than 100%, greater than 100% but less than 120%, greater than 120% but less than 140%, greater than 140% but less than 160%, greater than 160% but less than 180%, greater than 180% but less than 200%, greater than 200% but less than 250%, greater than 250% but less than 300%, greater than 300% but less than 400%, greater than 400% but less than 500%, greater than 500%.

Embodiment F—Two Structural Members Minimum in at Least 1 Framework

[0455] Embodiment F is an apparatus comprising an array (**1**) of frameworks and a matrix of cavities, the matrix of cavities being formed by the array of frameworks in and of itself ipso facto. The array of frameworks comprises one or more than one framework (**1***a*), with each framework comprising an array (**2**) of structural members and an array (**3**) of webs. The array of structural members within each framework comprises one or more than one structural member (**2***a*). The array of structural members within at least one framework comprises two or more structural members. Every two adjacent structural members within every framework forms a structural-member pair (**4**) of first and second structural members, and every two adjacent frameworks form a framework pair (**5**) of first and second frameworks. Every three adjacent structural members within a framework form a structural-member trio of first, second, and third structural members, and every three adjacent frameworks forming a framework trio of first, second, and third frameworks. Every array of webs comprises one intranetworking web (**3***a*) for each structural-member pair and one internetworking web (**3***b*) for each framework pair, each intranetworking web for a specified structural-member pair comprising one or more intranetworking-web members. The intranetworking-web members connect the first and second structural members within the specified structural-member pair. Each internetworking web for a specified framework pair comprises one or more internetworking-web members. The internetworking-web members connect the first and second frameworks of the specified framework pair. The intranetworking webs are configured to give a maximum rangewise indirectness within a statistical range of values for the flow of energy between the first and second structural members of one or more than one structural-member pair. In embodiments, the statistical range of values is as described above in Embodiment C.

Embodiment G—Sandwich 2D Framework Apparatus

[0456] Embodiment G is an apparatus comprising an array (**1**) of frameworks and a matrix of cavities, the matrix of cavities being formed by the array of frameworks in and of themselves ipso facto, the array of frameworks comprising one or more than one framework (**1***a*), each framework comprising an array of structural members (**2**) and an array of webs (**3**), the array of structural members within each framework comprising one or more than one structural member (**2***a*). The array of structural members within at least one framework comprise two or more structural members. Every two adjacent structural members within every framework form a structural-member pair (**4**) of first and second structural members, and every two adjacent frameworks forming a framework pair (**5**) of first and second frameworks. Every three adjacent structural members within a framework form a structural-member trio of first, second, and third structural members, and every three adjacent frameworks form a framework trio of first, second, and third frameworks. Every array of webs comprises one intranetworking web (**3***a*) for each structural-member pair. Every intranetworking web in the array of webs additionally may be an internetworking web. Each web for a specified structural-member pair comprises one or more networking-web members. Each networking-web member connecting the first and second structural members within the specified structural-member pair. Each networking-web member connects the first and second frameworks of the specified framework pair. The array of webs is configured to give a maximum rangewise indirectness within a statistical range of values for the flow of energy between the first and third structural members of one or more than one structural-member trio. In embodiments, the statistical range of values is as described above in Embodiment C.

Embodiment H—Lattice 2D Framework Apparatus

[0457] Embodiment H is an apparatus comprising an array (**1**) of frameworks and a matrix of cavities, the matrix of cavities being formed by the array of frameworks in and of themselves ipso facto, the array of frameworks comprising one or more than one framework (**1***a*), each framework comprising an array of structural formations and an array of webs (**3**), the array of structural formations within each framework comprising one or more structural formations. The array of structural formations within at least one framework comprise two or more structural formations. Each structural formation comprises one or more than one array of structural members (**2***a*). Each array of structural members comprises one or more than one structural member, every two adjacent structural formations within every framework form a structural-formation pair (**4**) of first and second structural formations, and every two adjacent frameworks form a framework pair (**5**) of first and second frameworks. Every three adjacent structural formations within a framework form a structural-member trio of first, second, and third structural formations, and every three adjacent frameworks forming a framework trio of first, second, and third frameworks. Every array of webs comprises one intranetworking web (**3***a*) for each structural-formation pair and one internetworking web (**3***b*) for each framework pair. Each intranetworking web for a specified structural-formation pair comprises one or more intranetworking-web members, the intranetworking-web members connecting all structural members in the first and second structural formations within the specified structural-formation pair. Each internetworking web for a specified framework pair comprises one or more internetworking-web members, the internetworking-web members connecting the first and second frameworks of the specified framework pair. The intranetworking webs are configured to give a maximum rangewise indirectness within a statistical range of values for the flow of energy through one or more than one structural-formation trio between any structural member in the first structural formation and any structural member in the third structural formation. In embodiments, the statistical range of values is as described above in Embodiment C. The indirectness ranges are as described in Embodiment E.

[0458] In embodiments, one or more than one framework member is an element selected from the group consisting of a collection of fibers, a collection of strands, a collection of threads, a collection of laminations, and a collection of veneers. In some cases, the framework is a solid formwork with a series of contiguous tunnels.

Embodiment I—Explicitly Uniaxial and Implicitly Multiaxial Framework Apparatuses

[0459] Embodiment I is an apparatus comprising two or more cavities, comprising a body, and a set of body members, the body exhibiting a set of metric paths and a first subset of metric paths. The set of body members comprises three or more structural members, including first, second, and third structural members, spaced apart from one another, two or more web members, including first and second web members, each connecting at least one of the three or more structural members to an adjacent structural member in a fixed positional relationship under self loading conditions, and together ensuring that every one of the three or more structural members is connected to the apparatus. The apparatus includes two or more webs, including a first and second web, each comprising one or more of the two or more web members, the first web more specifically comprising the first web member, each web member in the first web at least connecting the first and second structural members, the second web more specifically comprising the second web member, each web member in the second web at least connecting the second and third structural members. Each metric path in the first subset of metric paths is defined by the shortest path along which energy can flow through the body between a first end point, that is, any point on the first structural member and a second end point, that is, any point on the third structural member represented by a set of path segments with a sufficiently large cardinality. Each metric path is characterized by a range, a path length, and a rangewise indirectness equal to the path length divided by the range minus one. The first subset of metric paths is characterized by a first subset maximum rangewise indirectness equal to the maximum value of the rangewise indirectness for each and every path therein. The first and second webs are configured to give a first subset maximum rangewise indirectness greater than zero. The first and second webs are configured to give a value greater than zero for a statistical quantity selected from the group consisting of: maximum value of rangewise indirectness, minimum value of rangewise indirectness, maximum value of spanwise indirectness, and minimum value of spanwise indirectness.

Embodiment J—Explicitly Uniaxial and Implicitly Multiaxial Framework Apparatuses

[0460] Embodiment J is an apparatus comprising: a body with five or more body members, a first subset of the five or more body members, three or more structural members each of which is one of the five or more body members, two or more metric paths, a first subset of the two or more metric paths, two or more pairs of adjacent structural members comprising a first paired member of the three or more structural members and a second paired member of the three or more structural members, adjacent to the first paired member. The apparatus further includes two or more web members, each of which is one of the five or more body members and connects a pair from the set of two or more pairs of adjacent structural members together in a fixed positional relationship under self loading conditions such that the first paired member does not touch the second paired member, and two or more webs, each of which comprises one or more of the two or more web members. The apparatus exhibits two or more span direction line candidates, a first subset of the two or more span direction line candidates, two or more span direction lines, a first subset of the two or more span direction lines, two or more statistics, and a first subset of the two or more statistics. The first subset of the five or more body members comprises: a first structural member of the three or more structural members, a second structural member of the three or more structural members that is offset away from the interior of the first structural member, a third structural member of the three or more structural members that is offset away from the interior of the first structural member to a greater extent than the second structural member, a first web member of the two or more web members that connects the first structural member to the second structural member, and a second web member of the two or more web members that connects the second structural member to the third structural member, a first of the two or more webs, that comprises one or more of the two or more web members including the first web member each of which connects the first structural member to the second structural member, a second of the two or more webs, that comprises one or more of the two or more web members including the second web member each of which connects the second structural member to the third structural member, wherein the set of the two or more metric paths, the first subset of the two or more metric paths, the set of the two or more span direction line candidates, the first subset of the two or more span direction line candidates, the set of the two or more span direction lines, and the first subset of the two or more span direction lines have a cardinality that is large enough to achieve any required accuracy for the calculation of any dependent quantities.

[0461] Each candidate in the first subset of the two or more span direction line candidates is a line that runs through an initial point, that is any point on the surface of the first structural member and a reflection point, that is the point of closest approach between the initial point and the third structural member wherein each span direction line in the first subset of the two or more span direction lines is a line based upon a candidate in the first subset of two or more span direction line candidates and runs through an origination point, that is the point of closest approach between the reflection point of the candidate and the first structural member and a termination point, that is the point of closet approach between the origination point and the third structural member.

[0462] Each path in the first subset of the two or more metric paths is the shortest path, that is fully confined to the body, between a first end point, that is one origination point from the first subset of the two or more span direction lines, and a second end point, that is one termination point from the first subset of two or more span direction lines and is approximated by a set of path segments with a cardinality large enough to achieve any required accuracy for the calculation of any dependent quantity. Each path exhibits a range defined as the distance between the first end point and the second end point; a path length that is approximated as the sum total of each segment length for the set of path segments; a rangewise indirectness equal to a difference, that is the path length minus the range, divided by the range, wherein the first subset of statistics comprises a first subset maximum rangewise indirectness equal to the maximum value of each and every rangewise indirectness for the first subset of the two or more metric paths, such that, the first subset maximum rangewise indirectness is greater than zero.

Embodiment K—Explicitly Uniaxial and Implicitly Multiaxial Framework Apparatuses, Three Structural Members Minimum, Triplets

[0463] Embodiment K is an apparatus comprising: two or more cavities, first, second, and third structural members, spaced apart from one another, first and second webs, each layer comprising one or more structural members, the first and second webs each comprising one or more web members, each web member in the first web connecting one or more structural members in the first layer to one or more structural members in the second layer, each web member in the second web connecting one or more structural members in the second layer to one or more structural members in the third layer. Each web member in the first and second webs is configured to give a dimensional constraint selected from the group comprising: a greater than 0 value of maximum rangewise indirectness, a greater than 0 value of minimum rangewise indirectness, a greater than 0 value of maximum spanwise indirectness, and a greater than 0 value of minimum spanwise indirectness, for the flow of energy along the associated metric paths between any point at the interface of the first structural member with the first or more web members, and any point on the third structural member.

Embodiments L, M N O and P—Uniaxial—Three Structural Members Minimum in 1D Framework

[0464] Embodiment L is an apparatus comprising: first, second, and third structural members, spaced apart from one another, a first web member connecting the first structural member to the second structural member, a second web member connecting the second structural member to the third structural member, the first and second web members being configured to give a maximum rangewise indirectness greater than zero for the flow of energy between any point on the first structural member and any point on the third structural member.

[0465] Embodiment M is an apparatus comprising: first, second, and third structural members, spaced apart from one another, a first web member or more web members connecting the first structural member to the second structural member, a second web member or more web members connecting the second structural member to the third structural member, the first web member or more web members and the second web member or more web members being configured to give a maximum rangewise indirectness greater than zero for the flow of energy between any point on the first structural member and any point on the third structural member.

[0466] Embodiment N is an apparatus comprising first, second, and third structural members, spaced apart from one another, a first web member or more web members connecting the first structural member to the second structural member, a second web member or more web members connecting the second structural member to the third structural member, the first web member or more web members and the second web member or more web members being configured to give a minimum rangewise indirectness greater than zero for the flow of energy between any point on the first structural member and any point on the third structural member.

[0467] Embodiment O is an apparatus comprising: first, second, and third structural members, spaced apart from one another, a first or more web members connecting the first structural member to the second structural member, a second or more web members connecting the second structural member to the third structural member, the first or more web members and the second or more web members being configured to give a maximum rangewise indirectness greater than zero for the flow of energy between any point at the interface of the first structural member with the first or more web members, and any point on the third structural member.

[0468] Embodiment P is an apparatus comprising three or more structural members, two or more webs, and two or more web members, each of the two or more webs comprising at least one of the two or more web members and connecting an adjacent pair of the three or more structural members, that is, a first structural member and an adjacent structural member, exactly one of the two or more webs connecting the first structural member to the adjacent structural member of each pair of structural members.

Embodiments Q, R S and T—Explicitly Uniaxial and Implicitly Multiaxial Two Structural Members Minimum, Doublets

[0469] Embodiment Q1 is an apparatus comprising: first and second structural members, spaced apart from one another, a first web member connecting the first structural member to the second structural member, the first web member being configured to give a maximum rangewise indirectness greater than zero for the flow of energy between any point at the interface of the first web member with the first structural member, and any point on the second structural member.

[0470] Embodiment Q2 is an apparatus comprising: first and second structural members, spaced apart from one another, a first web member connecting the first structural member to the second structural member, the first web member being configured to give a minimum rangewise indirectness greater than zero for the flow of energy between any point at the interface of the first web member with the first structural member, and any point on the second structural member.

[0471] Embodiment R is an apparatus comprising first and second structural members, spaced apart from one another, a first web member connecting the first structural member to the second structural member, the first and second web members being configured to give a minimum rangewise indirectness greater than zero for the flow of energy between any point on the first structural member and any point on the second structural member. In embodiments, the “minimum spanwise indirectness” is greater than or equal to 150%±50%, 250%±50%, 350%±50%, 450%±50%, 550%±50%, or 650%±50%.

[0472] Embodiment S is an apparatus comprising: first and second structural members, spaced apart from one another, a first web member connecting the first structural member to the second structural member, the first and second web members being configured to give a normalized spread of spanwise indirectness that is less than or equal to 50% for the flow of energy between any point on the first structural member and any point on the second structural member.

[0473] Embodiment T is an apparatus comprising: first and second structural members, spaced apart from one another, a first web member connecting the first structural member to the second structural member, the first and second web members being configured to give a uniformity of spanwise indirectness less than or equal to 50% for the flow of energy between any point on the first structural member and any point on the second structural member.

Embodiment U—Triaxial Apparatus—Sandwich Framework

[0474] Embodiment U is an apparatus comprising the first apparatus Embodiment L, and further comprising one special additional layer, one or more additional layers, two or more special additional structural members, one or more additional structural members, one or more additional webs, and one or more additional web members wherein the special additional layer comprises three or more special additional structural members, each of the one or more additional layers comprises one or more additional structural members, each of the one or more additional webs comprises one or more of the one or more additional web members, the special additional layer has an index of zero, each of the one or more additional layers has an index greater than zero, each index is an integer between zero and the number of the one or more additional layers, each index greater than one forms a pair of adjacent indices comprising a first index and second index that equals the first index minus one, and each pair of adjacent indices forms a pair of adjacent layers between a first layer, the one of the one or more additional layers with an index equal to the first index in the pair of adjacent indices, and a second layer, the one of the one or more additional layers with an index equal to the second index in the pair of adjacent indices. As a result, each of the two or more webs in the first set of the first apparatus connects to two of the one or more special additional structural members, each one of the one or more additional webs connects each of the one or more additional layers to the third apparatus, and each of the one or more additional web members connects two of the additional structural members in the first layer in a pair of adjacent layers to the second layer in the pair of adjacent layers.

Embodiment V1—Single Solid Body Apparatus

[0475] Embodiment V1 is an apparatus in which the material of the apparatus fills each and every seam at the interface between the apparatus members wherein the apparatus members are the structural members and web members to form a solid body with structural-member-like parts and a web-member-like parts.

[0476] Embodiment V2 is an apparatus in which the material of the apparatus fills one or more seams, up to a maximum of one fewer than all seams, at the interface between the apparatus members wherein the apparatus members are the structural members and web members.

Embodiment W—Single Solid Body

[0477] Embodiment W is a window frame formed by adding a through-going cavity to the framework described in Embodiment L in the spanwise direction. In embodiments, one or more of the apparatus members has a different length than the others wherein the apparatus members are the structural members and web members.

[0478] Embodiment X is a framework as described above that is incorporated into a window opening, door opening, penetration, circular opening, portal, insulation cavity, room, chamber, indentation, open cavity, closed cavity, closed cell, capsule, microscopic cavity, nanoscopic cavity, and insignificant cavity.

[0479] Embodiment Y is similar to Embodiment L and further includes one special additional layer, one or more additional layers, two or more special additional structural members, one or more additional structural members, one or more additional webs, and one or more additional web members, wherein the special additional layer comprises three or more special additional structural members, each of the one or more additional layers comprises one or more additional structural members, each of the one or more additional webs comprises one or more of the one or more additional web members. In embodiments, the special additional layer has an index of zero, each of the one or more additional layers has an index greater than zero, each index is an integer between zero and the number of the one or more additional layers, each index greater than one forms a pair of adjacent indices comprising a first index and second index that equals the first index minus one, and each pair of adjacent indices forms a pair of adjacent layers between a first layer, the one of the one or more additional layers with an index equal to the first index in the pair of adjacent indices, and a second layer, the one of the one or more additional layers with an index equal to the second index in the pair of adjacent indices.

[0480] As a result, each of the two or more webs in the first set of the first apparatus connects to two of the one or more special additional structural members, each one of the one or more additional webs connects each of the one or more additional layers to the third apparatus, and each of the one or more additional web members connects two of the additional structural members in the first layer in a pair of adjacent layers to the second layer in the pair of adjacent layers. In this embodiment, the first feature is the most distal structural member along a first axis, the second feature is the most proximal structural member along the first axis, the third feature is the most distal structural member along a second axis, the fourth feature is the most proximal structural member along the second axis, and the second axis runs at an angle with respect to the first axis.

Embodiment Z

[0481] Embodiment Z is a temporary formwork that contains permanently installed autoclaved aerated concrete blocks arranged in a pattern of cavities for forming a concrete framework by pouring concrete into said formwork such that the concrete framework has a minimum spanwise indirectness of 0.25 (25%) for at least one minimized path between faces of the concrete framework that oppose one another in the depthwise direction.

[0482] Embodiment AB is a window framework as described above that includes a valve for depressurizing the space between at least two window panes when the valve is open and for resealing the space so as to preserve the low pressure within when the valve is closed. A household vacuum cleaner, handheld pump, or other suction device can depressurize the space with an appropriate fitting to mate with that of the window valve port. In some cases, this embodiment comprises a framework including three layers of offset encapsulated cells. In some cases, the framework pieces are formed from three struts connected by two webs.

[0483] Embodiment AC is an apparatus as described in the last paragraph of the Summary and in claims **16** and **17**, further comprising any number of additional structural-members for a total of N_sm structural-members labeled by a structural-member-array, any number of additional webs for a total of N_w webs labeled by a web-array,

[0484] the first web further comprising any number of additional web-members for a total of N_wm web-members in the first web,

[0485] the second web further comprising any number of additional web-members for a total of N_wm web-members in the second web, the structural-member-array indexed by an index, I_sm, that ranges between 1 and N_sm,

[0486] the first structural-member indexed by I_sm equal to 1,

[0487] the second structural-member indexed by I_sm equal to 2,

[0488] the third structural-member indexed by I_sm equal to 3,

[0489] the I_smth structural-member positioned between the (I_sm−1)th and (I_sm+1)th for I_sm running from 2 to N_sm−1, the web-array indexed by an index, I_w, that ranges between 1 and N_sm−1,

[0490] the first web indexed by I_w equal to 1,

[0491] the second web indexed by I_w equal to 2,

[0492] the I_w.sup.th web comprising a number of web-members, I_w.sup.th-web N_wm, ranging between 1 and any positive integer greater than zero,

[0493] the I_w.sup.th web indexed by an index, I_w.sup.th-web I_wm, that ranges between 1 and I_w.sup.th_web N_wm,

[0494] the first web comprising the first web-member,

[0495] the second web comprising the second web-member,

[0496] the first web-member indexed by a first-web N_wm value of 1,

[0497] the second web-member indexed by a second-web N_wm value of 1,

[0498] each web-member in the I_w.sup.th web connecting the I_w.sup.th structural-member to the (I_w+1)th structural-member in a spaced apart relationship for I_w running from 1 to the I_w.sup.th N_wm,

[0499] the structural parts further comprising the additional structural-members and additional webs and constituting a uniaxial framework,

[0500] Embodiment AD is the combination of embodiment AB with at least one additional framework for a total of N_f frameworks, and

N_f−1 internetworking-web-arrays, the frameworks labeled by a framework-array,
[0501] the framework-array indexed by an index, I_f,
[0502] the index, I_f, ranging between 1 and N_f,
[0503] the internetworking-web-arrays labeled by a internetworking-web-array-matrix,
[0504] the internetworking-web-array-matrix comprising a number, N_iwa, of internetworking-web-arrays, the number, N_iwa, being at least one,
[0505] the internetworking-web-array-matrix indexed with an index, I_iwa, that specifies the I_iwa.sup.th internetworking-web-array,
[0506] I_iwa, running between 1 and N_f−1,
[0507] the I_iwa.sup.th internetworking-web-array comprising a number, an I_iwa.sup.th N_iw, of internetworking webs, the I_iwa.sup.th N_iw, being at least one,
[0508] the I_iwa.sup.th internetworking-web-array indexed by an index, the I_iwa.sup.th I_iw, that specifies the I_iwa.sup.th I_iw.sup.th internetworking-web-array, the I_iwa.sup.th I_iw running between 1 and I_iwa.sup.th N_iw,
[0509] the I_iwa.sup.th I_iw.sup.th internetworking-web comprising a number, the I_iwa.sup.th I_iw.sup.th N_iwm, of internetworking-web-members,
[0510] the I_iwa.sup.th I_iw.sup.th N_iwm being at least one,
[0511] the I_iwa.sup.th I_iw.sup.th internetworking-web indexed by an index, the I_iwa.sup.th I_iw.sup.th I_iwm, that specifies the I_iwa.sup.th I_iw.sup.th I_iwm.sup.th internetworking-web-member, the I_iwa.sup.th I_iw.sup.th I_iwm running between 1 and I_iwa.sup.th I_iw.sup.th N_iwm,
[0512] the I_iwa.sup.th I_iw.sup.th internetworking-web connecting the I_iwa.sup.th framework to the (I_iwa+1)th framework for I_iwa running from 1 to N_f−1,
[0513] the I_iwa.sup.th I_iw.sup.th internetworking-web comprising at least one internetworking-web-member that connects at least one structural-member in the I_iwa.sup.th framework to at least one structural-member in the (I_iwa+1)th framework,
[0514] the structural parts further comprising the internetworking-web-arrays and additional frameworks, and the structural parts constituting a multiaxial framework.
[0515] Embodiment AE is Embodiment AC wherein wherein the structural parts are dimensioned and positioned so as to comprise at least one of (A) a most direct second path through the uniaxial frameworks starting from the first structural-member at least 1.5 times longer than the span of the most direct second path through the uniaxial frameworks starting from the first structural-member or (B) a most direct second path through the uniaxial frameworks starting from the first structural-member at least 2 times longer than the span of the most direct second path through the uniaxial frameworks starting from the first structural-member or (C) a most direct second path through the uniaxial frameworks starting from the first structural-member at least 2.5 times longer than the span of the most direct second path through the uniaxial frameworks starting from the first structural-member or (D) a most direct second path through the uniaxial frameworks starting from the first structural-member at least 3 times longer than the span of the most direct second path through the uniaxial frameworks starting from the first structural-member. In some cases each internetworking web-member is a piece of rigid insulation.
[0516] Embodiment AF is an apparatus comprising at least one of an array of structural formations, each structural formation comprising an array of structural members, each structural member comprising an array of structural sub-members and an array of webs, each web comprising an array of web members, each web comprising at least one of: (a) an interformation web, wherein the interformation web members are configured to give a span-wise indirectness greater than 100% for the shortest metric path between first and last formations within an array of structural formations.
[0517] Embodiment AF: (Preferred Embodiment) for installation in a barrier with a cooperative interior surface and exterior surface, an apparatus comprising a framework with more than one structural member and a global web comprising more than zero global web members wherein the global web members are configured to give (1) a first metric path between the interior surface and exterior surface with a first length L.sub.1 a first span S.sub.1 a first span-wise indirectness I.sub.1={L.sub.1/S.sub.1}−1 greater than 100% (insulative aspect) equivalent to a first structural insulation factor F.sub.1=L.sub.1/S.sub.1 greater than 2 wherein the first metric path is shorter than any other metric path between the interior and exterior surfaces, (2) a first direct path between the interior and exterior surfaces with a second span and a first cumulative distance between structural parts (a) greater than {(9%±1%) times the second span} (insulatable aspect) and (b) less than {80% times the second span} (not so insulatable that the structure becomes weak) wherein the first cumulative distance between structural parts is less than any other cumulative distance between structural parts for any other direct path between the interior and exterior surfaces, (3) a first path length that is less than 85 times first cumulative distance between structural parts (balance between the insulatable and insulative aspects).
[0518] wherein the structural parts include each structural member and the global web.
[0519] Embodiment AG: Embodiment AF wherein the same rules apply in any direction perpendicular to the structural members.
[0520] In another embodiment of the present invention, a panel structure **500** shown in FIG. **43** includes spaced first planar panel **502**, second planar panel **504** and a plurality of spaced structural members **510**A, **510**B, **510**C, **510**D connecting facing surfaces of the first panel **502** and second panel **504**. As shown in FIG. **44**, each of the structural members **510**A, **510**B, **510**C, **510**D includes a first frame member **520** in contact with the first planar panel **502** in a longitudinal direction, a second frame member **530** in contact with the second planar panel **504** in the longitudinal direction, the second frame member **530** being spaced from and substantially parallel to the first frame member **520**, and a connecting frame member **540** between and contacting the first frame member **520** and second frame member **530**, the connecting frame member **540** contacting the first frame member **520** at a plurality of first locations **525** and contacting the second frame member **530** at a plurality of second locations **550**, the first and second frame members **520**, **530** having free interior-facing surfaces **521**, **531** between the first and second locations **525**, **550**. The connecting frame member **540** provides no direct path of conductive heat flow, in a direction perpendicular to the longitudinal direction, between interior-facing surfaces **521**, **531** of the first and second frame members **520**, **530**. The structural members **510**A, **510**B, **510**C, **510**D may be made of wood or a composite thereof. The distance between first locations **525** is at least 2 times the distance between the first and second frame members **520**, **530**. The distance between second locations **550** is at least 2 times the distance between the first and second frame members **520**, **530**. The connecting frame member **540** comprises a central frame member **540**A substantially parallel to the first and second frame members **520**, **530** and a plurality of linking members **540**B, **540**C perpendicular to the central frame members **540**A in contact with the first and second frame members **520**, **540** at the first and second locations **525**, **550**. Alternately the connecting frame member **540** comprises a central frame member **540**A substantially parallel to the first and second frame members **520**, **540** and a plurality of first linking members **540**B connecting a first surface **550** of the central frame member **540**A to the first frame member **530** and a plurality of second linking members **540**C connecting a second surface of the central frame member **540**A opposite the first surface of the central frame member **540**A to the second frame member **520**, wherein none of the first linking members **540**B are directly opposite any of the second linking members **540**C. As shown in FIG. **44**, the connecting frame member

540 comprises a central frame member **540**A substantially parallel to the first and second frame members **520**, **530** and a plurality of linking members **540**B, **540**C, each linking member **540**B, **540**C secured either diagonally between the first frame member **530** and the central frame member **540**A or diagonally between the second frame member **520** and the central frame member **540**A. The panel structure **500** may include secondary linking members connecting one of the spaced structural members to at least one other spaced structural member. The secondary linking members may connect one of the spaced structural members to at least one other spaced structural member wherein the secondary linking members provide no direct path of conductive heat flow, in a direction perpendicular to the longitudinal direction, between spaced structural members.

[0521] Another aspect of the present invention is directed to a method of making a panel structure **500**, shown in FIG. **45**, the facing surfaces of the first and second panels are connected using the structural members **510**A, **510**B, **510**C, **510**D wherein the connecting frame member **540** provides no direct path of conductive heat flow in a direction perpendicular to the longitudinal direction, between interior-facing surfaces of the first and second frame members **520**, **530**.

[0522] Alternately, the method of making a panel structure **500** may include the plurality of spaced structural members **510**A, **510**B, **510**C, **510**D connecting the facing surfaces of the first and second panels **502**, **504** wherein the spaced structural members **510**A, **510**B, **510**C, **510**D provide no direct path of conductive heat flow in a direction perpendicular to the longitudinal direction, between interior-facing surfaces of the first and second panels **502**, **504**.

[0523] Another aspect of the present invention is directed to a structural member **510**A, **510**B, **510**C, **510**D which connects a first and a second panel **502**, **504** to make a panel structure **500**. The structural member **510**A, **510**B, **510**C, **510**D includes a first elongated frame member **520**, a second elongated frame member **530** spaced from and substantially parallel to the first elongated frame member **520** and a connecting frame member **540** between and contacting the first and second frame members **520**, **530**, the connecting frame member **540** contacting the first frame member **530** at a plurality of first locations **550** and contacting the second frame member **520** at a plurality of second locations **525**, the first and second frame members **520**, **530** having free interior-facing surfaces between the first and second locations **550**, **525**. The connecting frame member **540** provides no direct path of conductive heat flow, in a direction perpendicular to the longitudinal direction, between interior-facing surfaces of the first and second frame members **520**, **530**.

[0524] Another aspect of the present invention shown in FIG. **46** is directed to an insulative structural member **610** including a first elongated frame member **620** having a first length and a second elongated frame member **630** spaced from and substantially parallel to the first elongated frame member **620**, the second elongated frame member **630** having a second length substantially the same as the first length. The insulative structural member **610** includes a central elongated frame member **640** spaced between and parallel to the first and second frame members **620**, **630**, the central frame member **640** having a third length substantially the same as the first length. The insulative structural member **610** includes a plurality of first connecting members **650** joining the first elongated member **620** to one surface of the central frame member **640**, the first connecting members **650** having a connection length shorter than the first length. The insulative structural member **610** includes a plurality of second connecting members **660** joining the second elongated member **630** to an opposite surface of the central frame member **640**, the second connecting members **660** having a connection length substantially shorter than the first length.

[0525] The structural member **610** provides no direct path of conductive heat flow, in a direction perpendicular to the first length. The connection length of the plurality of first connecting members **650** and the plurality of second connecting members **660** may be less than 20% of the first length of the first elongated frame member **620** and additionally may be less than 10% of the first length of the first elongated frame member. The first, second and central elongated members **620**, **630**, **640** each may comprise a plurality of elongated lamination members **601** as shown in FIG. **46** and the first and second connecting members **650**, **660** comprise a plurality of connecting lamination members **602**. The connecting lamination members of the first connecting members **650** may be interwoven with the elongated lamination members of the first and central elongated members **620**, **640** and the connecting lamination members of the second connecting members **660** may be interwoven with the elongated lamination members of the second and central elongated members **630**, **640**. The first and second connecting members **650**, **660** may be secured diagonally between the corresponding first or second elongated frame member **620**, **630** and the central frame member **640**. The first and second connecting members may be configured to give a first metric path between an outside surface of the first elongated frame member an opposing outside surface of the second elongated frame member with a first length L.sub.1 a first span S.sub.1 a first span-wise indirectness 11={L.sub.1/S.sub.1}−1 greater than 100% (insulative aspect) equivalent to a first geometrical insulation factor F.sub.1=L.sub.1/S.sub.1 greater than 2, wherein the first metric path is shorter than any other metric path between the interior and exterior surfaces. The first and second connecting members may be configured to give a first direct path between an outside surface of the first elongated frame member an opposing outside surface of the second elongated frame member with a second span and a first cumulative distance between structural parts (a) greater than {(9% #1%) times the second span} (insulatable aspect) and (b) less than {80% times the second span} (not so insulatable that the structure becomes weak) wherein the first cumulative distance between structural parts is less than any other cumulative distance between structural parts for any other direct path between the interior and exterior surfaces. The first and second connecting members may be configured to give a first path length that is less than 85 times first cumulative distance between structural parts (balance between the insulatable and insulative aspects), wherein the structural parts include each structural member and the first and second connecting member.

[0526] Thus, the present invention provides one or more of the following advantages. The present invention provides a structural member which has insulative properties and provides a structural member which compliment insulative materials used with the structural member. The present invention provides a structural member for supporting panels on opposing sides of the structural member which resists heat transfer between the opposing panels and provides a panel structure having spaced first and second planar panels which provide structural integrity and resistance to heat transfer.

[0527] While the present invention has been particularly described, in conjunction with one or more specific embodiments, it is evident that many alternatives, modifications and variations will be apparent to those skilled in the art in light of the foregoing description. It is therefore contemplated that the appended claims will embrace any such alternatives, modifications and variations as falling within the true scope and spirit of the present invention.

Claims

1. A panel structure comprising: spaced first and second planar panels; and a plurality of spaced structural members connecting facing surfaces of the first and second panels, each of the structural members comprising: a first frame member in contact with the first planar panel in a longitudinal direction; a second frame member in contact with the second planar panel in the longitudinal direction, the second frame member being spaced from the first frame member and substantially parallel thereto; and a connecting frame member between and contacting the first and second frame members, the connecting frame member contacting the first frame member at a plurality of first locations and contacting the second frame member at a plurality of second locations, the first and second frame members having free interior facing surfaces between the first and second locations, wherein the connecting frame member provides no direct path of conductive heat flow, in a direction perpendicular to the longitudinal direction, between interior facing surfaces of the first and second frame members.