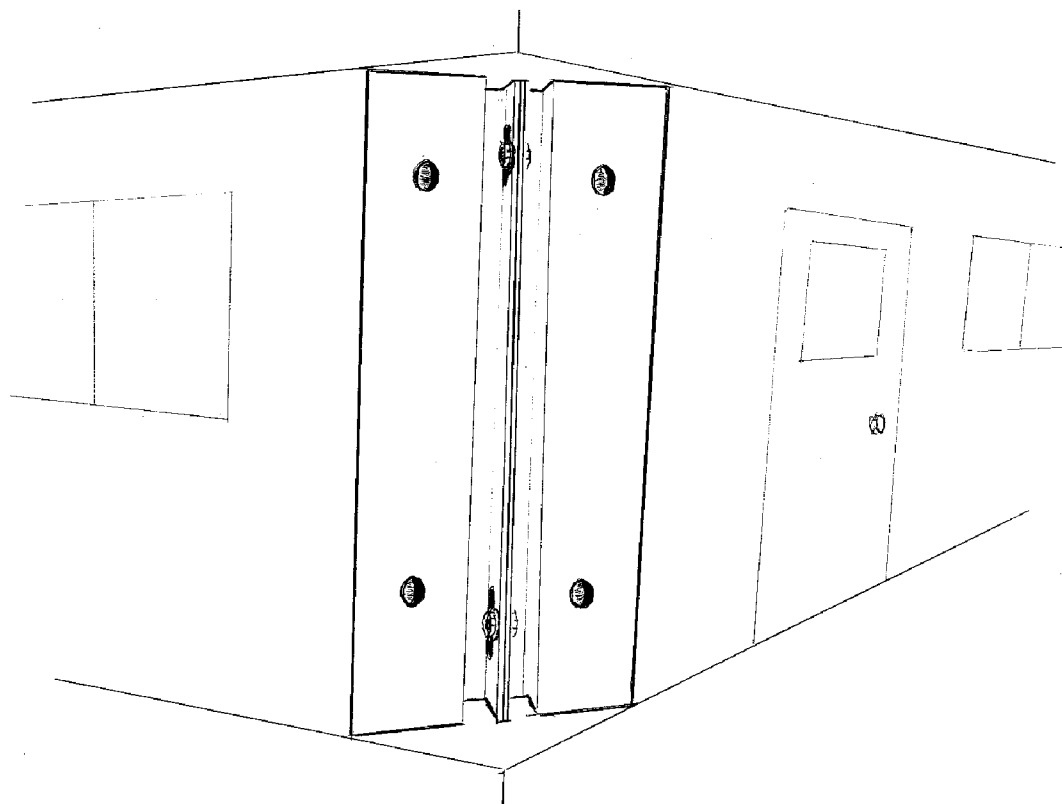


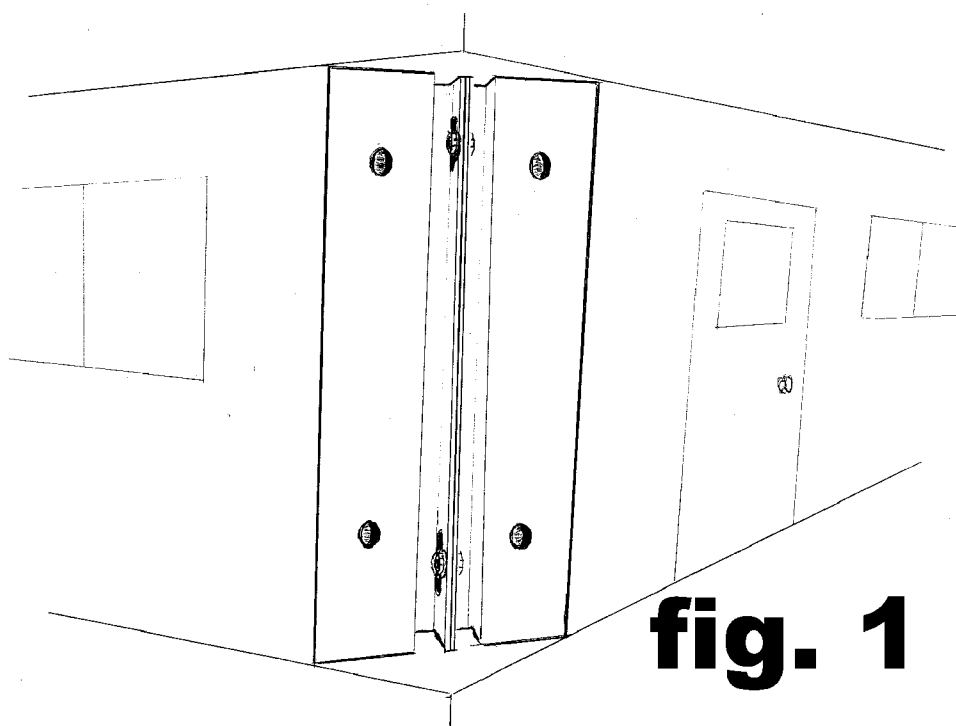


US 20080098676A1

(19) **United States**(12) **Patent Application Publication**  
**Hutchens**(10) **Pub. No.: US 2008/0098676 A1**(43) **Pub. Date: May 1, 2008**(54) **CONNECTORS AND METHODS OF  
CONSTRUCTION FOR A PRECAST SPECIAL  
CONCRETE MOMENT RESISTING SHEAR  
WALL AND PRECAST SPECIAL CONCRETE  
MOMENT RESISTING FRAME BUILDING  
PANEL SYSTEM**(76) Inventor: **John Francis Hutchens**, Orinda,  
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**P.O. BOX 182**  
**CANYON, CA 94516**(21) Appl. No.: **11/554,611**(22) Filed: **Oct. 31, 2006****Publication Classification**(51) **Int. Cl.**  
**E04B 1/38** (2006.01)  
**E04B 7/00** (2006.01)(52) **U.S. Cl. .... 52/281; 52/282.3**(57) **ABSTRACT**

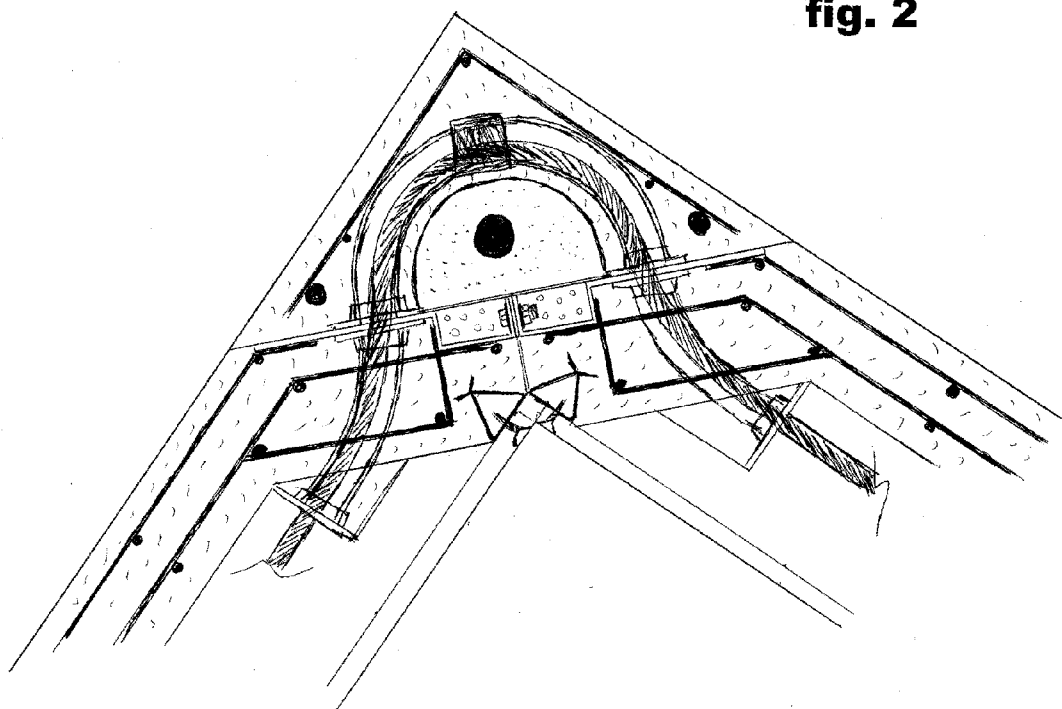
A precast concrete wall panel molding system for fabricating a wall shell and a plurality of ribs and beams. A precast concrete wall panel molding system with facilities for incorporating door and window frames. A ductile panel end connector for attaching panels one to another whether in parallel or angled as in inside or outside corners. A ductile panel end connector for attaching panels to columns. A wall anchor/shear plate with post-tensioning brace plate. A hybrid precast/cast-in-place special moment resisting shear wall/special moment resisting frame reinforced concrete building system for regions of potential seismic activity. A prescriptive method building system for composite structural building assemblies with conventional wood and light-gauge steel framing, structural steel, and other building code approved and tested building systems, building components, building panel systems, building roofing systems, modular and manufactured buildings, and building electrical, mechanical, and plumbing systems. A precast concrete wall panel system conforming to industry practices and standards as published by the Precast/Prestressed Concrete Institute, (PCI) in its "PCI Design Handbook" (fifth edition, 1999), the American Concrete Institute "Building Code Requirements for Structural Concrete" (ACI 318-05), The "International Building Code 2006" and the "Uniform Building Code".

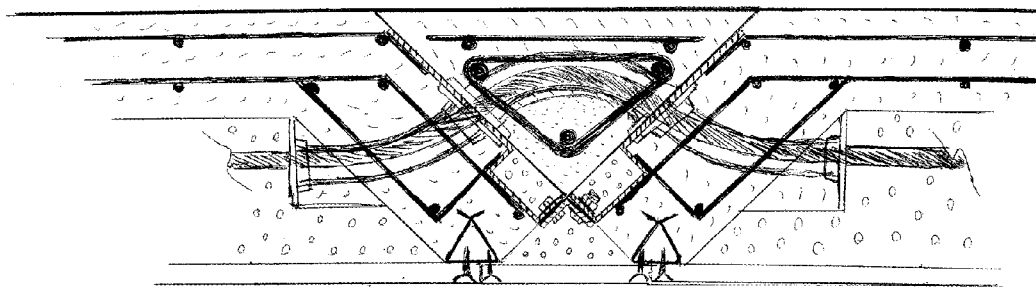




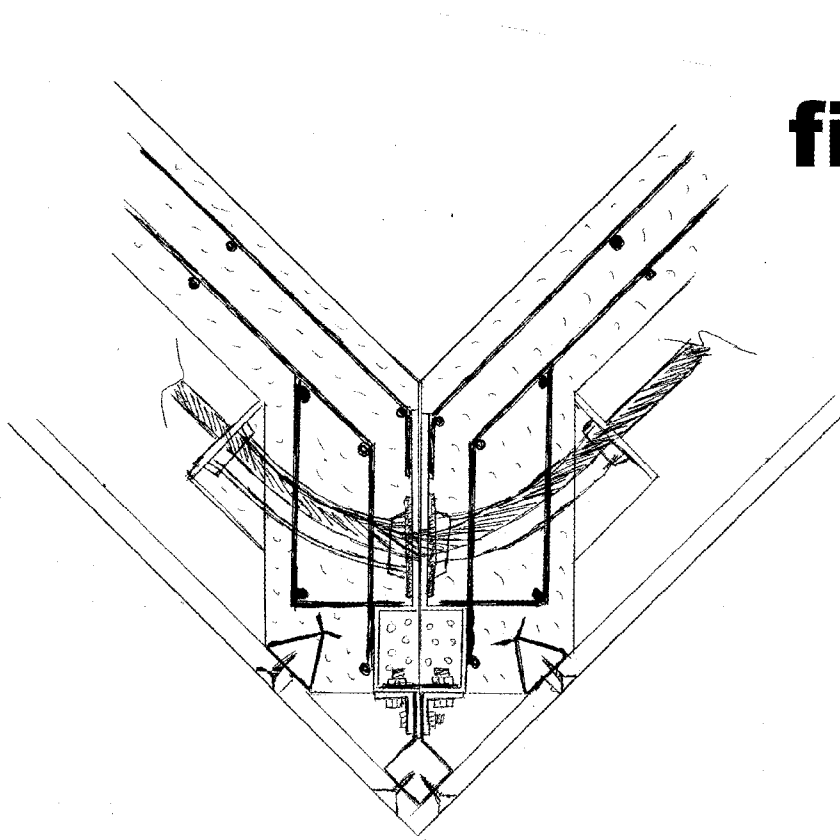
**fig. 1**

**fig. 2**



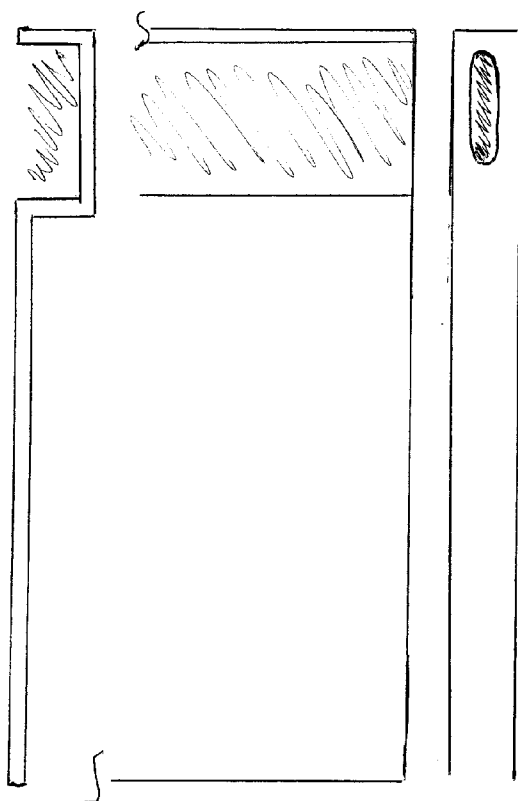


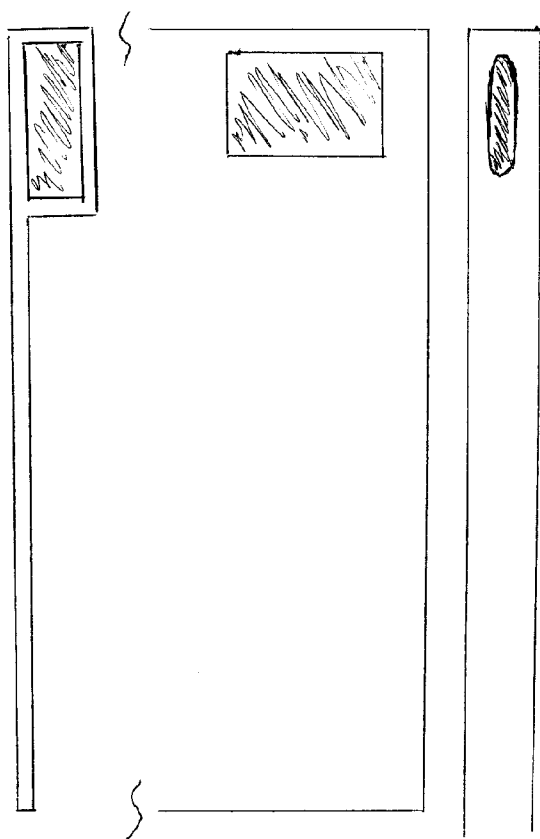
**fig. 3**



**fig. 4**

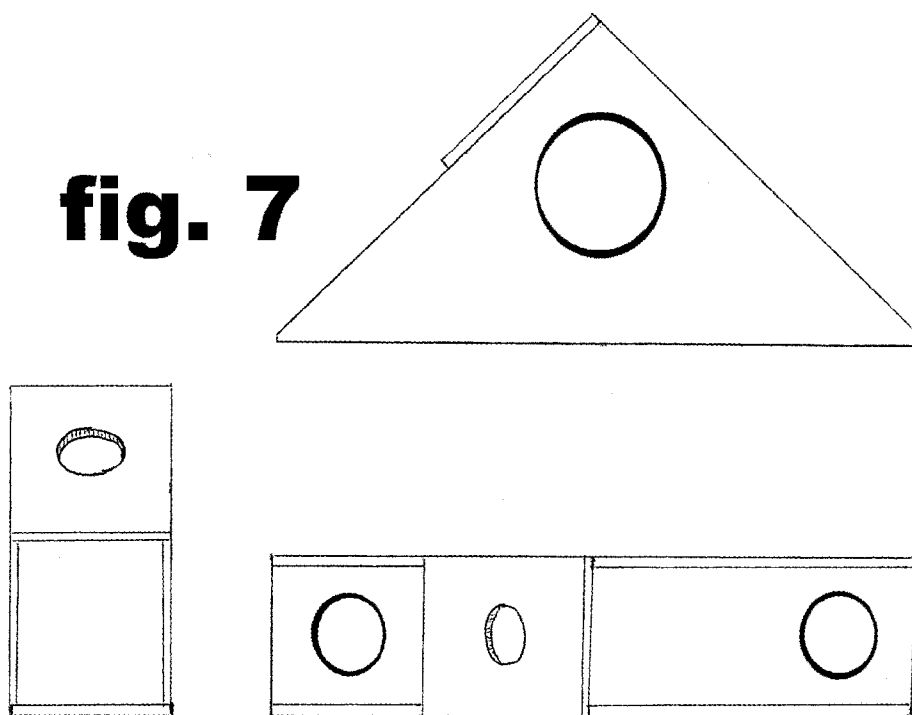
**fig. 5**





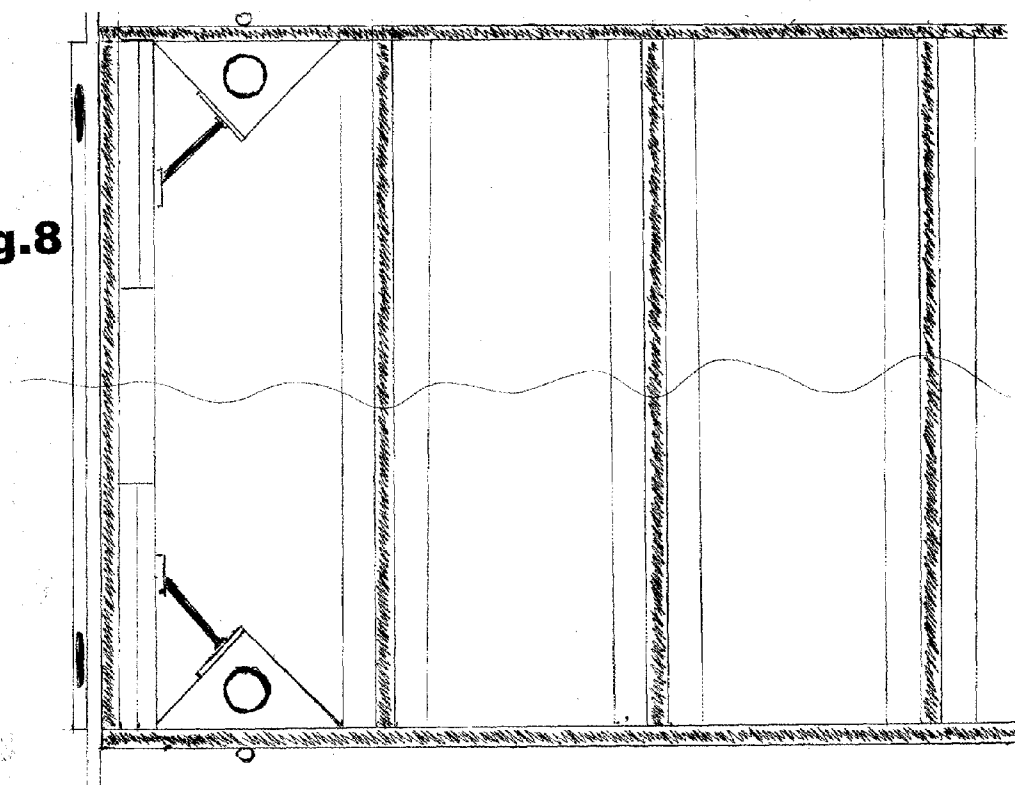
**fig. 6**

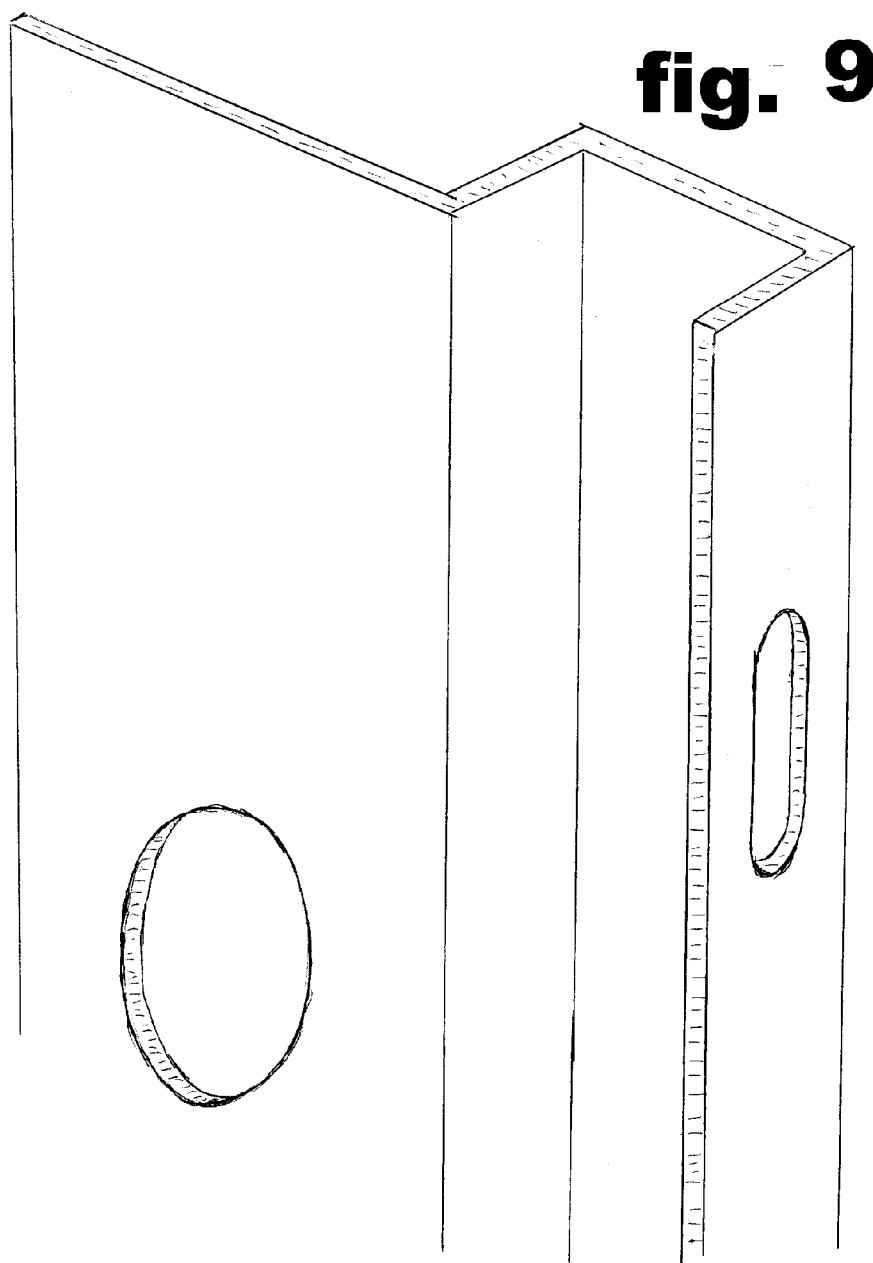
**fig. 7**

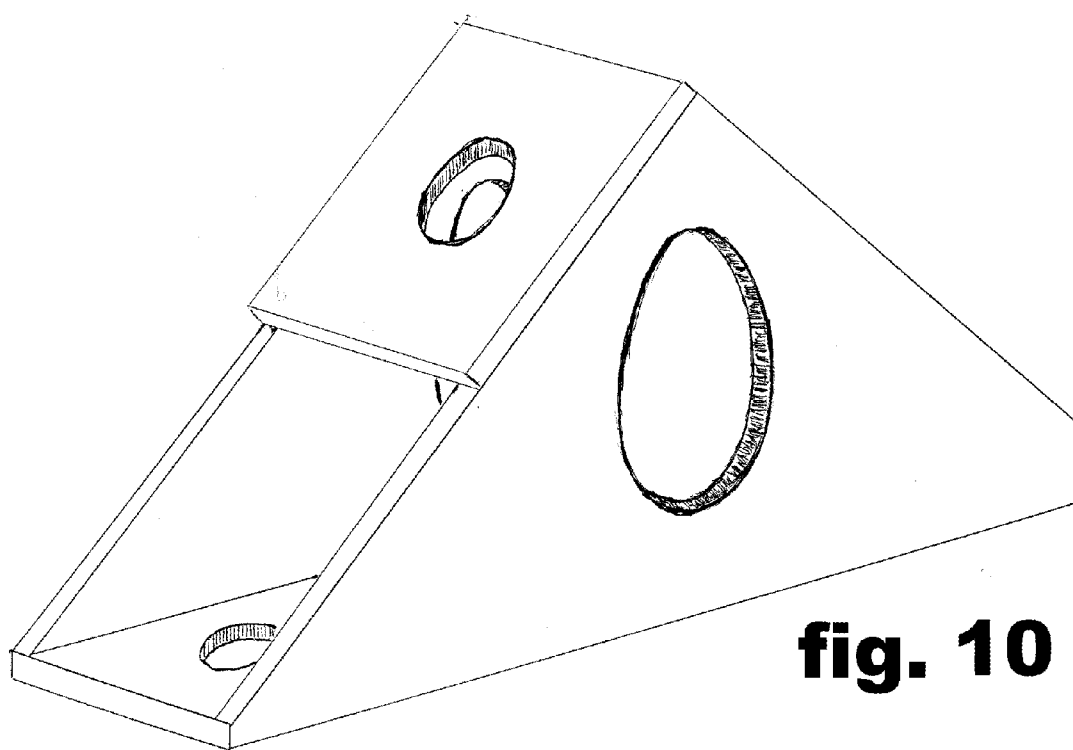




**fig.8**

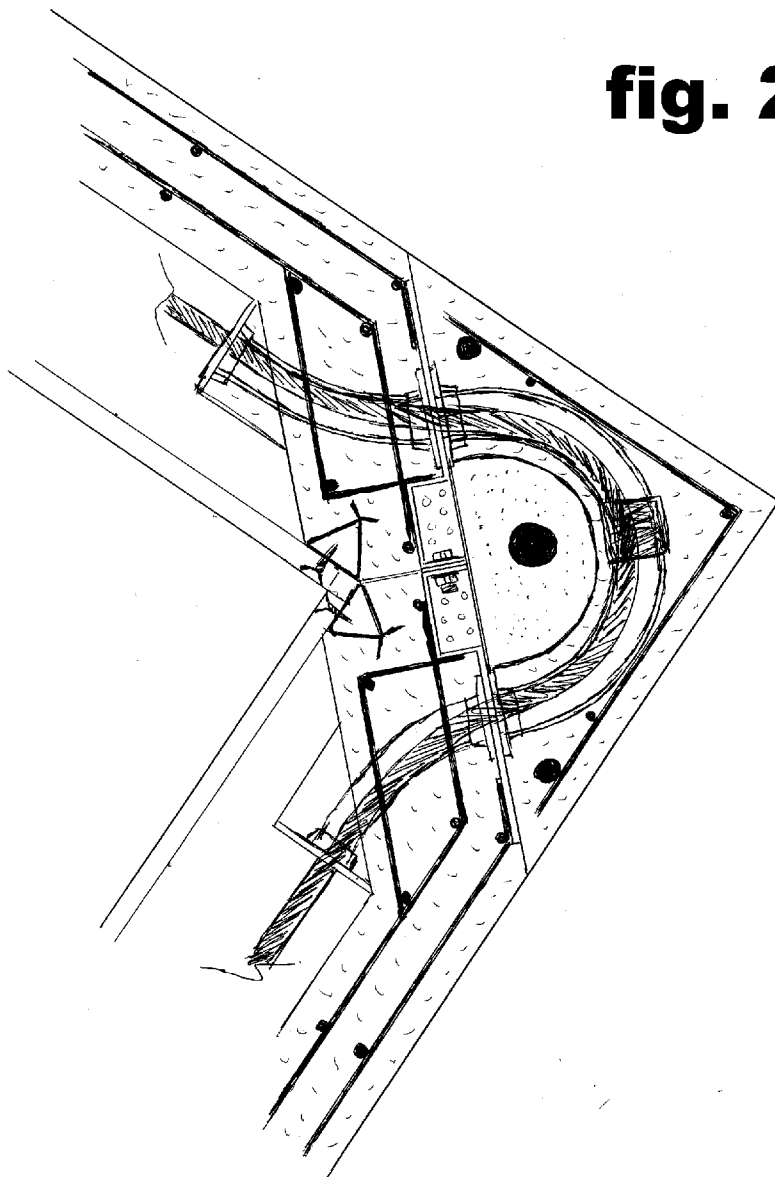




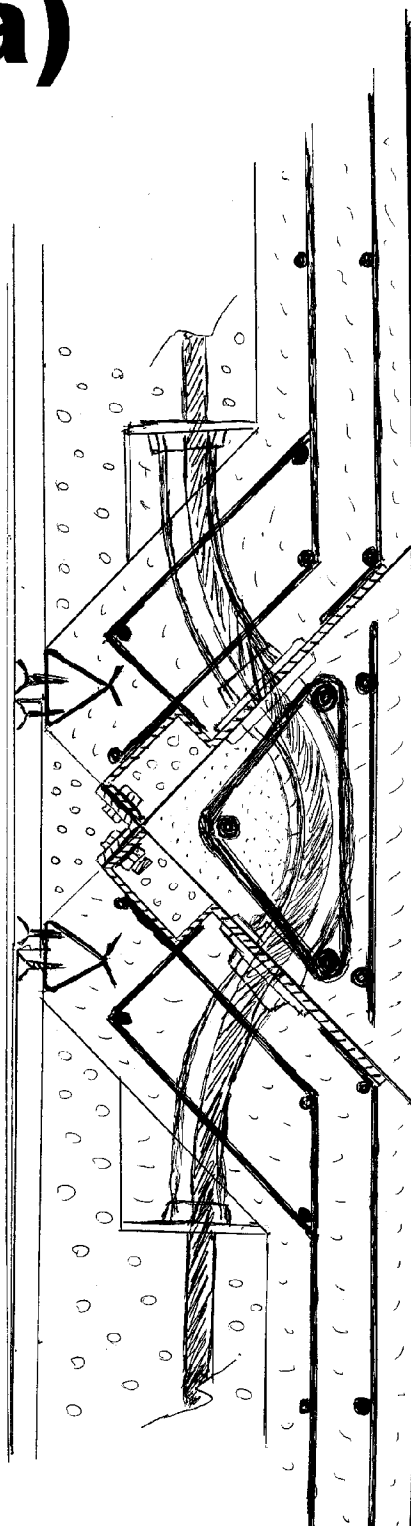


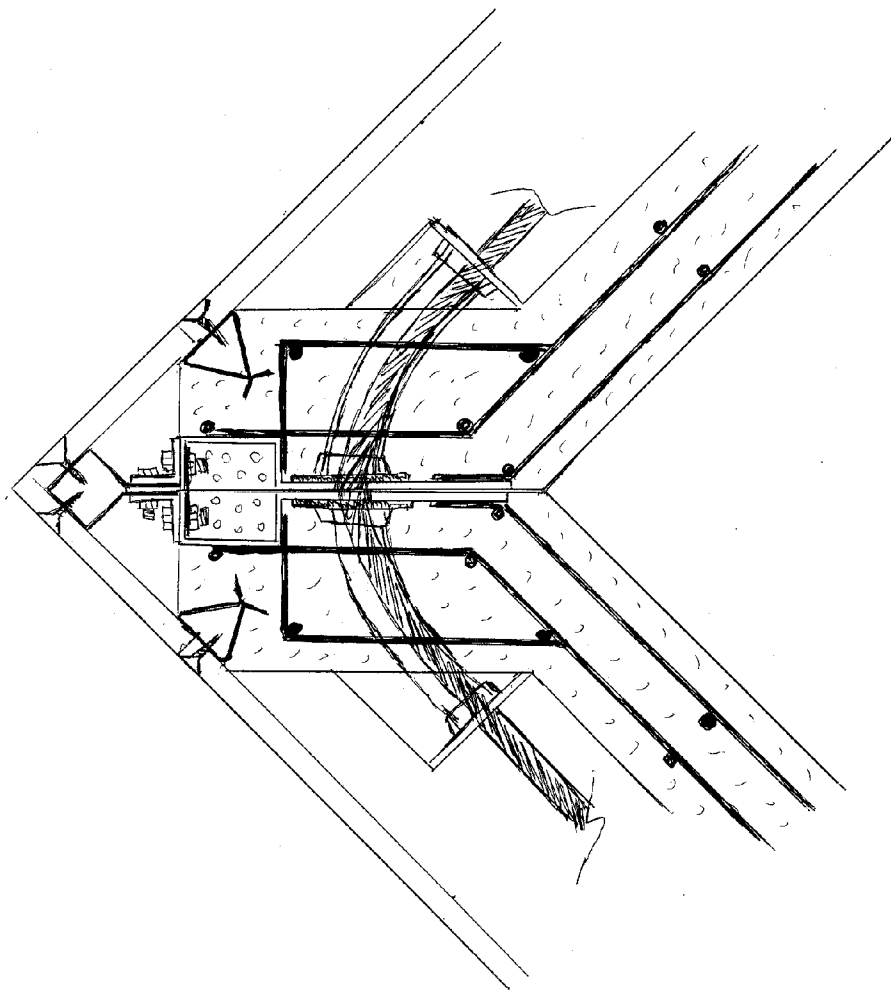
**fig. 10**

**fig. 2(a)**



**fig. 3(a)**





**fig. 4(a)**

**CONNECTORS AND METHODS OF  
CONSTRUCTION FOR A PRECAST SPECIAL  
CONCRETE MOMENT RESISTING SHEAR  
WALL AND PRECAST SPECIAL CONCRETE  
MOMENT RESISTING FRAME BUILDING  
PANEL SYSTEM**

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FIELD OF THE INVENTION

[0004] This invention deals with building construction and more specifically with the construction of prefabricated special concrete shear-walls, prefabricated special concrete moment frames, hybrid pre-cast/site cast concrete construction, ductile reinforcement connections, and new and novel methods of fulfilling the requirements of the seismic specifications of the current and proposed model building codes.

[0005] In a typical example of the preferred embodiment of the present invention, with a minimum rating of 5,000 psi concrete, a typical 7-1/2" wall section requires approximately 55% of the concrete required for an equivalent solid concrete wall, yet provides in excess of 85% of the equivalent effective load capacity, or about 8,000 lbs./lf.

[0006] This results in an effective factored load rated capacity for seismic applications of approximately 6,000 lbs./lf.

[0007] When filled with insulation, (R=5/1") the wall is engineered to a thermal rating of R-13.

[0008] Every 1,000 sq. ft. of wood construction replaced with concrete saves an estimated 15 to 20 trees, (and lasts many times as long.)

[0009] Pursuant to Chapters 16, 18 & 19 of the Uniform Building Code, for regular structures designed according to: Table 16 N, 1629.1-1629.10.2-1630.2.1-1630.2.3-1630.8.2.2-1630.9.2-1630.10.1-1630.11-1630.4-1630.5-1630.6-1630.7-1630.8-1630.8.2.2-1631.2-1631.5.5-1631.5.6-1631.5.7-1632.5-1633.2.4.1-1633.2.8-1633.2.9-1809.4-1921.3.2-

1921.3.3-1921.4.4.5-1921.6.6-2213.7.1.3 the maximum allowed building height for a special moment resisting frame in concrete is not limited

#### BACKGROUND OF THE INVENTION

**[0010]** Conventional methods of constructing prefabricated concrete buildings and particularly prefabricated concrete foundations and foundation walls in seismically active areas have become increasingly difficult to design in recent years as the requirements of State's building codes and the model building codes on which they are based have become more restrictive with the continuing scientific research and resultant improved understanding of the vulnerability of ordinary concrete and conventional reinforcement methods to seismic events.

**[0011]** These requirements have effectively prevented numerous innovative building systems from being utilized in seismically active areas.

**[0012]** A recent "quick" search of the U.S. Patent office database returns 1147 matches for "building panel".

**[0013]** Most State's model codes are regularly updated to implement improvements, standardizations, and new technologies that have been adopted by the model code organizations. During the last ten years, consolidation has resulted in one model code organization, the "International Code Council" (ICC).

**[0014]** Their publications, particularly the "International Residential Code" (IRC 2006), and the "International Building Code" (IBC 2006), when in reference to standards for concrete construction, refer to the "American Concrete Institute" and in particular their committee 318, and it's most recent publication; which is currently "Building Code Requirements for Structural Concrete (ACI 318-05) and Commentary (ACI 318-05R).

**[0015]** The IBC 2006 and ACI 318-05 further reference the "American Society of Civil Engineers Minimum Design Loads for Buildings and Other Structures", or "ASCE 7", Most of the specifications and details are for cast in place concrete, and any reference to pre-cast concrete generally or in regards to seismic requirements particularly are that any design with pre-cast concrete components should meet or exceed the strength requirements for cast in place concrete.

**[0016]** For construction details with exclusive relevance to precast concrete, readers are referred to the Precast Concrete Institute, (PCI), and its publication "PCI Precast and Prestressed Concrete Handbook", (PCI-99).

**[0017]** Further complicating the provisions is section 1908 of the "IBC 2006", and specifications 1908.1.1 through 1908.1.16, which are modifications, exceptions, or additions to the seismic provisions of ACI 318-05

**[0018]** Other organizations, regulatory bodies and bureaucracies contributing or participating in construction technologies evaluation, seismic safety, and concerns relevant to seismic design include the Department of Housing and Urban Development, (HUD), the Federal Emergency Management Agency, (FEMA), the Building Seismic Safety Council, (BSSC), the National Earthquake Hazard Reduction Program, (NEHRP), the Earthquake Engineering Research Institute, (EERI), the Applied Technology Council, (ATC), the Scientific Earthquake Studies Advisory Committee, (SESAC), the National Institute of Standards and Technologies, (NIST), the National Science Foundation, (NSF), the United States Geological Survey, (USGS), the U.S. Army Engineer Research and Development Center, (ERDC), the

Consortium of Universities for Research in Earthquake Engineering, (CUREE), the Multidisciplinary Center for Earthquake Engineering, (MCEER), the Pacific Earthquake Engineering Resource Center, (PEER), the National Hazards Center at the University of Colorado, (NHC), the Southern California Earthquake Center, (SCEC), the Mid-America Earthquake Center, (MAEC), and the Network for Earthquake Engineering Simulation, (NEES).

**[0019]** Earthquake preparedness organizations include the Cascadia Region Earthquake Workgroup, (CREW), the Western States Seismic Policy Council, (WSSPC), the Northeast States Emergency Consortium, (NSEC), and the Central US Earthquake Consortium, (CUSEC).

**[0020]** HUD has long recognized the potential benefits of panelized building construction and in September of 2004 it presented a document entitled "Residential Panels Benchmark Requirements", which outlined the state of the art at that time, categorized the various types of panel construction, and established some criteria for evaluating the various methods.

**[0021]** Except for "Structurally Insulated Panels Systems", (SIPS), and "concrete-skinned studs" (also known in the trade as Concrete Thin Shell, (CTS)), the model code makes no explicit provisions for the testing or use of other panel system in earthquake resistant construction, unless it is attached to a seismically designed structural steel.

**[0022]** HUD prepared a list of performance measures that was refined to "10 headings to focus the measures and to allow them to dovetail with code requirements, which would permit the performance measures to relate directly to relevant code citations."

**[0023]** 1. 1. Safety and Fire Performance

**[0024]** 2. 2. Weatherproofing

**[0025]** 3. 3. Energy Performance

**[0026]** 4. 4. Durability

**[0027]** 5. 5. Dimensions

**[0028]** 6. 6. Functions

**[0029]** 7. 7. Aesthetics

**[0030]** 8. 8. Maintenance

**[0031]** 9. 9. Handling

**[0032]** 10. 10. Flexibility

**[0033]** Commentary from the American Concrete Institute outlines the following considerations for seismic design:

**[0034]** "The principal steps involved in the earthquake-resistant design of a typical concrete structure according to building code provisions are as follows:

**[0035]** 1. Determination of design earthquake forces:

**[0036]** a. calculation of base shear corresponding to computed or estimated fundamental period of vibration of the structure (a preliminary design of the structure is assumed here).

**[0037]** b. distribution of the base shear over the height of the building

**[0038]** 2. Analysis of the structure under the (static) lateral earthquake forces calculated in step 1, as well as under gravity and wind loads, to obtain member design forces.

**[0039]** 3. Designing members and joints for the critical combinations of gravity and lateral (wind or seismic) loads, and detailing them for ductile behavior.

**[0040]** It is important to note that some buildings are required to be designed by a dynamic, rather than a static, lateral force procedure when one or more criteria of the static procedure are not satisfied."

**[0041]** Examples of attempts at resolving these needs are extensive in the patent literature and in the marketplace. The



purpose of this invention is to improve upon the prior art to achieve the promise of these technologies with a cost effective seismic code compliant building technology.

[0042] The primary focus of this invention pertains to affordable residential construction; however nothing about this invention limits it to such use.

[0043] In U.S. residential construction one of the more successful panel systems is the "Superior Wall System™", which is designed for basement/1<sup>st</sup> level construction with conventional light construction for up to an additional 2-½ floors. It is based on patents by Zimmerman, U.S. Pat. Nos. 6,494,004; 5,656,194; 5,055,252; 4,934,121; 4,751,803; 4,605,529; and 4,570,398. In its most recent iteration, the "Xi™" wall system, (patent #6,494,004), it fulfills the 10 categories of measure by HUD criteria effectively. It is manufactured at 17 facilities and is available in 24 States and the District of Columbia. It is the subject of ICC-ES legacy report #21-72 reissued Nov. 1<sup>st</sup>, 2005 (rated at 4,000 lb./lf), and HUD Structural Engineering Bulletin #1117 Rev. 5, (4,360 lbs./lf).

[0044] The "Superior Wall System™", is not, however, available in areas with significant potential for seismic activity, (seismic zones D, E, and F.)

[0045] Analysis of the Superior Wall System™, reveals that principle among the reasons that the system is not available for seismic applications is insufficient/untested anchorage to a foundation system to resist seismic shear, inadequate and/or non-continuous reinforcement resulting in plastic hinge regions, a lack of ductile connections for beams, shear walls, or columns within the building, and a lack of a damping mechanism for dissipating the energy of a seismic event by ductile yielding or other means. In the parlance of the current building codes, it does not meet the requirements for "Special Concrete Moment Resisting Shear Walls".

[0046] One of the compelling rationales for concrete panel construction is the presumption of fire resistance. The ICC re-issued legacy report of the UBC, ER-3264, on Dec. 1, 2003. Its subject is the "Design of Fire-resistive Construction for Precast and Prestressed Concrete. It further states "The design of fire-resistive construction requires the use of the PCI manual "Design for Fire Resistance of Precast Prestressed Concrete," 1989, a copy of which must be submitted to the building official when a fire-resistive design under this report is submitted for approval

#### SUMMARY

[0047] The wall panel system herein described, with the benefit of the connectors, boundary elements and ductile anchoring devices of the present invention, offers a building system conforming to the existing model codes for use anywhere including regions of high seismic activity. The wall panel system offers an economical building system that is beneficial to environmental conservation, durable, non-flammable, thermally efficient, attractive, and flexible to adaptations of conventional building technologies, components, and accessories.

[0048] It may be seen in all known examples of the prior art that in each embodiment a substantially orthogonal connection attaches each wall panel one to another. Even in panel systems with integral corner panels the panel connections are potential failure points during a seismic event.

[0049] The diagonal wall connectors and wall anchor/shear plate with post-tensioning brace plate connectors of the present invention, along with the building methods described,

provide a wall panel connection that is as strong or stronger than the wall panels themselves, as well as being ductile and therefore able to dissipate substantial energy as that energy is transmitted amongst the various portions of the building component system during a seismic event.

[0050] It will be seen in the following descriptions that the dimensions of the columns are not limited by the dimensions of the wall panels, and therefore a multiple story construction may be designed according to the engineering requirements of a precast concrete moment frame building.

#### BRIEF DESCRIPTION OF THE DRAWINGS

[0051] FIG. 1 is a perspective view of two joined wall panels of the preferred embodiment of the invention attached as an outside corner of a building.

[0052] FIG. 2 is a partial cross section view of the outside corner connection of two wall panels and an outside corner panel with the structural steel connector boundary element exposed and diagramming the typical reinforcement and tensioning strand of the preferred embodiment of the invention.

[0053] FIG. 3 is a partial cross section view of the planar wall connection of two wall panels and a center column panel with the structural steel connector boundary element exposed and diagramming the typical reinforcement and tensioning strand of the preferred embodiment of the invention.

[0054] FIG. 4 is a partial cross section view of the inside corner connection of two wall panels with the structural steel connector boundary element exposed and diagramming the typical reinforcement and tensioning strand of the preferred embodiment of the invention.

[0055] FIG. 5 is a plan and elevation view of the connector of claim 1.

[0056] FIG. 6 is a plan and elevation view of the connector of claim 6.

[0057] FIG. 7 is a plan and elevation view of the connector of claim 12.

[0058] FIG. 8 is an elevation view of the a wall anchor/shear plate with post-tensioning brace plate of claim 12 installed within the bottom and the top of the first wall cavity adjoining a panel end.

[0059] FIG. 9 is a perspective view of the connector of claim 1.

[0060] FIG. 10 is a perspective view of the wall anchor/shear plate with post-tensioning brace plate of claim 12.

[0061] FIG. 2(a) is an enlargement of FIG. 2.

[0062] FIG. 3(a) is an enlargement of FIG. 3.

[0063] FIG. 4(a) is an enlargement of FIG. 4.

#### DETAILED DESCRIPTION OF THE INVENTION

[0064] Conventional architectural building plans are prepared for a prospective building owner or developer by an architect or engineer. Soil, geo-technical, civil, and any other engineering studies required by the code and local building officials are prepared. The plans are submitted to a licensed panel manufacturer for evaluation of engineering requirements by an authorized engineer.

[0065] A feasibility study is performed and upon acceptance an estimate of the building and construction costs is prepared. When a contract to build is executed, the licensed panel manufacturer prepares the necessary plans and documentation for permit application, including engineering of the structural assembly components, structural walls, columns, beams, diaphragms, moment frames, trusses, rein-

forcement bar, wire, cable, anchors, inserts, plates, ductile connectors, channel, tubing, and any other embedded elements and any other structural members.

[0066] Engineering documentation of all loads, shear, stress, yield, moment calculations, inspections, tests, or other requirements are prepared.

[0067] Architectural engineering documentation and drawings of patterns, designs, art work, textures, colors, and chemistry of cement composites, admixtures, colorants, precise ratios of water, temperatures, mixing times, ASTM specifications, MSDS documentation, curing times and procedures, or other requirements are prepared.

[0068] Architectural engineering drawings with detailing, tolerances, and specifications are prepared.

[0069] Building plans and documentation are submitted to the local building officials for permits.

[0070] Any modifications necessary to comply with local codes or other requirements to obtain building permits are completed.

[0071] Upon issuance of approved building plan permits, shop drawings with detailing, tolerances, and specifications are prepared.

[0072] Site work and preparation commences and the foundation structural elements such as pilings, footings, grade beams, mat slabs or diaphragms are built. Engineering precision of all formwork and anchorage is essential with any precast structure. The code specified tolerance of 1/4" variation in 40' must be rigorously maintained.

[0073] Certified mill test reports are required for each shipment of reinforcing steel and/or structural steel to be used in structures assigned to Seismic Design Category D, E or F for resistance to flexural, shear and axial forces in reinforced concrete, intermediate and special moment frames, and boundary elements of special reinforced concrete shear walls. Structural steel must conform to one of the following specifications:

[0074] (a) "Specification for Carbon Structural Steel" (ASTM A 36);

[0075] (b) "Specification for High-Strength Low-Alloy Structural Steel" (ASTM A 242);

[0076] (c) "Specification for High-Strength Low-Alloy Columbium-Vanadium Structural Steel" (ASTM A 572);

[0077] (d) "Specification for High-Strength Low-Alloy Structural Steel with 50 ksi (345 MPa) Minimum Yield Point to 4 in. (100 mm) Thick" (ASTM A 588);

[0078] (e) "Specification for Structural Steel Shapes" (ASTM A 992).

[0079] Reusable assembly molds are formed on a horizontal surface or on a surface prepared with architectural features or designs, according to the drawings. The fascia of the mold may be crafted in a variety of ways to suit the particular application, or prepared directly upon a suitably flat surface with a proper seal and release agent. Some of the more common mold forming materials are lumber, plywood, polystyrene foam, stainless steel, or fiberglass and resins. Sometimes reinforced latex is used to make castings of existing complex shapes. Other applications may use gypsum and/or cement and urethanes or vinyl.

[0080] The panel is framed at its top and bottom to establish the precise height of the panel. Additional components to provide for openings in the panel for the attachment of frames for doors, windows, or other features are placed against the mold face, with bracing and clamping devices to secure the components precisely in the mold.

[0081] Corner column and center column panel molds are formed with fascia corresponding to the adjoining wall panels as described in the drawings.

[0082] The ends of wall panel molds have a diagonal face that is facilitated by a diagonal wedge to provide a bracing surface to the ductile panel end connector. The wedge is placed perpendicular between the top and bottom of the mold, aligned and set to the precise dimensions of the panel.

[0083] The mold is suitably prepared with sealants and release agents to facilitate the production of the panel.

[0084] A surface layer of fiber-reinforced engineered cement composite (ECC) or other approved exterior type cement coating material, (stucco) or other cementitious materials as specified by the architectural or engineering documentation containing the specified coloring and waterproofing agents is applied to the entire exterior surface of the panel, (the inner face of the mold) sufficient to reach a uniform level surface and then such additional depth as may be required for the engineering of the particular application, (typically a minimum of 1".)

[0085] Corner column panel molds are applied with a surface layer to each orthogonal face either simultaneously with the corner of the mold downwards, (each face of a typical corner at 45 degrees from horizontal), or in the case of molds which are particularly smooth or where the cement coating is not viscous enough to adhere to the mold face then each face is applied alternately in the horizontal position and allowed to set before alternating with the adjoining face.

[0086] Center column panel molds with diagonal wedges to form the sides (edges) of the column are applied with a surface layer to the face.

[0087] (The science of concrete chemistry has made tremendous strides in recent years as witnessed by the emergence of a variety of proprietary composites with extraordinary purported properties of strength and ductility, far in excess of values established for "ready mix" concrete. While it is beyond the scope of the present invention to address the merits of specific compositions, it is the recommendation of this inventor that every consideration be given to continuous improvements in the art of concrete preparation. Minor alterations in concrete formulations and admixtures with proprietary pozzolans, fly ash, silica fume, slag, wollastonite, steel and synthetic fibers, high range water reducers, crystallizers, artificial and specialty aggregates, etc., can have a profound affect on the material properties and by inference the presumed durability of concrete formulations.)

[0088] On each wall panel end a ductile panel end connector which is a boundary element plate that is fabricated of certified mill test steel plate and with slots in the end face are attached to the reinforcement assembly of Prestressing strand, welded wire and/or reinforcing bar. (In the preferred embodiment of this invention (shown in FIG. 1), a single continuous connector plate extends from the top to the bottom of the panels, however, in many cases it may be more economical to install two or more shorter connectors.) Any components such as threaded inserts, anchors, plates, sleeves, ductile connectors, pre-stressing connections and post-tensioning ducts and such other devices as may be necessary to fulfill the requirements of the code and as specified by the engineering documentation are placed into the mold with suitable means for precision placement of all components in relation to the dimensions of the panel and according to the drawings. Prestressing of the reinforcement is performed to the engineering specifications.

**[0089]** A second layer of fiber reinforced concrete, ECC, foamed concrete, or other cementitious material as specified in the engineering documentation is applied over the first layer and covering the reinforcement assembly to the prescribed thickness of the building shell, (typically a minimum of 1-1/4") or as specified in the engineering documentation. Threaded inserts for the attachment of hooks for lifting and moving the panels may be placed along the top of the panels if they are not already incorporated in the reinforcement assembly.

**[0090]** (Under most circumstances it is possible to install the entire reinforcement assembly as a single continuous assembly, which is the preferred embodiment of the present invention, and to apply the cementitious material more or less continuously; however nothing about the present invention precludes the subsequent installation of additional reinforcement, cementitious materials, or other components or assemblies when required.

**[0091]** Foam or other forming materials to shape the interior ribs and beams of the wall panel are inserted into the panel assembly and glued, clamped, and braced to secure its position within the mold.

**[0092]** A third layer of fiber reinforced concrete, ECC, foamed concrete, or other cementitious material as specified in the engineering documentation is applied over the second layer and covering the reinforcement assembly to the prescribed thickness of the wall panel, (typically a minimum of 3/4", for a typical minimum shell thickness of 2-3/4".)

**[0093]** The interior of the wall is typically molded by forming with polystyrene foam that remains attached to the wall panel. The forming creates "ribs" and "beams" that are designed to emulate conventional framing, (studs, plates, etc.) so that conventional wall board, moldings, etc. and fasteners can be attached in the customary way. An assembly of polystyrene foam blocks is placed into the mold and fastened or braced with suitable anchoring to maintain its position during the final casting procedure. The rib configuration reduces the weight of the wall, provides substantial strength while minimizing the surface area exposed to the interior for better thermal efficiency, provides an area for thermal insulation in the finished wall, and facilitates the wall panel conforming to the specified wall dimensions. Devices such as electrical boxes, cable clips, etc. which are ordinarily nailed in wood frame construction may have their nails replaced with appropriate screw type anchors and may be inserted into cut-outs of the polystyrene foam adjoining the ribbed portion of the form according to the plans.

**[0094]** A trowel is drawn between the forms or between the perimeters of door or window framed openings and the forms and any excess cementitious material is removed.

**[0095]** In this preferred embodiment, a modified 1-5/8" 25 gauge galvanized steel "hat channel" which has been riveted, welded, glued, or otherwise closed to form a triangular cross section is embedded into the concrete along the top, bottom, and along any other horizontal elements of the panel, (to replicate top and bottom plates, sub sills, headers, etc.), and along each rib or vertical element, (to replicate studs, trimmers, etc.), to facilitate the eventual attachment of the wall board and/or other interior wall materials.

**[0096]** In an alternative embodiment, an unmodified 1-5/8" 25 gauge galvanized steel "hat channel" which has been fitted with an insulation strip on its interior face is embedded into the concrete along the top, bottom, and along any other horizontal elements of the panel, (to replicate top and bottom

plates, sub sills, headers, etc.), and along each rib or vertical element, (to replicate studs, trimmers, etc.), to facilitate the eventual attachment of the wall board or other interior wall materials. This embodiment requires larger ribs and beam portions for embedment, and typically is somewhat more labor intensive.

**[0097]** Outside corner column molds are positioned with the corner down. Reinforcement according to the drawings, (including metallic or plastic ducts for the passage of post-tensioning cable), are placed within the mold and foam or other forming material is situated to create a cavity. The form is filled with a layer of fiber reinforced concrete, ECC, foamed concrete, or other cementitious material as specified in the engineering documentation is applied over the first layer of ECC and covering the reinforcement assembly to the prescribed thickness of the building shell, (typically a minimum of 1-1/4"). Threaded inserts for the attachment of hooks for lifting and moving the panels may be placed along the top of the panels if they are not already incorporated in the reinforcement assembly. The sides of the column fascia are now diagonal, to meet flush with the diagonal ends of the connected building panels to form the finished building corner assembly.

**[0098]** Center column molds are positioned with the panel face down. Reinforcement according to the drawings is placed upon the first layer of ECC within the mold. Diagonal ends partially enclose the mold cavity and it is therefore particularly important with this element to assure the proper consolidation of the ECC with vibration. The form is filled with a second layer of ECC, fiber reinforced concrete, foamed concrete, or other cementitious material as specified in the engineering documentation over the first layer of ECC and covering the reinforcement assembly to the prescribed thickness of the building shell, (typically a minimum of 1 1/4"). Threaded inserts for the attachment of hooks for lifting and moving the panels may be placed along the top of the panels if they are not already incorporated in the reinforcement assembly. The sides of the column fascia are now diagonal, to meet flush with the diagonal ends of the building panels.

**[0099]** (Center and corner Columns may be engineered to serve as supports for interior beams or interior walls as well as connections for exterior wall panels.)

**[0100]** Any excess concrete that may be extruded from between the edges of the hat channel is removed.

**[0101]** Rapid laminations of the wall assembly with appropriate admixtures in the ECC assure that no cold joints will form between the layers and that the wall will therefore behave as a unit.

**[0102]** Floor/ceiling diaphragms may be similarly prepared with ribs to emulate ceiling joists and embedded hat channel for attachment of wall board for the finished ceiling. (Threaded inserts may be substituted for the embedded hat channel when suspended ceilings are specified).

**[0103]** Each panel is allowed to cure (set) for a period of time and under such conditions as is described in the engineering documentation and according to the testing procedures provided in the code.

**[0104]** When the concrete has achieved its prescribed hardness, the panel may be removed from the mold assembly.

**[0105]** Additional structural elements such as beams, columns, diaphragms, moment frames, trusses, and any other pre-cast structural members are similarly prepared, with or without architectural decoration, as described in the building plans and engineering documentation.

[0106] Alternatively, conventional wood or steel framing, hollow-core or double -T floor panels, or modular or manufactured homes may be built above the pre-cast concrete panel structure.

[0107] The building components are assembled according to the plans and in the order specified in the architectural and engineering specifications, typically by crane. Brass plate dividers, with corresponding slots to the slots in the boundary element steel of the wall panel ends or the wall panel/center column connectors are placed between the faces of the end plates and attached with bolts forming a slotted bolt connector/friction slip surface Wall anchor/shear plate with post-tensioning brace plate is attached to cast-in-place anchors or to suitable building code approved wedge type or similar anchors in the end of wall openings adjoining wall connections. Any required site assembled reinforcement is attached or welded. Column panels are placed; grouted or caulked according plan specifications and post-tensioning cable or strand is threaded through the duct from wall panel to adjoining wall panel. The cable is tensioned to plan specifications, which secures the column panel securely to the wall panels in preparation for site casting. The post-tensioning cable provides a mechanism for self-righting of walls after minor seismic displacements as well as securing the intermediate or special concrete columns to the intermediate or special concrete shear walls. Vertical and horizontal post-tension cable may also be installed for additional reinforcement when specified in the engineering plans. Multiple floor assemblies may proceed directly after wall assembly of the previous floor. Column panels are installed after the upper wall anchor/shear plate with post-tensioning brace plate is attached with all-thread to the panel or other types of construction on the floor above. Column cavities with reinforcement as specified in the drawings is site cast by filling the column cavities with fiber reinforced concrete, ECC, or other cementitious material as specified in the engineering documentation. Site casting, grouting, and any other structural work is completed, each floor of the structure being completed in its turn, roofing, doors and windows, interior framing, electrical, mechanical, plumbing, insulation, and similar improvements are completed, wall board is installed, painting, flooring, cabinetry, and finishing work is completed. As work progresses all necessary regular and special inspections are requested and performed until final inspection of the finished building is completed and delivered for occupancy.

1. A connector for intermediate and special moment resisting precast concrete shear walls and moment frames; a steel connector plate which is a torsion/shear friction slip damping ductile slotted bolt connector; a connector for securing a first building structural member to a second building structural member comprising a back member, a center member attached to the back member and the front member, a front member attached to the center and to the end members; and an end member attached to the front member, a connector with each adjoining member disposed substantially orthogonally to one another; a connector wherein the end member contains at least one tension opening which is slotted to receive a tension bolt fastener; a connector with an "inside" portion which may be attached to the steel reinforcement assembly of the precast shear wall, a connector with an "outside" portion which adjoins to a column member of the wall system; a connector wherein the back member may contain at least one opening for the passage of tensioning cable; a connector

which is oriented diagonally to the plane of the wall at each end of a precast concrete wall panel.

2. The connector of claim 1 wherein the connecting means includes a plurality of steel studs for anchoring the plate to concrete.

3. The connector of claim 1 wherein the connecting means includes welded reinforcement bar.

4. The connector of claim 1 wherein the connecting means includes welded reinforcement wire.

5. The connector of claim 1 wherein the connecting means includes prestressing strand.

6. The connector of claim 1 wherein the end member is attached to both the front member and the back member with an opening in the back member for the insertion of a shear bolt, washers and nut.

7. A connector for attaching concrete shear panels of the present invention in planar fashion one to another; a steel connector plate which is a torsion/shear friction slip damping ductile slotted bolt connector; a connector comprising a left member attached to a right member, left member oriented orthogonally to the adjoining right member; a connector on which each member contains at least one tension opening which is slotted to receive a tension bolt fastener.

8. A connector for attaching concrete shear panels of the present invention in orthogonal fashion one to another, as for the inside corner of a building; a steel connector plate which is a torsion/shear friction slip damping ductile slotted bolt connector; a connector comprising a planar member; a connector on which the member contains at least two tension openings which are slotted to receive tension bolt fasteners.

9. A friction damping divider, which is a brass plate divider; which is a plate with at least one tension opening that is slotted for the passage of a tension bolt.

10. A 1-5/8" 25 gauge galvanized steel "hat channel" which has been partially filled on its interior side with a layer of foam insulation to prevent concrete from obstructing the passage of wallboard fasteners; a steel "hat channel" which is embedded into the concrete along the top, bottom, and along any other horizontal elements of the panel. (to replicate top and bottom plates, sub sills, headers, etc.), and along each rib or vertical element, (to replicate studs, trimmers, etc.), to facilitate the eventual attachment of the wall board or other interior wall materials.

11. A modified 1-5/8" 25 gauge galvanized steel "hat channel" which has been riveted, welded, glued, or otherwise closed to form a triangular cross section; a steel "hat channel" which is embedded into the concrete along the top, bottom, and along any other horizontal elements of the panel, (to replicate top and bottom plates, sub sills, headers, etc.), and along each rib or vertical element, (to replicate studs, trimmers, etc.), to facilitate the eventual attachment of the wall board or other interior wall materials.

12. A 25 gauge galvanized steel corner channel which forms a square cross section with arms that extend from a common corner diagonally and flush with one another and connect to 2 adjoining connectors of claim 7 as when attaching 2 panels in an inside corner assembly; a light gauge steel corner channel which is fabricated for the attachment of wall board or other approved wall coverings on the inside corner of a prefabricated concrete wall panel.

13. A wall anchor shear plate/post-tensioning brace plate for special moment resisting precast concrete shear walls and moment frames; a steel wall anchor shear plate/post-tensioning brace plate connector which is a post-tensioning cable

brace connector; a connector for securing a building structural panel member to a foundation comprising a back member attached to a bottom member and a top member, a bottom member attached to a back member and a front member, a front member attached to a bottom member and a top member, and a top member attached to a back member and a front member; a wall anchor shear plate/post-tensioning brace plate connector with each adjoining member disposed substantially orthogonally to one another; a wall anchor shear plate/post-tensioning brace plate connector wherein the bottom member contains two openings to receive anchor bolts; a wall anchor shear plate/post-tensioning brace plate with a top member with an opening for the passage of a post-tensioning cable; a wall anchor shear plate/post-tensioning brace plate with a top member that serves as a brace for a building code tested and approved post-tensioning cable anchor; a wall anchor shear plate which is post-tensioning cable brace oriented diagonally to the vertical plane of the wall within the wall cavity of a precast concrete wall panel; a wall anchor shear plate/post-tensioning brace plate with a front and a back member with openings for the insertion of a post-tensioning cable wedge.

**13.** A precast concrete wall panel with a method of making a wall panel for attachment to like wall panels for building a wall, the method comprising the steps of:

- (a) providing a mold for casting a concrete member (wall panel) having a generally planar portion including an inner surface and an outer surface, diagonally oriented planar end connectors, with engineered reinforcement, integral top and bottom beams, and a plurality of rib portions extending from the inner surface to the planar surface, (face of the wall), integral to beam portions along the top and bottom of each respective rib portion, with facility for casting openings for structural elements such as windows and doorways.
- (b) providing a mold for casting a concrete member (center column panel) having a generally planar portion including an inner surface and an outer surface, diagonally oriented planar ends, with a removable insert for creating an interior void for later casting in place, with engineered reinforcement, integral top and bottom beams, and embedded duct for the passage of tensioning strand.
- (c) providing a mold for casting a concrete member (outside corner column panel) having two generally planar portions oriented orthogonally, (two outer surfaces), diagonally oriented planar interior with a removable insert for creating an interior void for later casting in place, with engineered reinforcement, and embedded duct for the passage of tensioning strand.
- (d) Embedding connectors, reinforcement, ducts, and sleeves, electrical, mechanical, and plumbing connectors into the concrete body of the wall panel.
- (e) Embedding anchors, plates, and similar structural elements for the transport, movement, and assembly of the finished wall system.
- (f) Casting the concrete member in the mold with foam assemblies for forming rib and beam portions, the foam remaining in the wall portion to further serve as insulation in the finished wall assembly.

**14.** A method according to claims **1** and **6**, wherein a column panel of claim **13b** is attached to an 2 adjoining wall panels of claim **13a** to make a continuous planar wall to a building; said panels separated by a friction damping divider of claim **9**; said panels connected with a panel connector of

claim **7**, said panels bolted one to another with tension bolts, washers, and nuts; corner column panel of claim **13b** attached to the adjoining panels with tension strand; said corner column panel internal void cast in place with grout or concrete.

**15.** A method according to claims **1** and **6**, wherein a column panel of claim **13c** is attached to 2 adjoining wall panels of claim **13a** to make an outside corner to a building; said panels separated by a friction damping divider of claim **9**; said panels bolted one to another with tension bolts, washers, and nuts; corner column panel of claim **13c** secured to the adjoining panels with tension strand; said corner column panel interior void cast in place with grout or concrete.

**16.** A method according to claims **1** and **6**, wherein a wall panel is attached to an adjoining wall panel to make an inside corner of a building; said panels separated by a friction damping divider of claim **9**; said panels connected with two panel connectors of claim **7** and one panel connector of claim **8**, said panels bolted one to another with tension bolts, washers, and nuts.

**17.** A method according to claim **12**, wherein a wall panel of claim **13a** is attached to a foundation grade beam, pier, or similar foundation element with building code tested and approved anchor bolts and secured with a wall anchor shear plate/post-tensioning brace plate.

**18.** A method according to claim **12**, wherein wall panels of claim **13a** are attached one to another and to a column panel of claim **13b** or **13**, to form a wall panel connection assembly as in an outside corner, an inside corner, or continuous planar wall, with post-tensioning cable passing through cable duct from wall panel to column panel to wall panel, (or wall panel to wall panel for inside corners,) and anchored to the foundation with a wall anchor shear plate/post-tensioning brace plate by means of tension strand, which geometry thereby serves to restore to vertical the orientation of the walls in the event of a minor seismic event.

**19.** A looped duct tension anchor, which is a shaped metallic tubing or flexible metallic duct, for anchoring special moment resisting precast concrete shear walls and special concrete moment frames to foundations, piers, beams, diaphragms, and slabs, and for their attachment one to another. A looped duct tension anchor, which is an un-bonded post-tensioning cable duct; an anchor for securing a building structural panel member to a foundation comprising a tube which is shaped (typically with bending equaling 180 degrees) and embedded within a foundation or structural member to facilitate the passage of a tensioning strand, cable, or fiber. A looped duct tension anchor, which is a shaped metallic tubing or flexible metallic duct, which is embedded within a foundation or precast structural member.

**20.** A method according to claim **19**, whereby a looped duct tension anchor, which is a shaped metallic tubing or flexible metallic duct, for anchoring special moment resisting precast concrete shear walls and special concrete moment frames is precisely positioned within foundations, piers, beams, diaphragms, walls, columns, or slabs. The positioning and placement of a looped duct tension anchor, which is an un-bonded post-tensioning cable duct, such placement being precisely positioned to facilitate alignment with un-bonded post tensioning ducts embedded within adjoining wall, column, beam, diaphragm, or other structural elements, such alignment facilitating the passage of a tensioning strand, cable, or fiber after placement of the structural member is complete, as when after a wall or column panel of claim **13a**, **13b**, or **13c** is positioned upon a grade beam or slab, a tensioning strand may

be passed from the top of the wall or column, (through the embedded duct in the wall or column) thence through the looped tension anchor of claim **19**, (embedded in the foundation) thence returning through the wall or column, (through another tension duct) to the top of the wall or column whereby tensioning as required is applied to the strand, cable, or fiber which is then secured by a wedge anchor or similar approved

device. Similarly, precisely placed looped duct tension anchors embedded within the top of walls or columns facilitates the vertical attachment of wall or column panel's one to another for multiple story applications.

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