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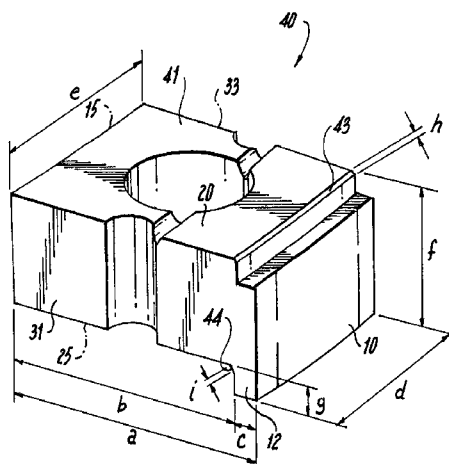


Fig. 3

(57) Abstract: A convex structural block which mates to other structural block to form a parabolic wall. The block is formed of geo-polymer to have a smaller carbon footprint and be lighter to facilitate material handling.

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CONVEX STRUCTURAL BLOCK FOR CONSTRUCTING PARABOLIC WALLS**CROSS REFERENCE TO RELATED APPLICATIONS**

[0001] The present application relates to US Provisional Patent Application 61/684,176 filed August 17, 2012. The Applicant hereby incorporates the aforementioned US Provisional Patent Applications as if fully set forth herein.

FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[0002] Not Applicable.

TECHNICAL FIELD

[0003] Disclosed is a structural block designed for the construction of safe rooms, ventilation control structures, retaining walls, seals, and stoppings. The block is preferably composed of cement or an environmentally friendly, lightweight cementitious material.

DEFINITIONS

[0004] The following definitions are intended to clarify the terminology used herein.

[0005] Cementitious: having the properties of cement; e.g. a building material which may be mixed with a liquid, such as water, to form a paste which may be pumped or poured into a mold or other cavity, and then cured to form a solid.

[0006] Drivage: A general term for a roadway, heading, or tunnel in course of construction. It may be horizontal or inclined but not vertical.

[0007] Geopolymer: an inorganic polymeric material comprised of chains or networks of mineral molecules linked with covalent bonds.

[0008] Mains (i.e. Main Roadways): Major travel-way of a mine. Starting at the portal and usually continuing to the farthest extent of the mine.

[0009] Overcast: A structure that channels intake and return air courses through a main roadway intersection.

[0010] Rib: The side of a pillar or the wall of an entry, e.g. the solid coal on the side of any underground passage.

[0011] Roadway: An underground drivage. It may be a heading, gate, stall, crosscut, level, or tunnel and driven in coal, ore, rock or in the waste area. It may form part of longwall or board-and-pillar workings or an exploration heading. A roadway is not steeply inclined.

[0012] Roof: The ceiling of a roadway.

[0013] Seals: A permanent solid wall built across a mine roadway or shaft.

[0014] Stopping: A temporary solid wall built across a mine roadway or shaft. A stopping is typically constructed to channel fresh air (intake air) to working areas and channel contaminated air (return air) away from the working area as in the construction of a ventilation control device.

BACKGROUND

[0015] Underground mines must be properly ventilated so as to provide a substantially continuous flow of fresh air of sufficient volume to dilute and remove dangerous particulates like rock and coal dust and toxic gases such as CH₄, CO, CO₂, NO_x, and SO₂. These gases are created by the combustion of fuel by engines used underground in various applications and from blasting with explosives. Toxic gases can also be released from the strata itself. Methane, CH₄, is of particular interest in coal mining since the gas is often found alongside coal deposits and because accumulations of this gas are odorless and can result in underground explosions.

[0016] Ventilation also plays an important role in the spontaneous heating of coal in an underground coal mine. If the ventilation rate is too high, heat is

carried away by convection. If the ventilation rate is too low, the reaction rate becomes oxygen-limited. It has been found that there is an optimum ventilation flow to produce the maximum rate of temperature rise at the critical ambient temperature. Ventilation controls that are well constructed will reduce air contamination, power and fan maintenance costs.

[0017] The basic principle underlying mine ventilation is that air always moves from high pressure regions to low pressure regions. Therefore, in order to get the air to flow from the intake to the exhaust, the exhaust air must be at a lower pressure than the intake. As fresh air is pulled into the mine, contaminated air must be drawn out. The fresh air and contaminated air streams must be segregated to prevent contamination of the fresh air entering the mine and to ensure that fresh air is maintained at a higher pressure than the pressure at the entrance of the exhaust system where contaminated air and fresh air commingle.

[0018] If shafts are used as the two main airways, the intake airway is called the downcast shaft, and the exhaust airway is referred to as the upcast shaft. Sometimes one shaft can be split to provide both an intake and exhaust airway. If this pressure difference exists naturally between the two airways, then the mine has natural ventilation. Natural ventilation is one of the two methods of ventilating a mine. The other method is mechanical ventilation where fans are used to create the pressure differential.

[0019] Stoppings are used to prevent contamination of intake air with return air and to direct air to where it is needed so as to keep intake air from short-circuiting to the exhaust before it reaches the working area. Seals are also used to contain water or liquid-like mine wastes (tailings or slurry). Failure of a seal or stopping could result in a disastrous inundation of an underground mine or expose miners to unacceptable risks through the contamination of fresh air with toxic gases.

[0020] Seals are typically built of concrete blocks, sand fill, or other incombustible material. They are sealed tightly against the floor and ribs (i.e. sides) of a mine roadway so that no air can leak through. Porous stoppings such as concrete block stoppings are usually plastered with a cementitious coating on the high-pressure side to reduce air leakage.

[0021] Sometimes stoppings have a door, e.g. air-lock, in them to allow miners to pass through. Man doors are not meant to be ventilation controls, but if a man door is propped open it can affect airflow and may cause intake air to short circuit into the return air.

[0022] Because intake and return air frequently cross paths at intersections within the mine, overcasts and undercasts are used to permit the two air currents to cross without the intake air short-circuiting into the exhaust. Overcasts are like enclosed bridges built above the normal back level of the mine. Undercasts are like tunnels built below the normal floor of the mine. Undercasts are seldom used in a mine because they are apt to fill with water or debris which would severely slow down the flow of air through them. Overcasts are used more often and are typically constructed with planar concrete block walls sealed against the ribs and floor, and with some type of airtight roof made of pre-stressed concrete, railroad ties, metal sheeting or steel beams. Steel and other metals can sometimes be difficult to use underground due to fumes caused from welding causing air contamination.

[0023] In areas of heavy traffic, such as along long haulage roads, mine doors are usually hung in pairs while being used as ventilation controls. They are used to completely close off a mine passage yet open to allow equipment and people to pass through. Mine doors are generally used to keep air from flowing to areas where it is not needed. Mine doors can also be used to isolate separate splits of air. Mine doors are usually hung in pairs, forming an air lock that prevents unnecessary air flow when one of the pairs is opened. The doors should always be opened and closed one at a time in order to maintain the air

lock. Mine doors are always hung so that the ventilating air pressure will push them closed if they are accidentally left open. However, the doors should always be closed after you pass through them. Some doors must be closed manually while others can be closed automatically.

[0024] Some mines also use fire doors to control airflow in the event of fire. They are usually built at shaft stations and other strategic locations so that if there is a fire they can be closed to serve as a barrier to the fire and contaminated air. In some mines the fire doors will close automatically when the carbon monoxide in the area reaches a certain level. Some mines will also have rollup doors in shop areas which close automatically when a mine fire warning is given.

[0025] When ventilation controls such as seals, stoppings, overcasts, and undercasts are installed in underground mines, they are required to meet the safety standards specified in 30 CFR 75.333. This safety standard requires that ventilation which includes overcasts, undercasts, shaft partitions, seals, stoppings, and regulators be constructed of noncombustible material. Noncombustible material is defined in 30 CFR 75.301 as a material which when used to construct a ventilation control results in a control that will continue to serve its intended function for one hour when subjected to a fire test incorporating an American Society for Testing and Materials, International, ASTM E-119-88 temperature/time heat input, or equivalent. Additionally, the ventilation control must meet a flexural strength that is equal to or greater than a conventional 20 cm hollow core concrete block stopping. The 20 cm hollow core concrete block with mortared joints has been tested and shown to have a minimum strength of 190 kg/m². ASTM E-72-80 is used to determine the flexural strength. Also, sealants or coatings applied to ventilation controls to reduce air leakage must have a flame spread index of 25 or less. The flame spread index test specified in 30 CFR 75.333 is detailed in ASTM E-162-87. The aforementioned codes, regulations, and specifications are intended to serve as

examples only with it being understood that other codes, regulations, and specifications can apply depending on the application and the jurisdiction.

[0026] The basis for the safety standard of fire endurance and flexural strength relates to concrete block. Concrete block has long been the material of choice for the construction of stoppings and seals. However, the construction of a concrete block stopping is labor intensive and time consuming. Concrete blocks are heavy, a typical 20 cm wide by 20 cm high by 41 cm long hollow concrete block has an average mass of approximately 18 kg, and injuries from carrying and lifting the blocks often result. Developments in material science have resulted in newer, lighter cementitious materials to replace the use of concrete block, particularly for the construction of retaining walls, stoppings, and seals.

SUMMARY

[0027] Provided is a convex, front-to-rear tapered building block formed of a cementitious material, e.g. geopolymer, or cement. The block is preferably pre-cast, but may be cast on-site as needed. The block is primarily intended for use in the construction of mine stoppings or seals by stacking a plurality of blocks in ascending layers between the walls of a mine shaft. The blocks, when assembled, form a parabolic, i.e. arcuate, wall which possesses superior compressive strength against shock waves from explosions as compared to a traditional flat wall, i.e. substantially non-parabolic wall.

[0028] The block may be formed with annular or semi-annular, e.g. semicircular, cylindrical cavities so as to create annular cylindrical channels through blocks stacked within the assembled wall. The channels can include smaller radius pathways through which linear reinforcements may be installed and larger pathways through which larger reinforcements can pass. The annular and semi-annular cavities are also useful to reduce the mass of each block, thus yield more efficient material handling when compared to solid blocks. The

annular cavities also add to strength through the formation of internal arch structures. The cylindrical pathways can be filled with a cementitious material for reinforcement so as to create a more permanent structure or “dry stacked” to create a temporary structure which can be subsequently deconstructed and moved for reassembly elsewhere.

BRIEF DESCRIPTION OF THE DRAWINGS

[0029] Fig. 1 depicts a parabolic wall constructed from the subject structural block.

[0030] Fig. 2 depicts a partial cutaway view of a block assembly with vertical and lateral supports.

[0031] Fig. 3 depicts a perspective view of a foundation-block embodiment of the subject structural block.

[0032] Fig. 4 depicts a plan view of the top face of one embodiment of the subject structural block.

[0033] Fig. 5 depicts a perspective view of one embodiment of the subject structural block utilizing left and right mated blocks.

[0034] Fig. 6 depicts a plan view of the top surface of the structural blocks of Fig. 5.

[0035] Fig. 7 depicts a perspective view of one embodiment of the subject structural block utilizing left and right mated blocks.

[0036] Fig. 8 depicts a plan view of the top surface of the structural blocks of Fig. 7.

[0037] Fig. 9 depicts an exploded perspective view of the wall assembly of the structural blocks of Fig. 3.

[0038] Fig. 10 depicts an exploded perspective view of the wall assembly of the structural blocks of Fig. 5.

[0039] Fig. 11 depicts an exploded perspective view of the wall assembly of the structural blocks of Fig. 7.

[0040] Fig. 12 depicts a cross-sectional view of a wall assembly of the subject structural block.

[0041] Fig. 13 depicts the subject structural block assembled as a parabolic wall with ends embedded in the ribs of a mine shaft.

[0042] Fig. 14 depicts a plan view of the subject structural block assembled as a parabolic wall with ends embedded in the ribs of a mine shaft and refocusing the energy from a shock wave.

[0043] Fig. 15 depicts a perspective view of the subject structural block assembled as a parabolic wall as part of a ventilation control device with an air-lock.

[0044] Fig. 16 depicts a plan view of a safe room and air-lock as part of a ventilation control device in a mine shaft.

DETAILED DESCRIPTION

[0045] Provided is a convex, front-to-rear tapered structural block **100** formed of a geopolymer or similar cementitious material or cement. The block **100** is preferably pre-cast, but may be cast on-site as needed. When properly assembled, the convex blocks **100** form a parabolic wall **80**. The length of a parabolic wall **80** constructed from the block **100** is related to its arc radius and thus the angle measure on the anterior face **10** and the posterior face **15** of the block **100**.

[0046] A structural block **100** embodiment, as shown in FIGS. 1-16, is stackable so as to mate or interlock with other blocks **100** to reinforce any structure assembled therefrom. In one embodiment, the block **100** of the present innovation is made available as a foundation-block **50**, see FIG. 3, and a wall-block **40**, see FIG. 2. As depicted in FIGS. 1-2 and 9-12, the wall-blocks **40** are preferably stacked in vertically ascending horizontal layers atop a bottom layer of foundation-blocks **60** or alternatively wall-blocks **40** and stacked in subsequent horizontal rows on top of each other until the head-blocks **65**, i.e. roof-blocks **65**, can be utilized in the last row abutting the roof **72**.

[0047] Each wall-block **40** possesses a key **12**, e.g. a lip **12**, extending down from the bottom face **25** of the block **100** from the anterior face **10** back towards the posterior face **15**, preferably at the bottom of the substantially planar anterior face **10** which extends downward in a substantially planar continuation of the face, extending part-way along the substantially planar bottom face **25** toward the posterior face **15** of the block **100**. The block **100** further possesses a keyway **14**, or seat **14**, to receive the key **12**. The keyway **14** is preferably a groove along the joint where the anterior face **10** of the wall-block **40** and the top face **20** of the wall-block **40** meet and is configured to receive the key **12** from the bottom face **25** or base **25** of a block **100** stacked upon the top face **20** of a lower block **100** so as to form a mechanical mating and/or friction fit arrangement.

[0048] The mating of the key **12** and keyway **14** ensures correct alignment of each block **100** and the integrity of the completed wall **80**. The key-to-keyway mating also aids in the transfer of the load between layered blocks **100**. In one embodiment, the wall-block **40** preferably possesses at least one central aperture **45** running from the top face **20** to the bottom face **25**. One purpose of the central aperture **45** is mass reduction. An additional purpose of the central aperture **45** is to provide a pathway through which a vertical support **33** may pass. Yet another purpose of the central aperture **45** is to provide a passageway which terminates at the floor **74** for introducing a cementitious filling into the wall

80 for reinforcement. The central aperture **45** vertically aligns with a vertical support aperture **37** in the block **100** above and the block **100** below in a staggered block configuration. In a still further embodiment, the blocks **100** possess vertical groove **35** on the each lateral face **30** which are configured to mate with other vertical grooves **35** when stacked next to each other so as to form annular, cylindrical vertical support apertures **37** which extend vertically between the blocks **100**. As depicted in FIGS. 2 and 9-12, the vertical support apertures **37** formed by the vertical groove **35** can be utilized for the installation of vertical supports **35** therein. The vertical supports **35** are preferably fabricated from steel.

[0049] A lateral groove **22** runs across the top face **20** of the block **100** at roughly the same arc radius as the vertical groove **35** and central aperture **45** and with no greater than the same arc angle measure as the anterior face **10** of the block **100** and no less than the arc angle measure of the posterior face **15**. In a preferred embodiment, the width of the lateral groove **22** is approximately 1.5 inches (3.8 cm) and is semi-annular in geometry so as to receive an arc shaped lateral support **24** along the length of the wall **80**. In a preferred embodiment, the lateral supports **24** may be mechanically affixed to the vertical supports **33** by tying with wire or clamping. In some applications, the lateral supports **24** can be welded to the vertical supports **33**.

[0050] As an example, the dimensions of a wall-block **50** embodiment as depicted in FIG. 7, are (a) a length of 16 inches (40.64 cm) along the left lateral face **31** and the right lateral face **33** including the wall-block body **51** and key **12**, (b) a length of 14.5 inches (36.83 cm) along the along the left lateral face **31** and the right lateral face **32** including the wall-block body **51** but excluding the key **12**, (c) a length of 1.5 inches (3.81 cm) along the left side face and the right side face excluding the wall-block body **51** but including the key **12**, 1.5 inches (3.81 cm), (d) an arc length of 8.35 inches (21.21 cm) along the anterior face **10**, an arc length of 7.3 inches (18.54 cm) along the posterior face **15**, (e) an arc angle of

approximately 2°, (f) a height of 5 inches (12.7 cm) along the wall-block body **51**, (g) a 5 inch (12.7 cm) tall key **12** extending 1.5 inches (3.81 cm) anteriorly from the anterior end of the wall-block body **51** and vertically offset down the anterior face **10** of the half-wall-block body **51** approximately 1.25 inches (3.18 cm), (h) a 0.25 inch x 0.25 inch (6.35 mm x 6.35 mm) top chamfer **43** in the top anterior edge of the wall-block body **41**, and (i) a 0.25 inch x 0.25 inch (6.35 mm x 6.35 mm) bottom chamfer **44** in the posterior bottom edge of the key **12**. When one wall-block **50** is placed above another wall-block **50**, the bottom chamfers **44** of the top wall-block **50** mates with the bottom chamfer **44** of the bottom block **50**. Ideally the blocks **100** are stacked so as to offset their vertical seams **48**, thus a wall-block **50** will engage two wall-blocks **50** on its top face **20** and two wall-blocks **50** on its bottom face **25**.

[0051] The aforementioned wall-block **50** embodiment is preferably comprised of two versions, a left-wall-block **55** and a right-wall-block **57**. Each wall-block **50** possesses the same keyway **14**, i.e. seating groove **14**, and key **12** and the same arc angle measure across its anterior face **10**. In a preferred embodiment, the left-wall-block and right-wall-block are substantially half large-wall-blocks **40** which allow the user to adjust the length of the assembled wall without blocking the central apertures **45** and vertical support apertures **37** so as to interfere with the use of vertical supports **33** to reinforce the wall **80**.

[0052] As an example, the dimensions of a large-wall-block **40** embodiment, as depicted in FIG. 9, for use with an 18 ft (5.5 m) wide roadway are (a) a length of 16 inches (40.64 cm) along the left lateral face **31** and the right lateral face **32** including the large-wall-block body **41** and key **12**, (b) a length of 14.5 inches (36.83 cm) along the along the left side face and the right side face including the large-wall-block body **41** but excluding the key **12**, (c) a length of 1.5 inches (3.81 cm) along the left lateral face **31** and the right lateral face **32** excluding the large-wall-block body **41** but including the key **12**, 1.5 inches (3.81 cm), (d) an arc length of 16.7 inches (42.42 cm) along the anterior face **10**, an arc length of 14.6

inches (37.08 cm) along the anterior face, (e) an arc angle of approximately 4°, (f) a height of 5 inches (12.7 cm) along the large-wall-block body **41**, (g) a 5 inch (12.7 cm) tall key **12** extending 1.5 inches (3.81 cm) anteriorly from the anterior end of the large-wall-block body **41** and vertically offset down the anterior face **10** of the large-wall-block body **41** approximately 1.25 inches (3.18 cm), (h) a 0.25 inch x 0.25 inch (6.35 mm x 6.35 mm) top chamfer **43** in the top anterior edge of the large-wall-block **40**, and (i) a 0.25 inch x 0.25 inch (6.35 mm x 6.35 mm) bottom chamfer **44** in the posterior bottom edge of the key **12**. When one wall-block **40** is placed above another large-wall-block **40**, the bottom chamfers **44** of the top large-wall-block **40** mates with the bottom chamfer **44** of the bottom large-wall-block **40**. Ideally the large-wall-blocks **40** are stacked so as to offset their vertical seams **48**, thus a large-wall-block **40** will engage two large-wall-blocks **40** on its top face **25** and two large-wall-blocks **40** on its bottom face **25**.

[0053] As depicted in FIG. 3, a foundation-block **60**, i.e. starter block, is substantially identical to a wall-block **50** or large-wall-block **40** without the key **12** for seating. A further embodiment utilizes a head-block **65**, i.e. roof-block **65**, which possesses a key **12** formulated or cured to possess a lower compressive strength relative to the wall-block **50** to allow for settling of a mine roof **72**.

[0054] As depicted in FIGS. 13-16, an underground mine seal or stopping may be by stacking layers of wall-block **40** atop the foundation-block **60**. A cementitious product either identical or similar to the cementitious material from which the blocks **100** are fabricated may be used as a mortar, a coating, and/or a filler. The blocks **100** are mated by key **12** to keyway **14** and form a parabolic wall **80** across a roadway **70**. The ends of the wall **80** terminate in excavated restraining pockets **93** within the ribs **76** so as to redirect and disperse some of the force from a blast wave along the arc of the wall **80** and into the ribs **76**. A parabolic wall **80** is better suited than a flat-faced wall, i.e. a wall whose face is substantially an un-curved planar wall, for withstanding the forces of shock wave from a blast as measured by ASTM E72-80 - Section 12, "transverse loading of a

vertical specimen.” A parabolic wall absorbs some of the shock wave from a blast but redirects the remainder along the arc length of the parabolic wall **80** and into the ribs **76** of a mine shaft. Ideally, a cementitious coating for sealing covers the surface of the parabolic wall **80** and its joints along the mine shaft walls **76**, i.e. ribs **76**, floor **74**, and roof **72**.

[0055] The blocks **100** may be utilized to create walls **80** for safe rooms, ventilation control devices, dams, and similar underground structures which require sealing. Such walls **80** can also be utilized to create air- to allow miners to pass from areas of high pressure to areas of low pressure without short-circuiting air flow. Additional uses include the construction of walls, e.g. retaining walls, and other walled civil engineering projects in loose soil. When cast from geopolymers, these blocks **100** have the added advantage of being faster to assemble than traditional concrete blocks due to reduced mass, and result in improved workplace ergonomics and safety.

[0056] One such useful cementitious material is HySSIL™, a geopolymer available from HySSIL PTY LTD. Geopolymers are chains or networks of mineral molecules linked with co-valent bonds. Hardened geopolymers are x-ray amorphous at ambient and medium temperatures and x-ray crystalline at temperatures >500°C. They are created in an alkaline medium, e.g. (Na, K, Ca) hydroxides and alkali-silicates yielding poly(silicates)-poly(siloxo) types of geopolymers or poly(silico-aluminates)-poly(sialate) types of geopolymers, or in an acidic medium, e.g. Phosphoric acid yielding poly(phospho-siloxo) and poly(alumino-phospho) types of geopolymers. As an example, one of the geopolymeric precursors, MK-750 (metakaolin) with its alumoxyl group –Si-O-Al=O, reacts in both systems, alkaline and acidic. Siloxo-based and organo-siloxo-based geopolymeric species also react in both alkaline and acidic medium.

[0057] Geopolymer terminology is based on different chemical units, essentially for silicate and aluminosilicate materials, classified according to the Si:Al atomic ratio:

Si:Al = 0, siloxo

Si:Al = 1, sialate (acronym for silicon-oxo-aluminate of Na, K, Ca, Li)

Si:Al = 2, sialate-siloxo

Si:Al = 3, sialate-disiloxo

Si:Al > 3, sialate link.

See *IUPAC Symposium on Long-Term Properties of Polymers and Polymeric Materials*, Stockholm 1976, Topic III: Joseph Davidovits, Solid-Phase Synthesis of a Mineral Blockpolymer by Low Temperature Polycondensation of Alumino-Silicate Polymers.

[0058] Silicates and their crystal structures were originally classified based on the concept of the ionic theory by L. Pauling. The fundamental unit is a tetrahedral complex consisting of a small cation such as Si^{4+} , or Al^{3+} in tetrahedral coordination with four oxygens. The structures involved with geopolymerization are in fact siloxonate/sialate covalent constructs, not ionic. Geo-chemical syntheses are carried out through oligomers (dimer, trimer, tetramer, pentamer) which provide the actual unit structures of the three dimensional macromolecular edifice.

[0059] Geopolymers are generally comprised of the following molecular units (i.e. chemical groups):

- -Si-O-Si-O- siloxo, poly(siloxo)
- -Si-O-Al-O- sialate, poly(sialate)
- -Si-O-Al-O-Si-O- sialate-siloxo, poly(sialate-siloxo)
- -Si-O-Al-O-Si-O-Si-O- sialate-disiloxo, poly(sialate-disiloxo)

- -P-O-P-O- phosphate, poly(phosphate)
- -P-O-Si-O-P-O- phospho-siloxo, poly(phospho-siloxo)
- -P-O-Si-O-Al-O-P-O- phospho-sialate, poly(phospho-sialate)
- -(R)-Si-O-Si-O-(R) organo-siloxo, poly-silicone
- -Al-O-P-O- alumino-phospho, poly(alumino-phospho)
- -Fe-O-Si-O-Al-O-Si-O- ferro-sialate, poly(ferro-sialate).

[0060] Generally, geopolymers are developed and applied in 10 main classes of materials:

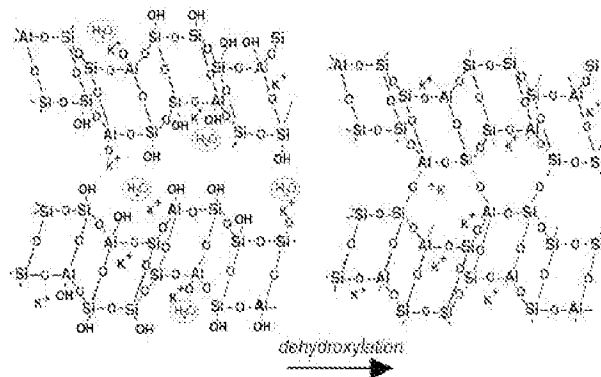
- Waterglass-based geopolymer, poly(siloxonate), soluble silicate, Si:Al=1:0
- Kaolinite / Hydrosodalite-based geopolymer, poly(sialate) Si:Al=1:1
- Metakaolin MK-750-based geopolymer, poly(sialate-siloxo) Si:Al=2:1
- Calcium-based geopolymer, (Ca, K, Na)-sialate, Si:Al=1, 2, 3
- Rock-based geopolymer, poly(sialate-multisiloxo) $1 < \text{Si:Al} < 5$
- Silica-based geopolymer, sialate link and siloxo link in poly(siloxonate) Si:Al>5
- Fly ash-based geopolymer
- Ferro-sialate-based geopolymer
- Phosphate-based geopolymer, AlPO₄-based geopolymer
- Organic-mineral geopolymer.

[0061] As an example: geopolymerization with metakaolin MK-750 involves three phases:

1. Alkaline depolymerization of the poly(siloxo) layer of kaolinite.
2. Formation of the ortho-sialate (OH)₃-Si-O-Al-(OH)₃ molecule.

3. polymerization (polycondensation) into higher oligomers and polymers.

The geopolymerization kinetics for Na-poly(sialate-siloxo) and K-poly(sialate-siloxo) are slightly different. This is probably due to the different dimensions of the Na^+ and K^+ cations, K^+ being bigger than Na^+ . Polycondensation into a Na-poly(sialate-disiloxo) albite framework results in the more crystalline structure as shown below.



[0062] The geopolymer block **100** of a preferred embodiment has a density of approximately half that of concrete, but with similar durability and higher strength. The lower mass product possesses less embodied energy in its creation, requires less energy to transport than similar ordinary Portland cement concrete blocks, thus generating a cost savings in fuel and a benefit to the environment. The use of recycled fly ash in the preferred geopolymer results in a reduction of CO_2 emissions of approximately 60% and a block cast therefrom embodies approximately 60% less energy in its manufacture than a similar concrete block. The geopolymer block possesses a higher resistance to fire and chemicals as well as greater flexural and compressive strength. The geopolymer may be formulated and/or cured to possess a reduced compressive strength for use with the wall-block **40** laid at the top of the wall **80**, i.e. head-block **65**, in contact with the roof **72** to allow for some roof **72** convergence along the top layer.

[0063] A geopolymer formed block **100** has the advantage of being a “green” product whose environmental benefits result in a lower carbon footprint and can

result in carbon credits for greenhouse gas mitigation which can then be used for expanded growth or sold in the carbon credit market.

What is claimed is:

1. A structural block system for constructing arcuate walls comprising:
a wall-block comprising:
 - a. a wall-block body cast from a cementitious product, said block body having height, a convex anterior face forming a minor arc and having a convex anterior face angle measure, an convex posterior face forming a minor arc having an convex posterior face angle measure no greater than said convex anterior face angle measure, a length from said convex anterior face to said convex posterior face, a top face, a bottom face, a height from said top face to said bottom face, a right lateral face, a left lateral face, and a width from said first lateral face to said second lateral face wherein said width decreases from said anterior face to said posterior face;
 - b. at least one vertical support groove in said first lateral face of said wall-block body and at least one vertical support groove in said second lateral face of said block body, configured to form a vertical support aperture along a lateral face joint between two said structural blocks laid side-by-side wherein said vertical support grooves lie at the same arc radius across said width of said wall-block body; and
 - c. means to mechanically mate a plurality of said wall-block bodies together in a friction fit arrangement comprising at least one male connector and at least one female receiver configured to receive said male connector.
2. The structural block system of claim 1, further comprising a mated left-wall-block and right-wall-block configured with different arc lengths across said anterior faces and said posterior faces so as to horizontally offset the lateral face joint seam anteriorly to said vertical support aperture formed between

two said structural blocks relative to said lateral face joint seam formed posteriorly to said vertical support aperture.

3. The structural block system of claim 1, wherein an arcuate lateral groove extends across said top face of said width of said wall-block, wherein said arcuate lateral channel possesses the same angle measure as the anterior face and passes across said vertical grooves in said lateral faces.
4. The structural block of claim 1, wherein said means to mechanically mate comprises an arcuate key and an arcuate keyway.
5. The structural block of claim 4, wherein said key and keyway are arranged across said anterior face of said wall-block body.
6. The structural block system of claim 1, further comprising a large wall-block comprising:
 - a. a large-wall-block body cast from a cementitious product, said large-wall-block body having height, a convex anterior face forming a minor arc and having a convex anterior face angle measure, an convex posterior face forming a minor arc having an convex posterior face angle measure no greater than said convex anterior face angle measure, a length from said convex anterior face to said convex posterior face, a top face, a bottom face, a height from said top face to said bottom face, a first lateral face, a second lateral face, a width from said first lateral face to said second lateral face wherein said width is substantially twice the width of said wall-block and decreases from said anterior face to said posterior face;
 - b. at least one vertical support groove in said first lateral face of said large-wall-block body and at least one vertical support groove in said second lateral face of said block body, configured to form a vertical aperture along a lateral face joint between two said structural blocks laid side-by-side

- wherein said vertical support grooves lie at the same arc radius across said width of said wall-block body; and
- c. means to mechanically mate a plurality of said large-wall-block bodies together in a friction fit arrangement comprising at least one male connector and at least one female receiver configured to receive said male connector;
 - d. a central aperture from said top face through said bottom face which lies along the same arc radius as said vertical grooves in said lateral faces.
7. The structural block system of claim 1, further comprising a roof-block having less compressive strength, wherein said roof block is laid between a top layer of said wall-blocks assembled as a wall and a mine roof in an underground wall assembly.
 8. The structural block of claim 1, wherein said wall-block is comprised at least in part of a cementitious material.
 9. The structural block of claim 8, wherein said cementitious material is selected from the group consisting of cements and geopolymers.
 10. The structural block of claim 9, further comprising an aggregate.
 11. A structural block system for constructing arcuate walls comprising:
a wall-block formed of a geopolymer comprising:
 - a. a wall-block body cast from a cementitious product, said block body having height, a convex anterior face forming a minor arc and having a convex anterior face angle measure, a convex posterior face forming a minor arc having a convex posterior face angle measure no greater than said convex anterior face angle measure, a length from said convex anterior face to said convex posterior face, a top face, a bottom face, a

- height from said top face to said bottom face, a first lateral face, a second lateral face, a width from said first lateral face to said second lateral face wherein said width decreases from said anterior face to said posterior face;
- b. at least one vertical support groove in said first lateral face of said wall-block body and at least one vertical support groove in said second lateral face of said block body, configured to form a vertical aperture along a lateral face joint between two said structural blocks laid side-by-side wherein said vertical support grooves lie at the same arc radius across said width of said wall-block body; and
 - c. means to mechanically mate a plurality of said wall-block bodies together in a friction fit arrangement comprising at least one male connector and at least one female receiver configured to receive said male connector.
12. The structural block system of claim 11, further comprising a mated left-wall-block and right-wall-block configured with different arc lengths across said anterior faces and said posterior faces so as to horizontally offset the lateral face joint seam anteriorly to said vertical support aperture formed between two said structural blocks relative to said lateral face joint seam formed posteriorly to said vertical support aperture.
13. The structural block system of claim 11, wherein an arcuate lateral groove extends across said top face of said width of said wall-block, wherein said arcuate lateral channel possesses the same angle measure as the anterior face and passes across said vertical grooves in said lateral faces.
14. The structural block of claim 11, wherein said means to mechanically mate comprises an arcuate key and an arcuate keyway.
15. The structural block of claim 14, wherein said key and keyway are arranged across said anterior face of said wall-block body.

16. The structural block system of claim 11, further comprising a large wall-block comprising:
- a. a large-wall-block body cast from a cementitious product, said large-wall-block body having height, a convex anterior face forming a minor arc and having a convex anterior face angle measure, a convex posterior face forming a minor arc having a convex posterior face angle measure no greater than said convex anterior face angle measure, a length from said convex anterior face to said convex posterior face, a top face, a bottom face, a height from said top face to said bottom face, a first lateral face, a second lateral face, a width from said first lateral face to said second lateral face wherein said width is substantially twice the width of said wall-block and decreases from said anterior face to said posterior face;
 - b. at least one vertical support groove in said first lateral face of said large-wall-block body and at least one vertical support groove in said second lateral face of said block body, configured to form a vertical aperture along a lateral face joint between two said structural blocks laid side-by-side wherein said vertical support grooves lie at the same arc radius across said width of said wall-block body; and
 - c. means to mechanically mate a plurality of said large-wall-block bodies together in a friction fit arrangement comprising at least one male connector and at least one female receiver configured to receive said male connector;
 - d. a central aperture from said top face through said bottom face which lies along the same arc radius as said vertical grooves in said lateral faces.
17. The structural block system of claim 11, further comprising a roof-block having less compressive strength, wherein said roof block is laid between a top layer of said wall-blocks assembled as a wall and a mine roof in an underground wall assembly.

18. The structural block of claim 1, wherein said geopolymer has a smaller carbon footprint than cement.
19. The structural block of claim 18, further comprising an aggregate.
20. The structural block of claim 19, wherein said aggregate is glass.

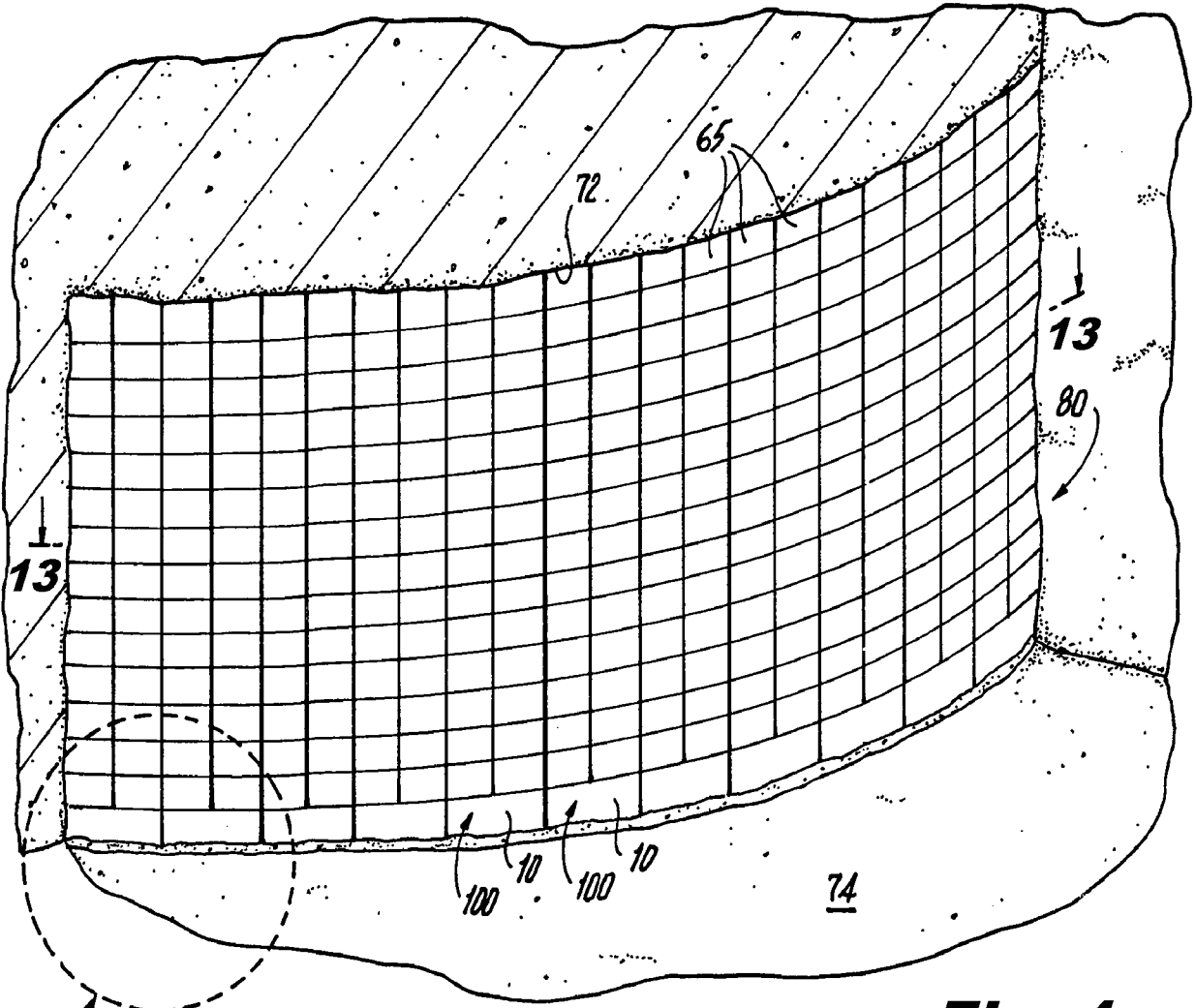


Fig. 1

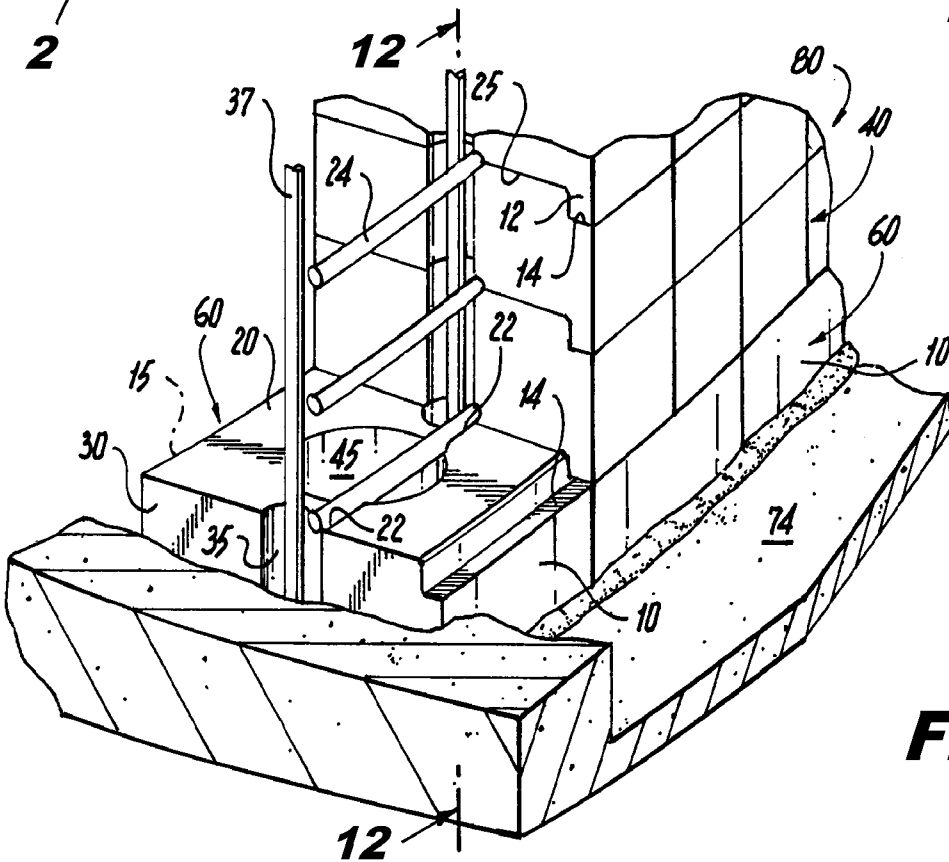


Fig. 2

Fig. 3

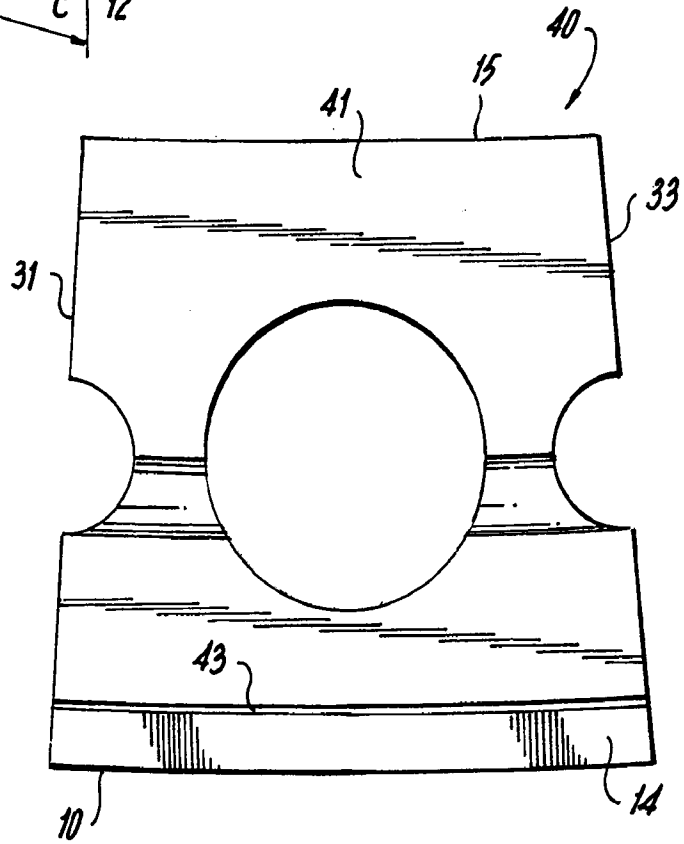
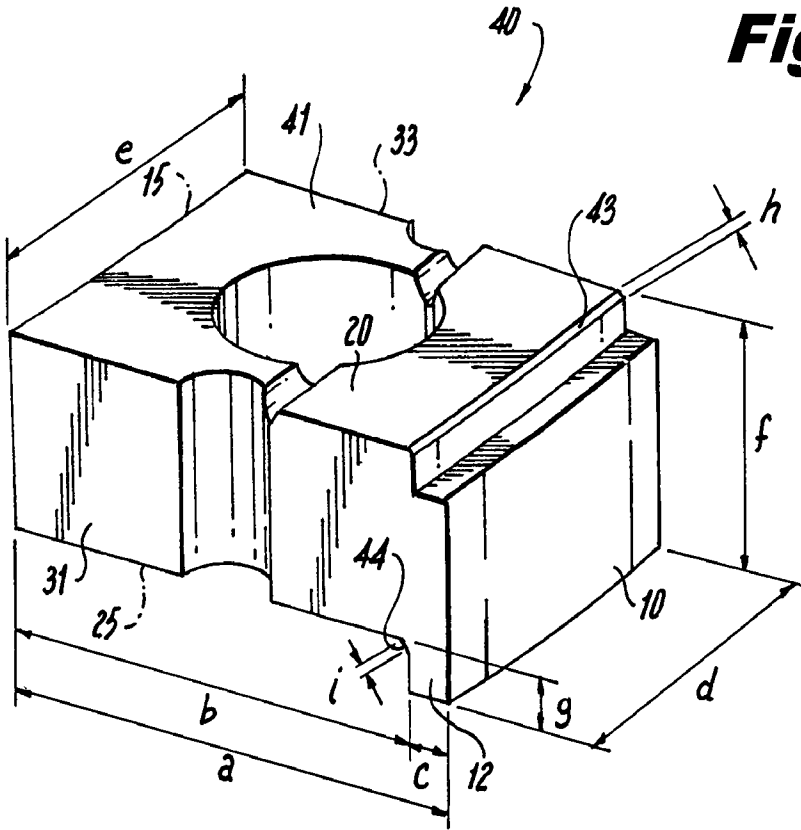


Fig. 4

Fig. 5

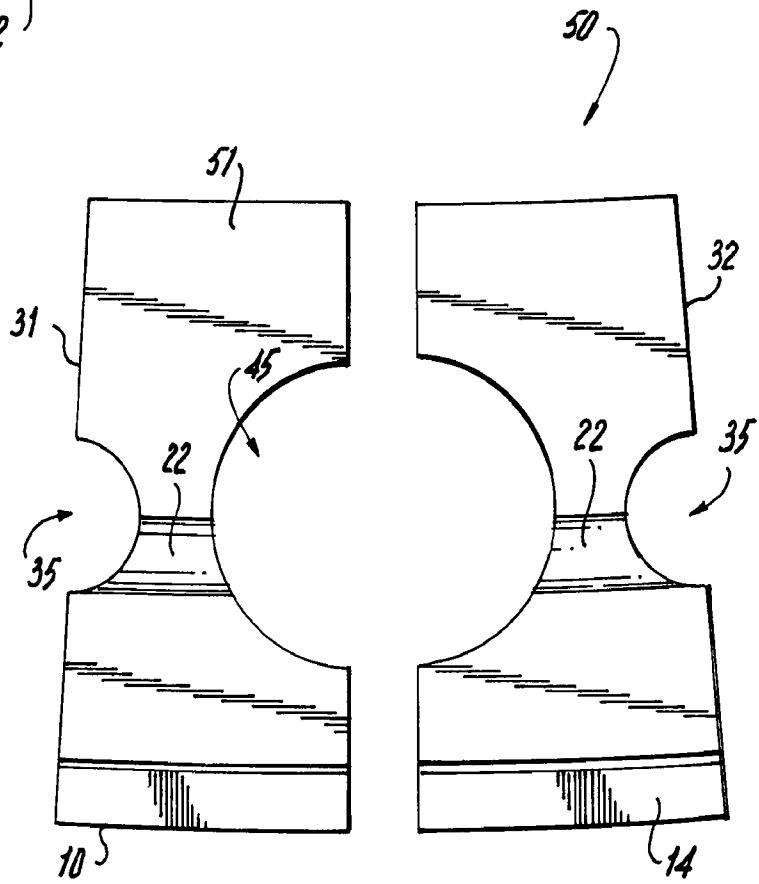
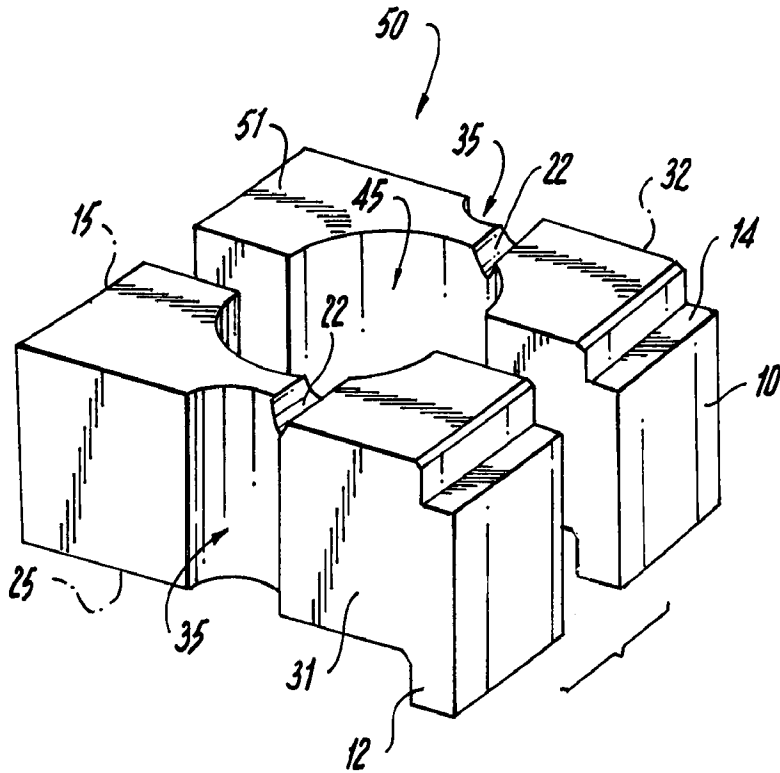


Fig. 6

Fig. 7

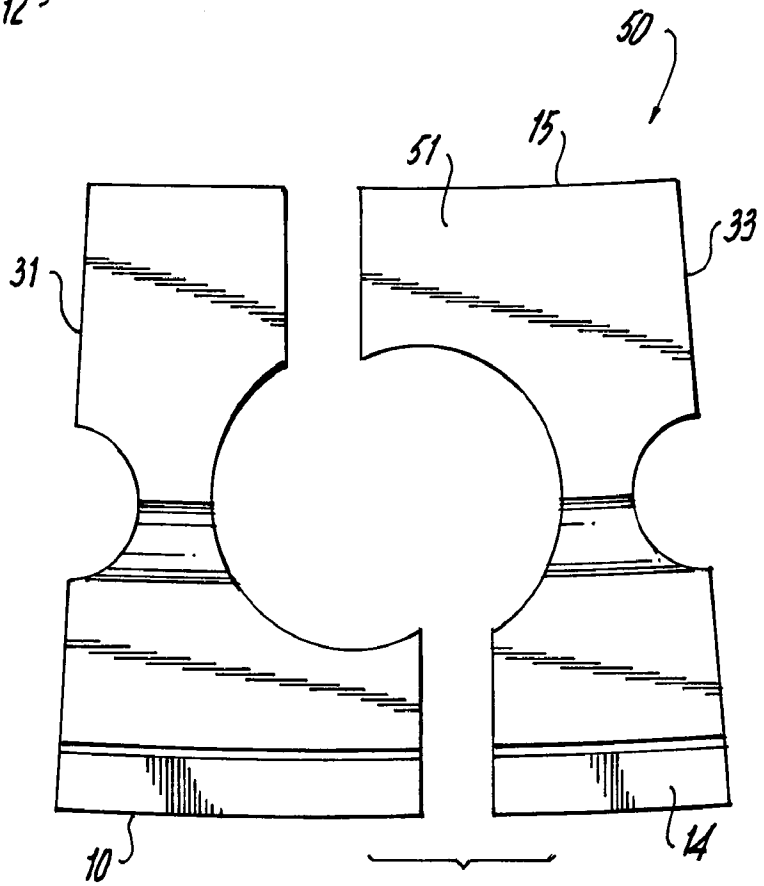
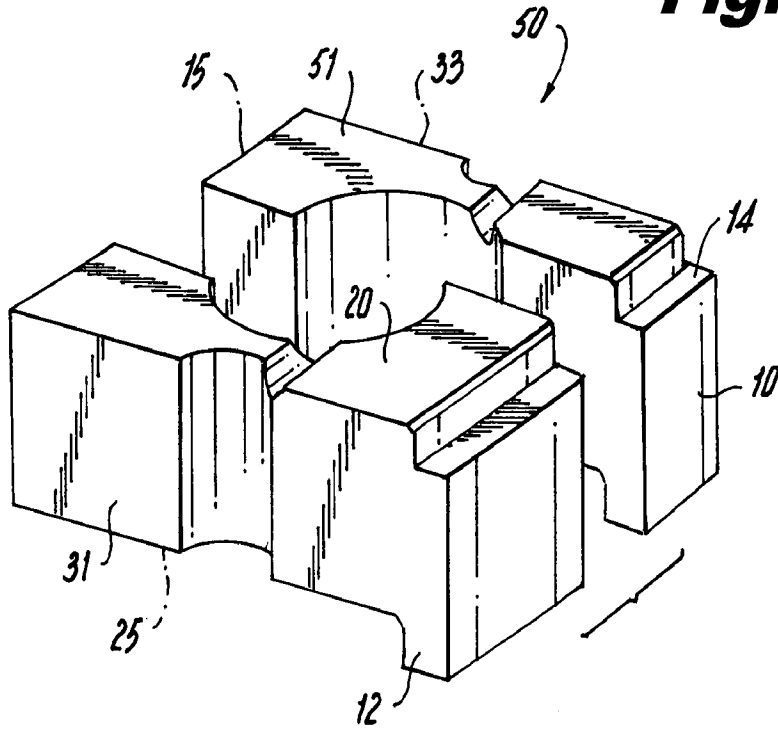


Fig. 8

Fig. 9

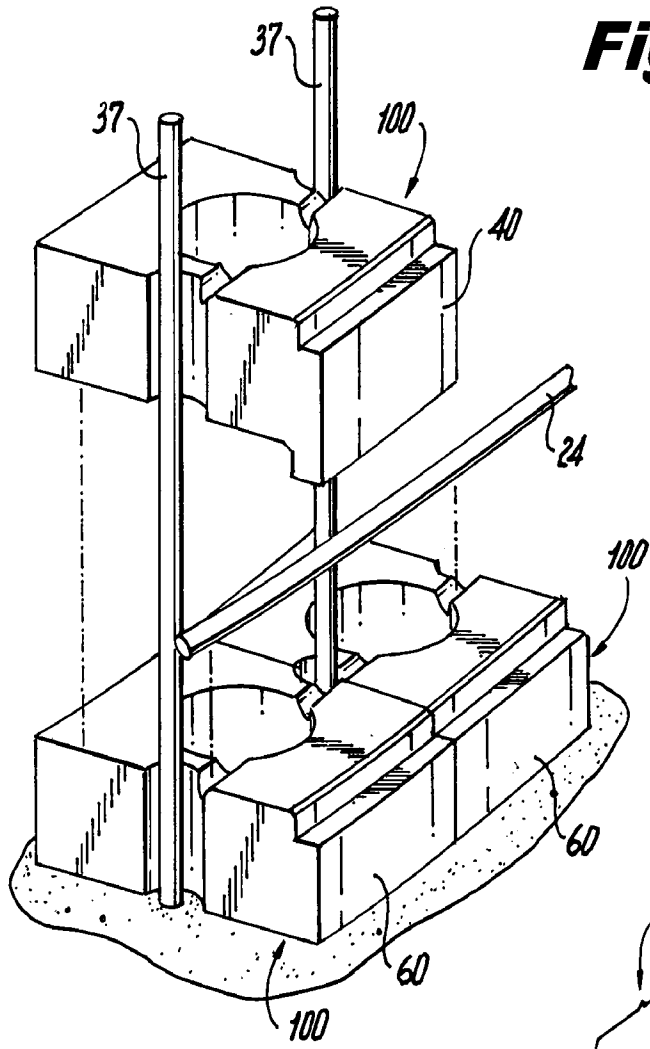


Fig. 10

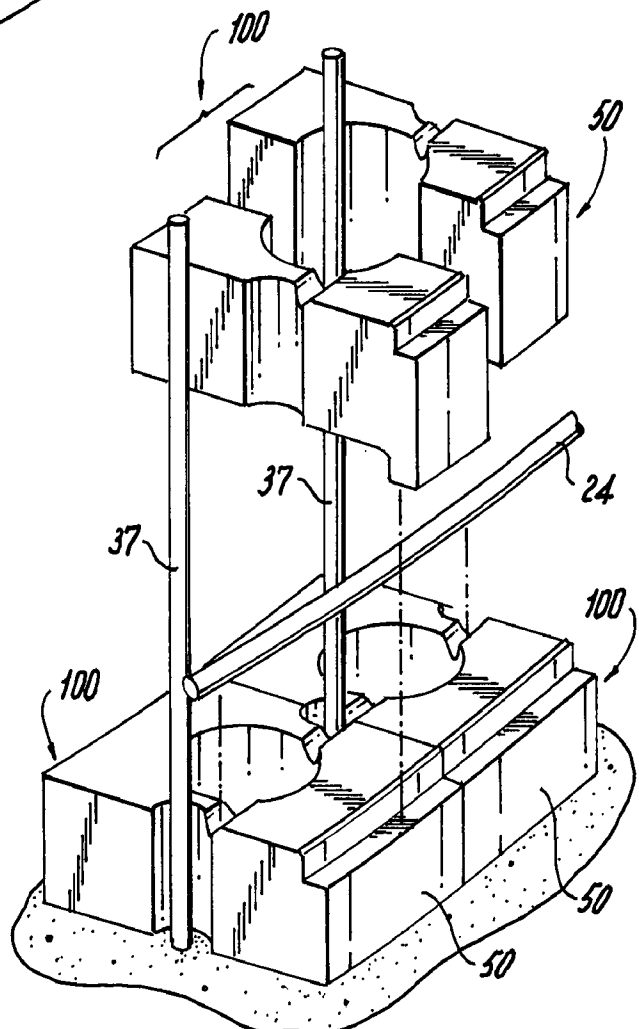


Fig. 11

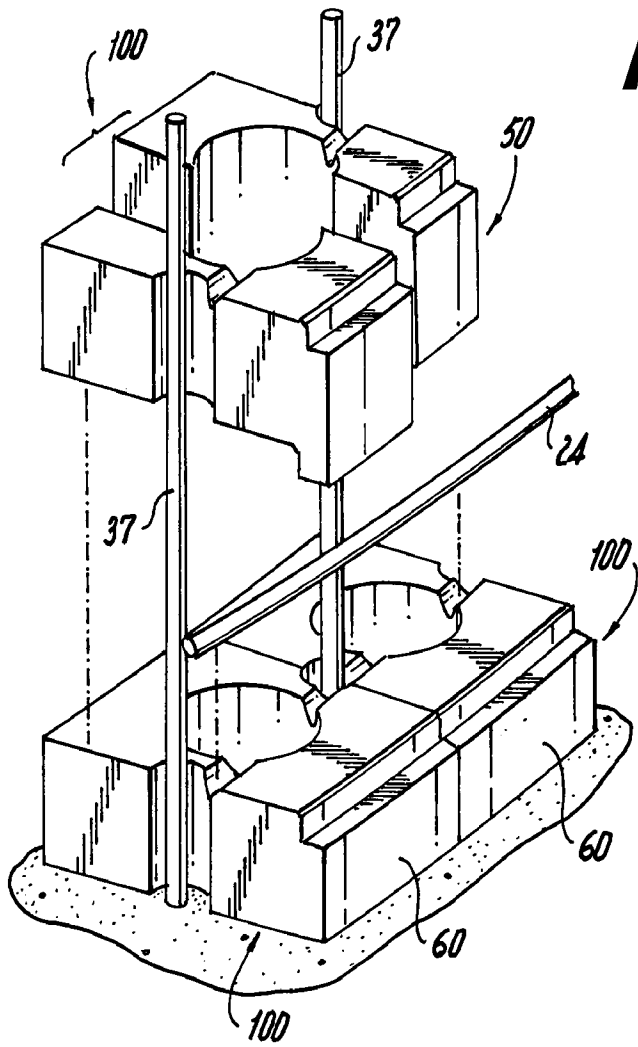
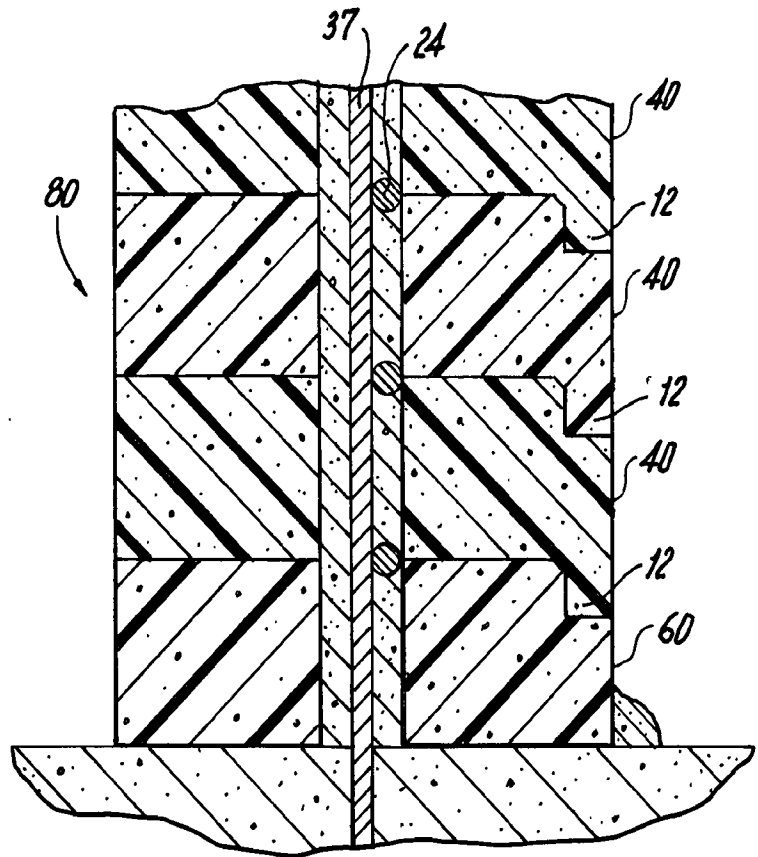


Fig. 12



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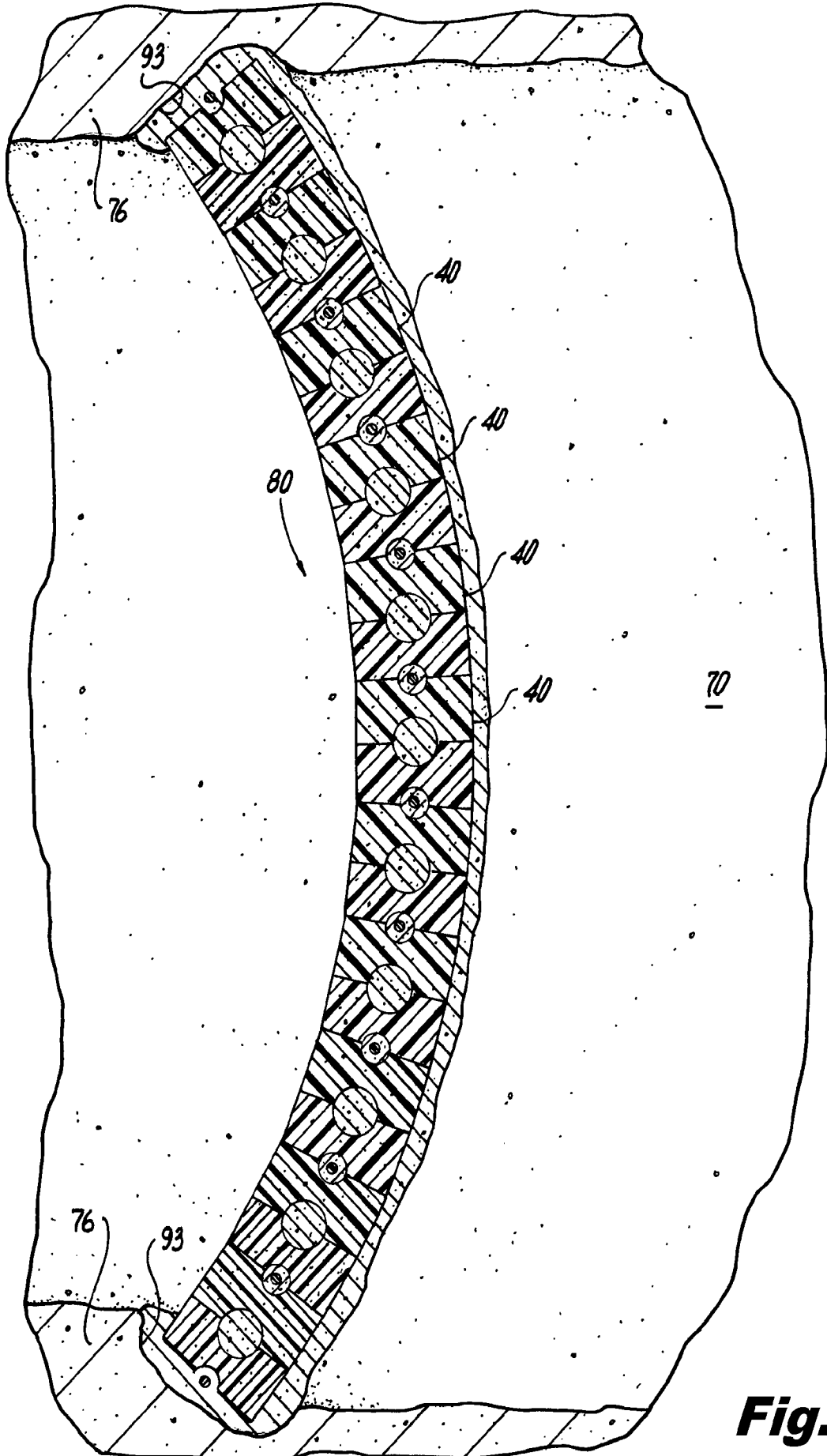


Fig. 13

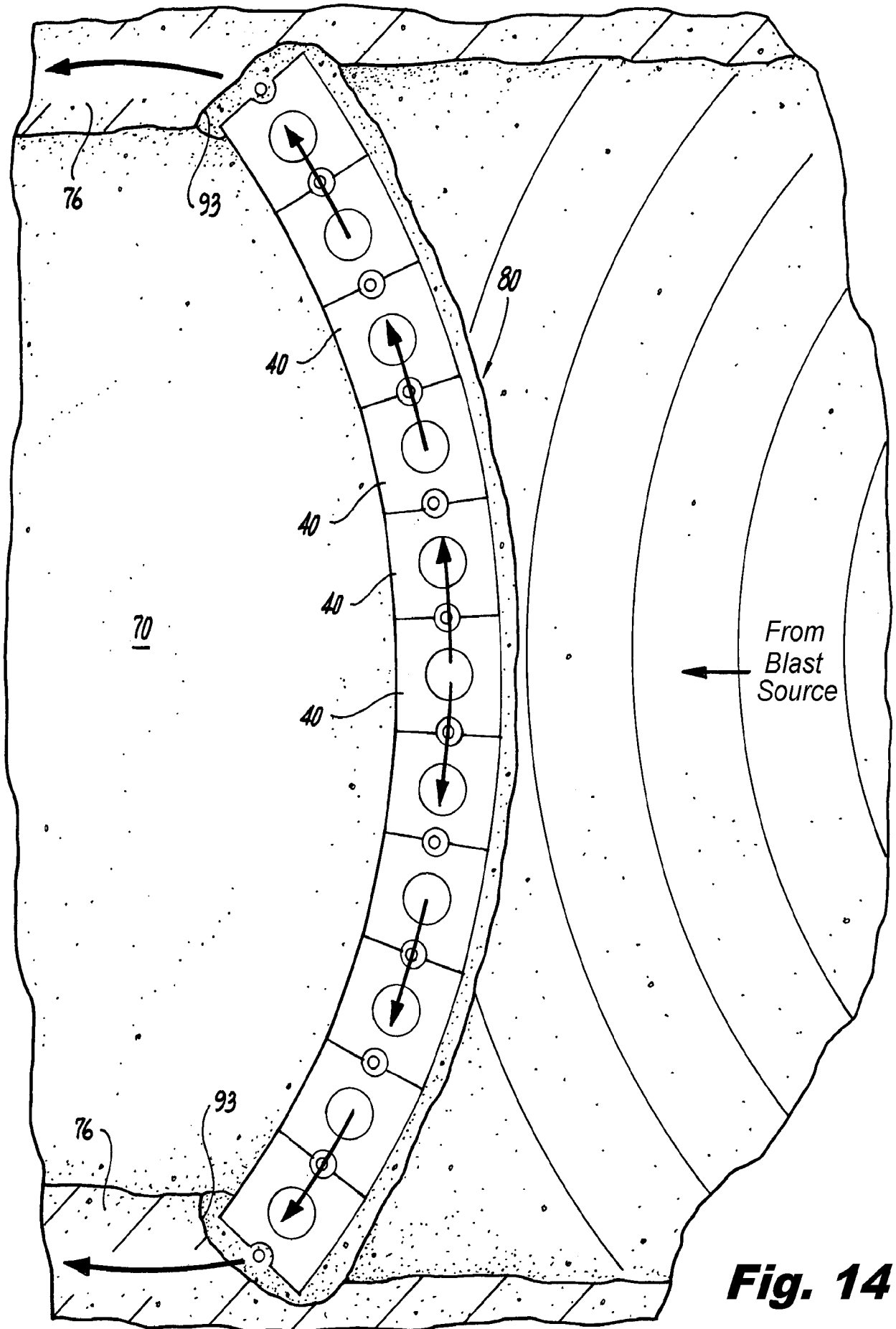


Fig. 14

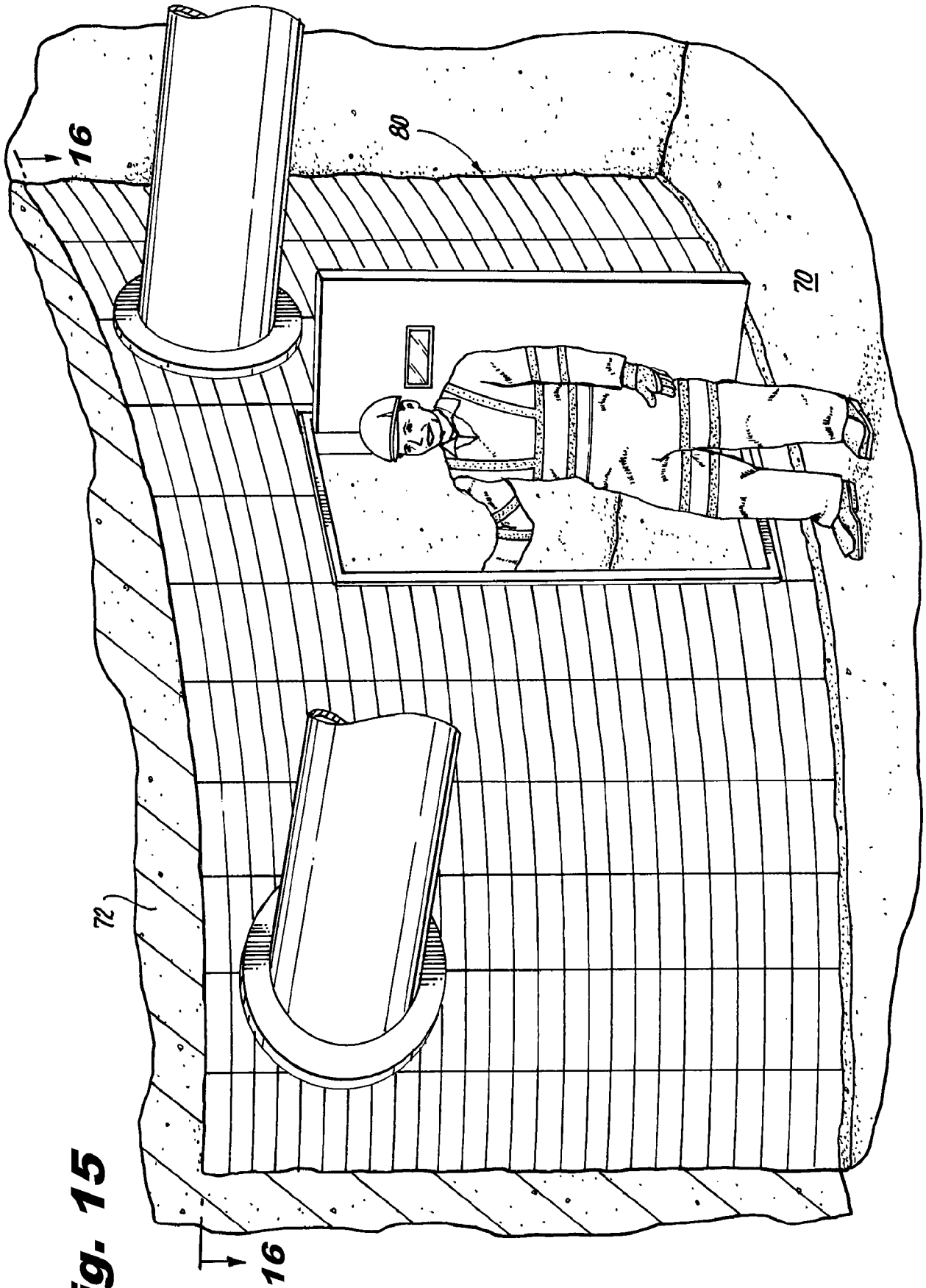


Fig. 15

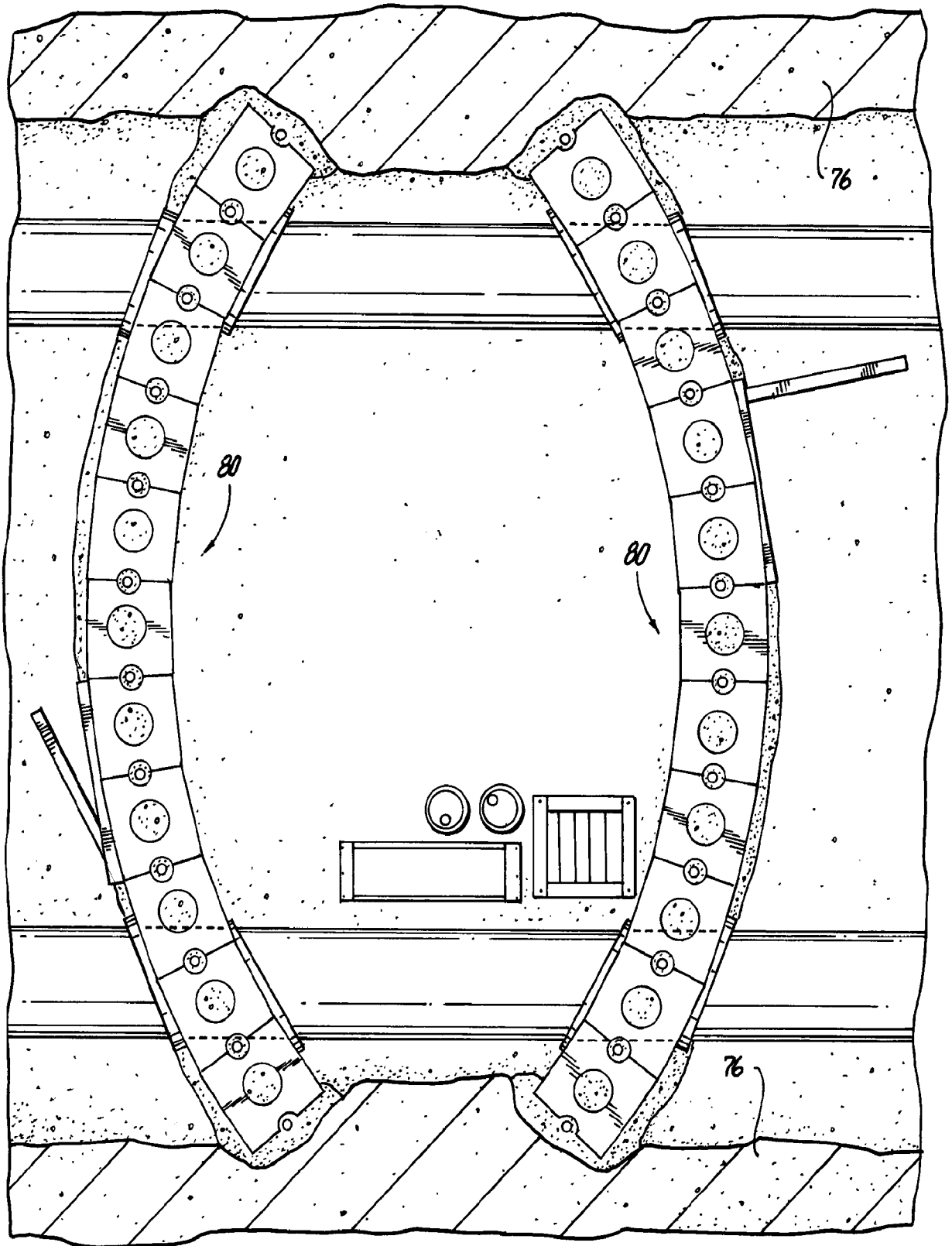


Fig. 16

INTERNATIONAL SEARCH REPORT		International application No. PCT/US13/26611												
A. CLASSIFICATION OF SUBJECT MATTER IPC: E04B 1/32 (2006.01), 1/02 (2006.01); E04G 11/04 (2006.01); E04C 3/30 (2006.01); E02D 3/02 (2006.01), 5/00 (2006.01), 17/00 (2006.01) USPC: 52/245-247,561-562,564-568,596,600,601,603,604,606-610 According to International Patent Classification (IPC) or to both national classification and IPC														
B. FIELDS SEARCHED														
Minimum documentation searched (classification system followed by classification symbols) U.S. : 52/245-247, 561-562, 564-568, 596, 600, 601, 603, 604, 606-610														
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched														
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) Please See Continuation Sheet														
C. DOCUMENTS CONSIDERED TO BE RELEVANT														
Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.												
X --- Y	US 2005/0178081 A1 (BOTT) 18 August 2005 (18.08.2005), see entire document.	1-2, 4, 6, 8-10, 18-19 ----- 3, 5, 7, 11-17, 20												
Y	US 6,912,823 B2 (MACDONALD et al.) 05 July 2005 (05.07.2005), see entire document.	3												
Y	US 894,122 A (DOUGHERTY) 21 July 1908 (21/07.1908), see entire document.	5												
Y	US 6,394,707 B1 (KENNEDY et al.) 28 May 2002 (28.05.2002), see entire document.	7												
Y	US 2008/0267718 A1 (COSTIN) 30 October 2008 (30.10.2008), see entire document.	11-12, 14, 16												
Y	US 3,905,170 A (HUETTEMANN) 16 September 1975 (16.09.1975), see entire document.	20												
<input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C. <input type="checkbox"/> See patent family annex.														
* Special categories of cited documents: <table border="0" style="width: 100%;"> <tr> <td style="width: 40%;">"A" document defining the general state of the art which is not considered to be of particular relevance</td> <td style="width: 10%;">"T"</td> <td>later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</td> </tr> <tr> <td>"E" earlier application or patent published on or after the international filing date</td> <td>"X"</td> <td>document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone</td> </tr> <tr> <td>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</td> <td>"Y"</td> <td>document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art</td> </tr> <tr> <td>"O" document referring to an oral disclosure, use, exhibition or other means</td> <td>"&"</td> <td>document member of the same patent family</td> </tr> </table>			"A" document defining the general state of the art which is not considered to be of particular relevance	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention	"E" earlier application or patent published on or after the international filing date	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone	"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art	"O" document referring to an oral disclosure, use, exhibition or other means	"&"	document member of the same patent family
"A" document defining the general state of the art which is not considered to be of particular relevance	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention												
"E" earlier application or patent published on or after the international filing date	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone												
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art												
"O" document referring to an oral disclosure, use, exhibition or other means	"&"	document member of the same patent family												
Date of the actual completion of the international search 05 March 2014 (05.03.2014)		Date of mailing of the international search report 06 MAR 2014												
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450 Alexandria, Virginia 22313-1450 Facsimile No. (571) 273-3201		Authorized officer William Krynski Telephone No. 571-272-1700												

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US13/26611

Continuation of B. FIELDS SEARCHED Item 3:

US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; IBM_TDB: roof, less, decreased, lower, declin, reduc, reduction, shrink, drop, fall, get, trend, down, downward, wall, mine, block, compressive, strength