LIGHTWEIGHT, HIGH STRENGTH, REINFORCED CONCRETE CONSTRUCTIONS

Inventor: Richard G. Reineman, 601 Clubhouse Ave., Newport Beach, Calif. 92660

Filed: June 3, 1974

References Cited

UNITED STATES PATENTS
1,465,653 8/1923 Olander ...................... 52/DIG. 9
1,477,520 12/1923 Pittman ...................... 52/576
1,598,700 9/1926 Baumgartl ...................... 161/43
2,839,442 6/1958 Whitaker ...................... 161/43 X

ABSTRACT

Lightweight, high strength, reinforced concrete constructions formed of a plurality of substantially coextensive, parallel, spaced apart membranes consisting of alternate, integrally bonded layers of fiber-reinforced epoxy resin and epoxy resin-containing concrete interconnected by continuous longitudinal and lateral transverse webs of epoxy resin-containing concrete that form a unitary structure having a plurality of enclosed cavities which are each filled with a hollow-form core. The construction can be in the form of a flat sheet or panel of any desired size, or it can have a curvilinear configuration.

21 Claims, 8 Drawing Figures
3,922,413

LIGHTWEIGHT, HIGH STRENGTH, REINFORCED CONCRETE CONSTRUCTIONS

This invention relates to lightweight, high strength reinforced concrete constructions, and more particularly to relatively lightweight flat or curved, high strength, concrete members useful in the construction of buildings, and for like purposes.

Many of the heretofore commonly employed materials used in the construction of buildings, such as wood, steel, brick, masonry, and the like, are becoming increasingly less available and more costly. Also, the construction systems employing these materials do not provide adequate fire, flood, tornado, and earthquake resistance; nor do these materials adapt readily to the construction of buildings of non-rectangular design, which often prohibits the use of imaginative and otherwise practical and economic architectural designs.

Because of its relatively low cost, durability, high compressive strength, availability, and other desirable properties, reinforced concrete has been widely used as a material of construction. However, reinforced concrete has been largely limited to use in constructions where weight and bulk are not limiting factors. U.S. Pat. No. 3,753,849 issued to Raymond A. Duff on Aug. 21, 1973, discloses improved cementitious constructions formed of alternate integrally bonded layers of epoxy resin-containing concrete and fiber-reinforced epoxy resin. These constructions exhibit high tensile and flexural strengths and have excellent utility in the form of thin sheets and panels and in a wide variety of molded and formed articles. Although the patented constructions can have substantial thickness and bulk, because of the high strength of this material, the thicker constructions are not warranted in many applications; the patented constructions being most often used in relatively thin-wall articles having thicknesses of about ¼-inch to about 2-inches, and more often of about ½-inch to about 1-inch. However, many applications require a bulkier or thicker construction, but do not require the extraordinary strength provided by a solid body of alternate integrally bonded layers of epoxy resin-containing concrete and fiber-reinforced epoxy resin.

While need exists throughout the building construction industry, and elsewhere, for relatively bulky, lightweight, high strength, concrete constructions, one particular need exists in the manufacture of prefabricated buildings where the various components of the building are individually fabricated and assembled into the completed building at the installation site.

Accordingly, a principal object of this invention is to provide relatively bulky, lightweight, high strength, concrete constructions.

Another object of the invention is to provide lightweight concrete articles of construction that exhibit relatively high strengths.

Still another object of the invention is to provide lightweight, high strength, concrete constructions useful in architectural applications, and particularly in the construction of prefabricated buildings.

A yet further object of the invention is to provide lightweight, high strength, concrete panels, beams and architectural shapes.

These and other objects will be apparent from the following disclosure and accompanying drawings, in which:
FIG. 3 illustrates an embodiment of the invention in which the hollow-form cores 34 are in the form of alternate upright and inverted triangular blocks interspaced by longitudinal transverse webs 36 and lateral transverse webs 38 disposed at oblique angles with respect to the longitudinal axis of the member. FIG. 4 illustrates a further embodiment in which the hollow-form cores 40 are in the form of hexagonal blocks interspaced by hexagonally shaped transverse webs 42.

FIG. 5 illustrates an embodiment of the invention in which membrane 50 is formed of alternate layers of epoxy resin-containing concrete 52 and 54 interspaced with integrally bonded fiber-reinforced epoxy resin layer 56, and membrane 60 is formed of alternate layers of epoxy resin-containing concrete 62 and 64 interspaced with integrally bonded fiber-reinforced epoxy resin layer 66. Membranes 50 and 60 are interconnected by transverse webs 68 of epoxy resin-containing concrete. The cavities 70 are voids defined by enclosed containers 72, such as metal, plastic, or paperboard cans; or balloons; or inflated bladders of a resilient material.

In the embodiment illustrated in FIG. 6, membrane 80 is comprised of alternate layers of epoxy resin-containing concrete 82 and 84, interspaced by integrally bonded layer 86 of fiber-reinforced epoxy resin, and membrane 90 is similarly comprised of layers 92 and 94 of epoxy resin-containing concrete interspaced by integrally bonded layer 96 of fiber-reinforced epoxy resin. Membrane 90 is provided with an outer layer 98 of epoxy resin or polyester resin gel coat, as will be hereinafter more particularly described. The substantially coextensive membranes 80 and 90 are interconnected by transverse webs 100 of epoxy resin-containing concrete defining a plurality of enclosed cavities filled with hollow-form cores 102.

The embodiment illustrated in FIG. 7 is particularly useful in applications where higher strength members are required, such as in beams, or the like. This embodiment consists of a plurality of substantially coextensive, parallel membranes 110, 112 and 114 consisting of alternate, integrally bonded layers of epoxy resin-containing concrete 116 and 118 interspaced by integrally bonded layers 120 of fiber-reinforced epoxy resin. Membranes 110 and 112 are interconnected by transverse webs 122 and membranes 112 and 114 are interconnected by transverse webs 124 so as to define a plurality of enclosed cavities filled by hollow-form cores 126.

In the embodiment illustrated in FIG. 8, parallel membranes 130 and 132 are formed of a plurality of layers 134, 138 and 142 of epoxy resin-containing concrete interspaced by integrally bonded layers 136 and 140 of fiber-reinforced epoxy resin. The membranes 130 and 132 are interconnected by transverse webs 144 so as to form a plurality of enclosed cavities filled by hollow-form cores 146.

The hollow-form cores serve as forms during the casting of the construction and further have insulating properties which reduce the heat and sound conductivities of the construction. Any of a wide variety of cellular materials can be employed as the core material. By "cellular material" it is meant a low density solid structural system such as a body comprised of a contiguous solid material having a high proportion of air pockets or void spaces. Among the useful cellular materials are corrugated and honeycomb paperboard and natural and synthetic cellular materials including balsa wood, natural sponge, synthetic sponge, foam rubber, foamed nylon and foamed plastics such as foamed epoxies, foamed polystyrene, foamed polyvinyl chloride, foamed polyethylene, foamed cellulose acetate, foamed polyurethane, and the like. Foamed polyurethane is a preferred core material.

Also, as illustrated in FIG. 5, the hollow-form cores can be closed cans or containers constructed of metal, paperboard, or plastic, or can be inflatable balloons or bladders of a resilient material such as rubber, or the like. The hollow-form cores can be employed in any of a variety of regular and irregular shapes such as cylindrical and polygonal blocks, and particularly blocks having triangular, rectangular, pentagonal, hexagonal, and like cross sections.

The cementitious material used in the constructions of this invention is a hardenable admixture of hydraulic cement, aggregate, epoxy resin, water reducing additive, and sufficient water to hydrate the cement. When first admixed, the material has a soft, semisolid consistency and can be molded, cast, trowelled, or applied by gun. On curing, the material hardens into a hard rigid solid having high strength and durability.

The hydraulic cement and admixture of the commercial hydraulic cements such as ASTM Type I or normal Portland cement, ASTM Type II or modified Portland cement, ASTM Type III or high-early-strength Portland cement, ASTM Type IV or low-heat Portland cement, ASTM Type V or sulphate resistance Portland cement, ASTM Type IP or Portland-pozzolana cement, plastic cement, or gun plastic cement. Also, the cement can optionally contain additives to improve various properties, such as workability, aggregate segregation, air entrainment, and to accelerate or slow setting time. The aggregate is sand, although fine pea gravel and crushed aggregate can be used in part, particularly in thicker constructions, and lightweight or low density aggregate can be employed where it is desired to minimize weight.

Various commercial epoxy resin compositions can be employed in the practice of this invention. These are typically undiluted low viscosity liquids or more viscous resins diluted with a solvent, and are conventionally employed in a two component system, i.e., the resin and the catalyst are separately packaged and admixed only at the time of use. The epoxy resins preferred in the practice of this invention are undiluted liquids that exhibit the following properties after curing for 7 days:

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile strength</td>
<td>8,000 psi minimum</td>
</tr>
<tr>
<td>Tensile elongation</td>
<td>10 percent maximum</td>
</tr>
<tr>
<td>Flexural strength</td>
<td>15,000 psi minimum</td>
</tr>
<tr>
<td>Compressive yield</td>
<td>12,000 psi minimum</td>
</tr>
<tr>
<td>Hardness</td>
<td>above 60 shore D</td>
</tr>
</tbody>
</table>

A commercial epoxy resin exhibiting the foregoing properties and which is particularly useful in the practice of this invention is a relatively low viscosity, two component epoxy resin marketed by the Adhesive Engineering Company under the trademark Concrese No. 1170, and identified as Part A and Part B. This material is admixed in the ratio of about 2 parts of Part A to 3 parts of Part B to about 3 parts of Part A to 2 parts of Part B, and is preferably employed in the proportion of about equal parts of Part A and Part B. Preferably, the two epoxy resin components are intimately ad-
mixed prior to adding them to the wet cement mixture. The fiber reinforcing material for the epoxy resin layer can be metallic, plastic, cloth, or fiber glass in the form of matting, woven material, or short lengths of chopped fibers. Other fibers that can be employed in addition to fiber glass are sisal, hemp, cotton, nylon, rayon, polyethylene terephthalate (Dacron) acrylic fibers (Orlon), and other synthetic and natural fibers. Included within the woven materials are metal, plastic, cloth or glass screen or mesh. A particularly preferred fiber reinforcing material that imparts superior strength to the ultimate structure is woven fiber glass roving. Fiber glass roving is a woven-type material in which bundles of glass fibers are woven in a basket-like weave.

A suitable epoxy resin is the diglycidyl ether of bisphenol A which can be formed by the condensation of epichlorohydrin and bisphenol A, i.e., bis(4-hydroxyphenyl)dimethyl methane. A preferred bisphenol A diglycidyl ether is a liquid thermosetting resin having a Brookfield viscosity of about 10,000 to 16,000 centipoise at a temperature of 25°C and an epoxide equivalent weight of about 185 to 200. A suitable bisphenol A diglycidyl ether of this type is marketed by the Celanese Coatings Company under the trademark Epi-Rez 510.

The bisphenol A diglycidyl ether can be admixed with a reactive diluent to provide a modified resin system. A preferred epoxy resin is an admixture of bisphenol A diglycidyl ether and 27 parts of ortho-creosyl glycidyl ether containing about 20 to 40 percent of the reactive diluent. A particularly preferred resin combination is an admixture of about 73 parts of bisphenol A diglycidyl ether and 27 parts of ortho-creosyl glycidyl ether. A suitable ortho-creosyl glycidyl ether reactive diluent having a Brookfield viscosity of 5 to 25 centipoises at 25°C and an epoxide equivalent weight of 180 to 200 is marketed by the Celanese Coatings Company under the trademark Epi-Rez 5011. A commercially available admixture of 73 percent diglycidyl ether of bisphenol A and 27 percent ortho-creosyl glycidyl ether suitable for use in the compositions of this invention is marketed by the Celanese Coatings Company under the trademark Epi-Rez 5077. This resin mixture has a Brookfield viscosity of 500 to 700 centipoises at 25°C and an epoxide equivalent weight of 185 to 200.

A wide variety of catalysts and reactive hardeners are known that cure or harden epoxy resins. While a number of different agents can be employed to cure the epoxy resins employed in the compositions of this invention, the reactive amine-type hardeners are preferred. A particularly preferred hardener is an admixture of a reactive amido-amine such as dicyandiamide and a high reactive modified amine converter. A suitable hardening agent of this type is marketed by the Celanese Coatings Company under the trademark Epi-Cure 872. The preferred hardening agent is added to the epoxy resin in the proportions of about 0.3 to 1 part of hardening agent per part of resin, and preferably in the proportion of about 0.5 part of hardener per part of resin.

The water reducing additive employed in the composition of this invention is a liquid admixture consisting principally of superplasticizers, polymers, calcium lignosulfonate, and an organic accelerator. A suitable water reducing agent is marketed by Master Builders under the trademark Pozzolith 300-N. The liquid water reducing additive is employed in small amounts, such as in the proportion of about 1 to 6 fluid ounces per 94 pound sack of cement, and preferably in the proportion of about 2 to 4 fluid ounces per sack of cement.

The cementitious material is prepared by admixing the ingredients in the proportion of about ¾ to 3, and preferably about ¾ to 1½ gallons of combined epoxy resin and hardener, about 1 to 3 cubic feet of aggregate, about 1 to 6 fluid ounces of liquid water reducing additive, and about 4 to 6, and preferably about 4½ to 5 gallons of water per 94 pound sack of cement. A preferred composition comprises an admixture of about three-fourths gallon of epoxy resin and hardener, about 2 cubic feet of aggregate, about 3 fluid ounces of liquid water reducing additive, and about 4 to 6 gallons of water per 94 pound sack of cement, the exact amount of water depending upon the moisture content of the sand. The aggregate content of this composition on a weight basis is about 100 to 300 pounds, and preferably about 200 pounds per 94 pound sack of cement when using regular sand, and about 55 to 165 pounds per sack when using lightweight aggregates. The amount of water employed in the cementitious material is substantially less than would be required to hydrate and cure conventional concrete.

Also, it has been found that the cementitious material cures or hardens substantially faster than conventional concrete, curing often being sufficiently complete in only a few hours at ambient temperature to permit an article to be removed from a mold or subjected to a moderate amount of handling, although several days will be required for the material to reach substantially full strength.

The cementitious material is preferably prepared by admixing the water and the water reducing additive, then adding the cement and mixing the mass to a uniform consistency. Next, the aggregate is added and thoroughly mixed. The epoxy resin and the hardener is premixed and, as a final step, thoroughly mixed into the cementitious composition. It should be noted that no more water can be added to the cementitious mixture after the resin has been added. Any adjustment of moisture content must be done before addition of the resin. Also, in an alternative mode of preparation, the water reducing additive can be premixed with the epoxy resin and hardener, and this admixture added to the wet cement.

The lightweight, high strength, reinforced concrete constructions of this invention can be manufactured in a wide variety of shapes and sizes depending upon the ultimate use of the construction. These constructions can be in the form of flat panels or panels having simple or compound curved surfaces or regular or irregular shapes. The constructions can be readily manufactured in a variety of complex architectural shapes useful in the construction of buildings, and particularly in the manufacture of prefabricated buildings. Also, the constructions can be in the form of elongated members useful as posts or beams, and particularly as load-carrying structural beams.

The exterior surfaces of the constructions of the invention can be left unfinished, or all or a portion of the surfaces can be provided with one or more coats of a suitable paint. A particularly desirable finish is provided by coating the exterior surfaces with epoxy paint. Also, the constructions can optionally be provided with a resinous surface coating, such as exterior coating 98 illustrated in FIG. 6, integrally bonded to the surface of epoxy resin-containing concrete layer 94 to provide a
decorative and/or serviceable outer surface. Various clear or pigmented resins such as polyester and epoxy resins are suitable for use in this application. Where these surface coatings are not utilized, conventional concrete pigments can be incorporated into the outer layers of epoxy resin-containing concrete to provide the desired color.

The constructions of this invention are manufactured by casting, or by a combination of casting and spray application, in a suitable mold of any desired configuration and surface pattern. The mold is preferably coated with a suitable concrete form release, mold release, or separating compound to facilitate removal of the completed construction from the mold.

To manufacture a construction in accordance with the embodiment illustrated in FIGS. 1 and 2, the layer 32 of uncured epoxy resin-containing cement is applied to the mold and overlayed with layer 28 of epoxy resin-saturated fibers. Next, blocks of hollow-form core materials 24 are placed on epoxy resin layer 28 and suitably spaced to provide the desired configuration of transverse webs. Separate units of the core material can be placed in the mold, or the core material can be placed in the mold in the form of one or more large slabs, in which case the grooves for the webs are formed by cutting out or routing the desired pattern of grooves in the core material. After the hollow-form core material is in place and properly positioned or cut, the grooves between adjacent pieces of core material and around the periphery of the core material is filled with uncured epoxy resin-containing cement. Layer 26 of epoxy resin-saturated fibers is applied directly to the surface of the core material and the wet epoxy resin-containing cement in the web and peripheral grooves. The construction is completed by applying the layer 30 of epoxy resin-containing cement. This final layer of uncured cementitious material can be finished in any conventional manner to provide the desired finish, such as by trowelling, floating, rubber floating, brooming, and the like, or it can be left unfinished. It is sometimes preferable to apply a light coat of epoxy resin over this final layer to act as a sealer and to inhibit crazing of the cementitious material. After the wet cement mixture and epoxy resin have set sufficiently that the structure has sufficient strength to be handled, the construction can be removed from the mold. Also, where desired for decorative purposes, a light finish coat of stucco or plaster, not shown, can be applied to the exterior surfaces of the construction.

The constructions illustrated in FIG. 5 are manufactured by applying layer 62 of wet cement mixture to the mold, and next applying the layer 66 of epoxy resin-saturated fibers and the layer 64 of wet cement mixture. The hollow-form cores, such as the sealed cans 72, are positioned in the mold and the spaces between and around the periphery of the cores filled with wet cement mixture and the layer 54 of wet cement mixture applied over the cores. This layer is overlayed with layer 56 of epoxy resin-saturated fibers and the final layer 52 of wet cement mixture.

In the manufacture of the embodiment illustrated in FIG. 6, a first relatively thin layer 98 of polyester or epoxy gel coat is applied to the mold by spray or hand application. The gel coat reproduces the mold surface exactly to form a mirror image of the mold on the surface of the construction. In this manner, any form of surface from a smooth, porcelain-like finish to a grained, textured pattern can be obtained. Once the gel coat is applied, a thin layer of epoxy resin-saturated fibers is applied and the construction completed in the above-described manner.

The constructions illustrated in FIGS. 7 and 8 are manufactured by the above-described general method with multiple layers of core material being applied in the case of the embodiment illustrated in FIG. 7, and a plurality of alternate layers of wet cement mixture and epoxy resin-saturated fibers being applied in forming each membrane of the embodiment illustrated in FIG. 8.

The various layers of wet cement mixture and the wet cement mixture forming the interconnected transverse webs can be placed in the mold by any convenient method, it being convenient in many applications to pump the wet cement mixture into the grooves between and about the periphery of the hollow-form cores and, alternatively, to either hand apply the material onto the larger surfaces or to spray the wet cement with a conventional plaster gun.

The epoxy resin utilized in fiber-reinforced epoxy resin layers can be of the same composition as the epoxy resin used in preparing the wet cement mixture. The fiber-reinforced epoxy resin layer can be formed by presaturating the fibers with epoxy resin and applying the epoxy resin-saturated fibers to the construction. Alternatively, the fiber reinforcing material can be applied to the appropriate surface, and the epoxy resin then applied by brushing, rolling, or spraying. Where chopped fibers are employed, such as chopped glass fibers, it is convenient to apply the fibers with a hopper gun that simultaneously chops and blows the fibers and sprays the epoxy resin onto the surface to be coated.

The constructions of this invention are relatively lightweight, high strength, rigid, precisely formed members exhibiting low heat and sound conductivities and possessing excellent fire, weather, and vermin resistances. Because of their high flexural strengths and impact resistance, these constructions have high earthquake and shock loading properties.

While various embodiments of the invention have been described, it will be obvious to those skilled in the art that it is not so limited, but is susceptible of various changes and modifications, which are considered within the spirit and scope of the invention as defined by the attached claims.

Having now described my invention, I claim:

1. A relatively lightweight, high strength, cementitious construction comprising a plurality of substantially coextensive, parallel, spaced-apart membranes consisting of alternate, integrally bonded layers of fiber-reinforced epoxy resin and epoxy resin-containing concrete, said membranes being interconnected by continuous longitudinal and lateral transverse webs of epoxy resin-containing concrete so as to form a unitary structure having a plurality of enclosed cavities which are filled with cellular core material.

2. The article defined in claim 1 wherein said fiber-reinforced epoxy resin is epoxy resin reinforced with metal, plastic, or glass fibers.

3. The article defined in claim 1 wherein said epoxy resin-containing concrete is a hardened admixture in the proportion of 1 to 3 cubic feet of aggregate, ¼ to 3 gallons of epoxy resin, 1 to 6 fluid ounces of water reducing additive, and about 4 to 6 gallons of water per 94 pound sack of cement.

4. The article defined in claim 1 wherein said epoxy resin is an admixture of diglycidal ether of bisphenol A
and a reactive hardener.

5. The article defined in claim 1 wherein said epoxy resin is an admixture of diglycidal ether of bisphenol A, ortho cresyl glycidal ether and a reactive hardener.

6. The article defined in claim 1 wherein said cellular core material is foamed polystyrene.

7. The article defined in claim 1 wherein said cellular core material is a closed hollow member.

8. The article defined in claim 1 wherein said construction is comprised of two spaced apart membranes, each membrane including an interior layer of fiber-reinforced epoxy resin and an exterior layer of epoxy resin-containing concrete.

9. The article defined in claim 1 wherein said spaced apart membranes are each comprised of first and second layers of epoxy resin-containing concrete and an intermediate integrally bonded layer of fiber-reinforced epoxy resin.

10. The article defined in claim 1 wherein said spaced apart membranes are each comprised of at least three alternate layers of epoxy resin-containing concrete interspaced by integrally bonded layers of fiber-reinforced epoxy resin.

11. The article defined in claim 1 including three spaced apart membranes.

12. The article defined in claim 1 wherein at least a portion of the outer exposed surface of said membranes is coated with epoxy paint.

13. The article defined in claim 1 including an integrally bonded coating of polyester or epoxy gel coat on the outer exposed surface of said membranes.

14. A relatively lightweight, high strength, cementitious construction comprising first and second substantially coextensive, parallel, spaced apart membranes consisting of alternate, integrally bonded layers of glass fiber-reinforced epoxy resin and epoxy resin-containing concrete, said membranes being interconnected by continuous longitudinal and lateral transverse webs of epoxy resin-containing concrete so as to form a unitary structure having a plurality of enclosed cavities filled with foamed plastic, said epoxy resin-containing concrete comprising a hardened admixture in the proportion of 1 to 3 cubic feet of aggregate, ¼ to 3 gallons of epoxy resin, 1 to 6 fluid ounces of a water reducing additive, and sufficient water to harden the cement per 94 pound sack of cement.

15. The article defined in claim 14 wherein said epoxy resin is an admixture of diglycidal ether of bisphenol A, ortho cresyl glycidal ether and a reactive hardener.

16. The article defined in claim 14 wherein said epoxy resin is an admixture of diglycidal ether of bisphenol A, ortho cresyl glycidal ether and a reactive hardener.

17. The article defined in claim 14 wherein said foamed plastic is foamed polystyrene.

18. The article defined in claim 14 wherein said first and second spaced apart membranes are each comprised of an interior layer of glass-fiber reinforced epoxy resin and an exterior layer of epoxy resin-containing concrete.

19. The article defined in claim 14 wherein said first and second spaced apart membranes are each comprised of at least three alternate layers of epoxy resin-containing concrete interspaced by integrally bonded layers of glass fiber-reinforced epoxy resin.

20. A relatively lightweight, high strength, cementitious construction comprising first and second substantially coextensive, parallel, spaced apart membranes consisting of alternate, integrally bonded layers of glass fiber-reinforced epoxy resin and epoxy resin-containing concrete, said membranes being interconnected by continuous longitudinal and lateral transverse webs of epoxy resin-containing concrete so as to form a unitary structure having a plurality of enclosed cavities filled with foamed polystyrene, said epoxy resin-containing concrete comprising a hardened admixture in the proportion of 1 to 3 cubic feet of sand, ¼ to 3 gallons of epoxy resin, 1 to 6 fluid ounces of a water reducing additive, and sufficient water to harden the cement per 94 pound sack of cement.

21. The article defined in claim 1 wherein said lateral transverse webs are disposed at oblique angles with respect to the longitudinal axis of said membranes.

* * * * *