

Aug. 25, 1964

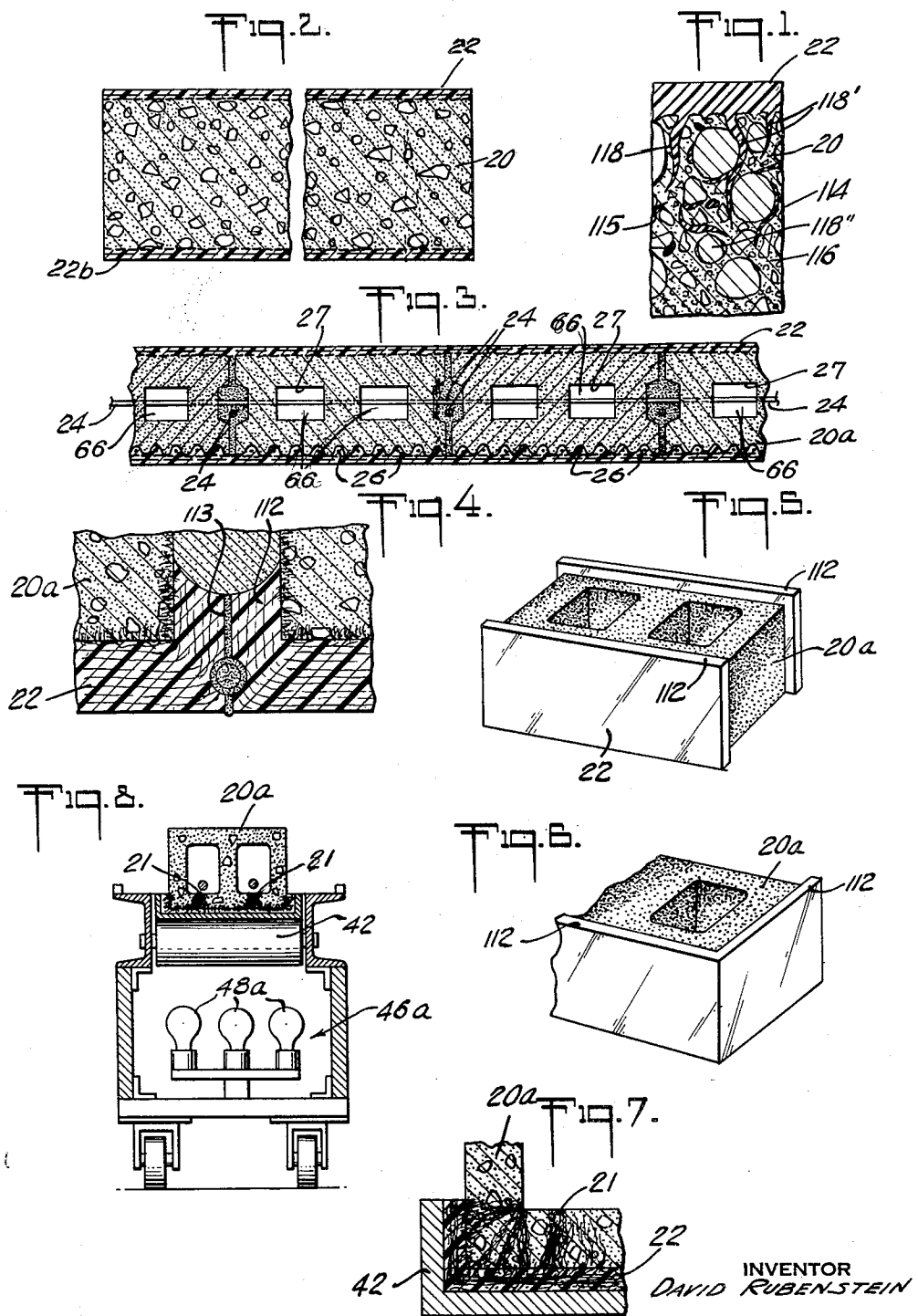
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3,145,502

STRUCTURAL ELEMENT AND METHOD OF MAKING

Filed April 1, 1955

3 Sheets-Sheet 1



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3 Sheets-Sheet 2

Fig. 9.

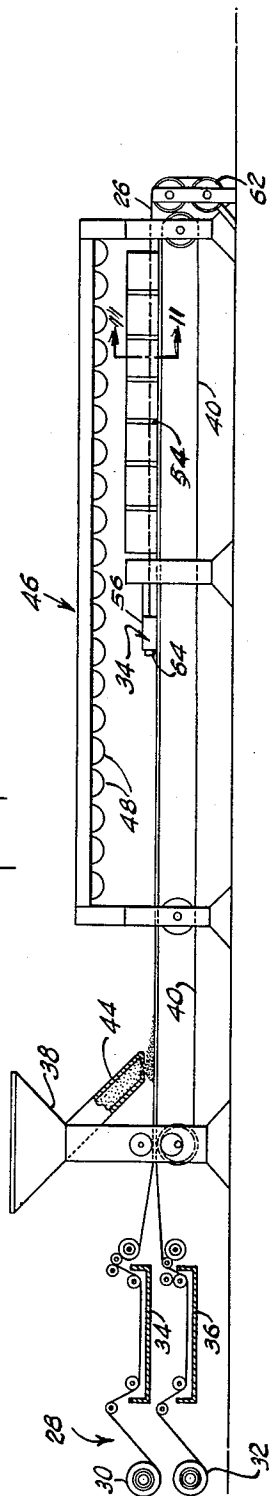


Fig. 10.

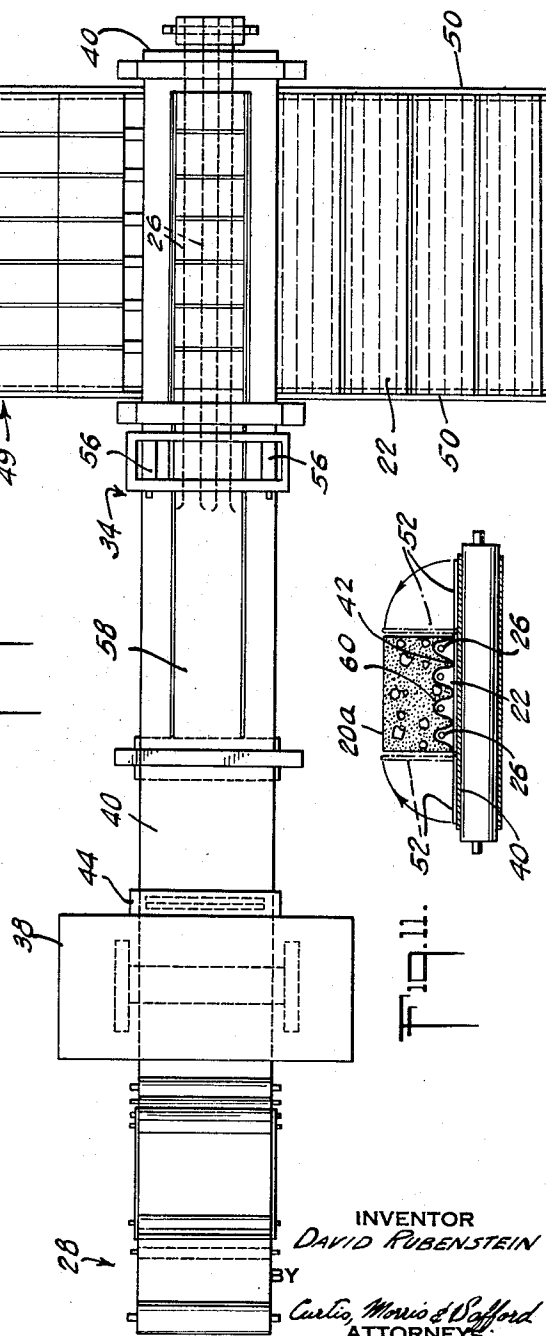
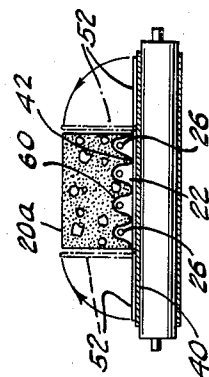


Fig. 11.



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3 Sheets-Sheet 3

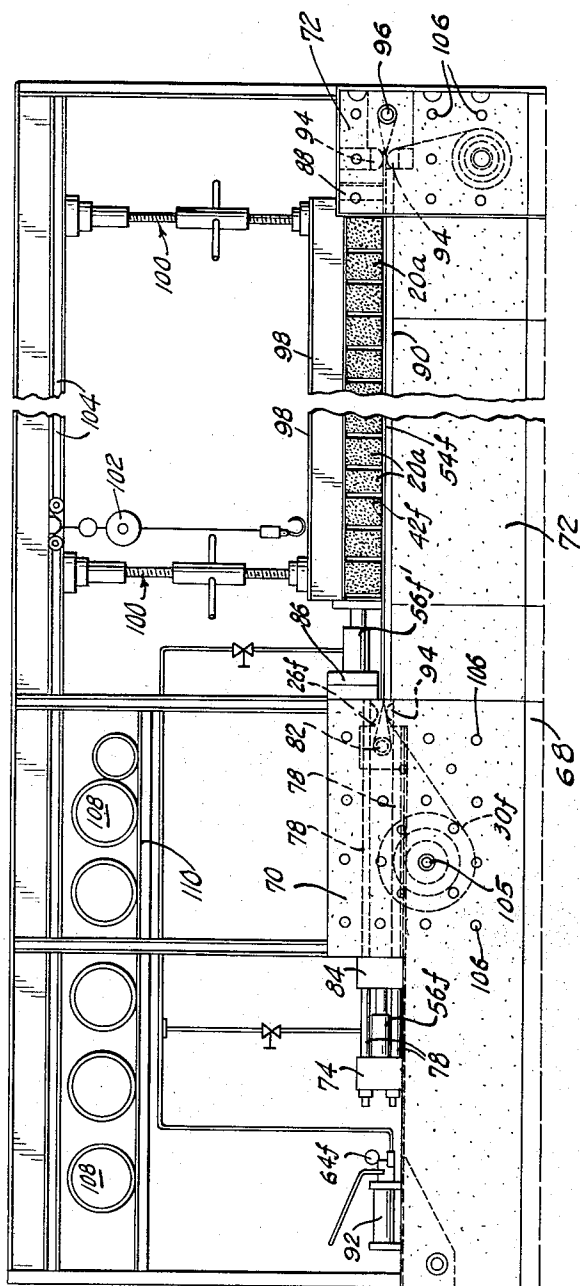


Fig. 12.

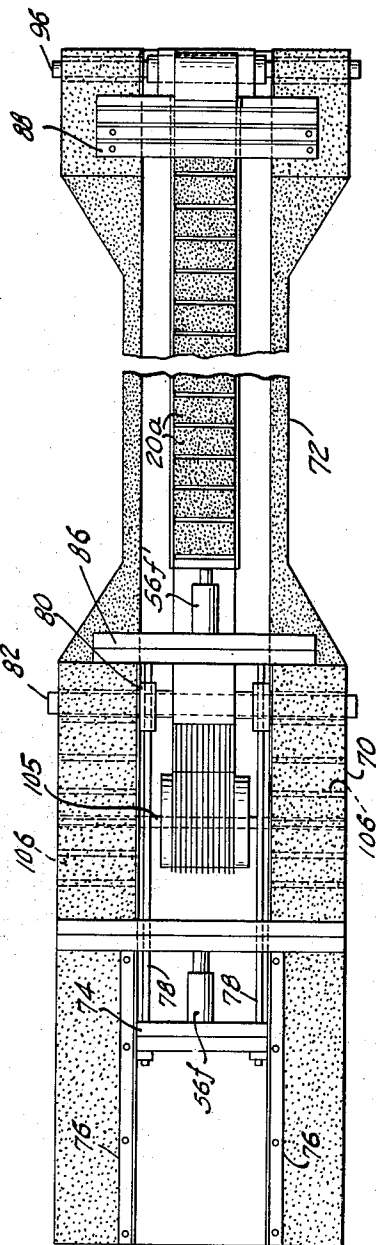


Fig. 13.

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3,145,502 STRUCTURAL ELEMENT AND METHOD OF MAKING

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13 Claims. (Cl. 50-128)

This invention relates to high strength, shock and impact resistant building elements and components, and to methods of making them.

This application is a continuation-in-part of my co-pending applications Serial No. 345,084 filed March 27, 1953, Serial No. 340,642 filed January 16, 1953, now Patent No. 2,951,006 Serial No. 267,166 filed December 17, 1951 (now Patent No. 2,671,158), and Serial No. 229,852 filed June 4, 1951, and a portion of which is now Patent No. 2,850,890.

It is one object of my invention to make available a superior building material having advantages of concrete or other existing structural materials, but improved in respects in which such materials are now deficient. Specifically, it is an object of the invention to so modify and supplement concrete and other compressionally strong, porous building materials as to give them high tensile, compressive, torsional and shear strengths and greater resistance to shock, impact and surface crumbling.

A further object of this invention is to provide a method and construction which will enable structural elements to be produced in a factory under industrialized conditions and processes, and thus to lower costs of high quality building elements that may be erected, placed and used in a building, or the like.

Yet another object of the invention is to provide methods and constructions which will produce laminates with waterproof surfaces that will resist deterioration under interior or even exterior conditions and even in extreme heat or cold, dryness or dampness; and which will, if required, be impervious to mildew, rot and insects.

A further object of this invention is to reinforce the surface of concrete walls, ceilings and floors, also beams, columns, roofs or any structural part that can be made out of concrete or other stone-like material, so as to prevent or minimize "spalling" of the concrete, etc.

A further object is to reduce the cost and improve the quality of buildings and other structures made with building units.

This invention provides materials possessing great strength in tension, laminated with materials of relatively low tensile strength but possessing great compressive strength.

By virtue of this invention structural materials are provided suitable for normal and extraordinary loading with compression loads, shear loads, tension loads and/or torsion loads, whether or not subject to temperature changes, impact, shock or other distorting tendency.

The invention also makes it possible to design materials with properties and characteristics tailored to the particular requirements of use. It is thus possible to accentuate any desirable characteristic, such as resilience, soundproofing, moistureproofing, shockproofing, light weight, thermal insulation or conductivity, smoothness, texture, load bearing capacities in compression, tension, shear and torsion. All these capacities and properties can be designed into the resulting structure and all factory produced.

In addition, by my invention structural members are easily designed to be fireproof or fire resisting and impervious and unattractive to insects.

In the drawings:

FIGURE 1 shows a vertical cross section of a fragment of FIGURE 2 on an enlarged scale and;

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FIGURE 2 is a vertical cross section of a concrete floor or roof slab embodying the invention;

FIGURE 3 shows a series of preformed concrete blocks prestressed and joined by reinforcing members, e.g. steel bars, steel wire or fibers bonded and coated with resin composition;

FIGURE 4 is a fragmentary cross section on an enlarged scale of two single concrete blocks faced and reinforced on one side according to this invention and built into a masonry wall;

FIGURE 5 is an isometric view of a block similar to that of FIGURE 4 but faced and reinforced on both sides;

FIGURE 6 is an isometric view of a corner block faced and reinforced on one side and one end;

FIGURE 7 is a fragmentary cross section on enlarged scale of the block still in the mold pan in which its reinforced plastic layer has been molded, as shown in FIG. 8;

FIGURE 8 is a cross section of an apparatus used in manufacturing structural units of this invention and showing a block in position on the conveyor;

FIGURE 9 is a diagrammatic view in side elevation of a machine for manufacture of precast, prestressed composite blocks of concrete and fiber-reinforced resin;

FIGURE 10 is a top plan view of the same;

FIGURE 11 is a cross section taken on line 11-11 of FIGURE 9;

FIGURES 12 and 13 are diagrammatic views in side elevation and in plan, respectively, of a machine used in manufacturing pre-stressed decorative structural components.

In these drawings, various structural embodiments have been depicted as an exemplification of certain of the principles of the invention. It will readily be understood that the invention is not limited to the actual constructions disclosed, since the invention can be readily applied in other constructions.

To overcome the complex stresses and strains applied to structures, this invention provides building units and unit structures reinforced with materials which although rigid to designed loads, are resilient, so that stretching, compressing, torsion and shear in any direction can be met by yield while the structure retains and resists the forces thus imposed. Also this invention provides bonded, smooth-textured, matte-faced, ribbed or patterned, white, grey or colored constructions.

As one example of the invention an unsaturated polyester resin, pigmented or unpigmented, is applied on a hard, non-porous mold surface, smooth, textured or ribbed. A fiberglass mat or other filler or reinforcement is incorporated in the resin. The mixture is subsequently gelled to a point where it is firm but tacky. A porous body, the surface of which has been previously impregnated with a coating of the same type or of a compatible resin, is then pressed against the gelled mixture.

The resin is cured at normal air temperatures or with a heated platen or in a heated chamber, on a non-porous mold surface, e.g., glass, metal sheet, aluminum, stainless steel, or plastic film, e.g., Celluloid, or any suitable material which, after removal, leaves an exposed hard surface of the plastic layer.

In this example, the porous bodies are Portland cement concrete blocks; but the invention can likewise be used for manufacture of pre-cast concrete slabs, poured in situ concrete slabs and shapes, structural members, bricks, clay products, wood, fiber boards, pressed fiber boards, so-called "hard board," plaster boards, gypsum blocks and other shapes, concrete made with perlite, pumice, or other light weight aggregate, natural and artificial stone, plastics and other materials of porous material and substantial compressive strength.

In one test concrete block having ultimate strength in tension of 500 pounds per square inch was provided with $\frac{1}{8}$ " layer of fiberglass-reinforced polyester resin on one side applied, bonded and cured as herein set forth. The resulting finished block was then stressed in flexure by third-point loading in a testing machine until it broke at 6200 p.s.i. Failure was by complete fracture in a single crack and with some spalling on the uncoated side of the block, but the fiber-reinforced resin layer did not break, leaving the surface as whole as before the test except for strain marks as hairlines showing beneath the surface.

It had become well known before my present invention to pre-stress concrete structures (i.e., to apply an extraneous force to the concrete before its useful load is applied) either by post-tensioning (engaging the structure with a tensile member stressed after it is applied to the finished concrete structural) or pre-tensioning (reinforcing the concrete with bars or other members which are stressed in tension before they are set in the concrete and are then released after the concrete is set around them, so that the irrisilient tendency to recovery exerts a force tending to pre-stress the concrete structure in compression). My present invention is applicable with such pre-stressed structures but surprisingly can actually provide pre-stressing by action of the resin, and especially by the combination of resin and high tensile strength fiber.

The resin which I use is advantageously one which has high shrinkage after preliminary setting and either should be one with extraordinarily high adhesive bond strength or should be so anchored and enmeshed in the porous structure of the concrete that the shrinkage imposes and maintains the desired pre-stress on the concrete without pulling away from its surface. The resin which is anchored into the concrete may, with advantage, effect its mayor shrinkage before an overlying layer of resin. This may be either by use of a faster setting resin (more catalyst or promoter) in the layer which impregnates the porous structure of the concrete than in the overlying layer, or by applying the impregnating layer in advance and pregelling it, so that in its final setting and high shrinkage period the layer of resin above it will still be sufficiently soft so that it can be sucked down to accommodate itself to the shrinkage of the impregnating layer.

Advantageously a thin layer at the surface, which is applied onto the face of the mold also is faster setting or applied and partially gelled in advance so that here also its shrinkage will be accommodated by flow of the still unset resin of the intermediate layer. When the intermediate layer finally does set its shrinkage is imposed against both the surface layer and the impregnating layer so that both are reinforced against tensile stresses; and since it is this intermediate layer which carries the fiber reinforcement, it is most advantageous that it should thus carry the severe tensile stress.

Thus, an 8" thick wall of concrete having 5000 p.s.i. compressive strength may have laminated thereon 2-oz. fiberglass mat with an additional layer of sisal fiber, all laminated together with polyester resin giving a combined tensile strength of about 21,000 p.s.i. Such a laminate of about $\frac{1}{8}$ " depth on a wall structure $7\frac{3}{8}$ " thick gives a building component of great strength and utility. I may use for such structures concrete of about 5,000-9,000 p.s.i.; and this may be laminated with woven fiberglass and sisal fibers impregnated with polyester resins which per se would have ultimate flexural strength, flatwise, of about 56,000 p.s.i. at room temperature. The shrinkage of the plastic pre-compresses the concrete and pre-stresses the resin fiber layer in tension. Use of such pre-stressed plastic and concrete structural members reduces substantially the cubic content required in the structure and also reduces need for steel reinforcing. Strengths hold up well at elevated temperatures; e.g., a 56,000

p.s.i. plastic and fiberglass reinforced concrete structural member, when heated to 160° F., dropped only to 50,300 p.s.i.

The use of externally induced prestressed preload forces which are "captured" in place by plastics having insufficient shrinkage or little or no shrinkage which when set, are also an important feature, especially when of high tensile strength, and either when used as the sole means of "capturing" prestressed preload, hold and "freeze" the preload in place or when used in combination with the plastic resins which induce prestressed preload by expansion or by shrinkage.

FIGURES 1-3 show a typical concrete slab section consisting of a concrete body 20 on both sides of which the plastic reinforcing layers 22 and 22b are laminated and bonded to form the composite cross section as shown. These layers 22 and 22b are advantageously fiberglass impregnated and bonded by polyester resin; but this is also representative of the many plastic—especially filled and reinforced plastic—compositions which are available for such use.

As shown in FIGURE 2, the concrete may be a concrete slab cast in situ, or cast in a mold and lifted into position in the building. In the latter case, it would most conveniently have the plastic reinforcing layers 22 and 22b applied in a press before it is brought to its final position; but in either case the layers 22 and 22b can be applied without a press, e.g., as set forth in my Patent No. 2,671,158. Or the concrete may be an ordinary concrete block treated according to this invention on one side only as shown in FIGURES 8 and 10 or on opposite sides as shown in FIGURE 5 or on 2 adjacent sides as in FIGURE 6 or on 3 adjacent sides as in FIGURE 11.

FIGURE 3 shows a slab like that of FIGURE 2, but built up in both horizontal directions from concrete blocks 20a joined and faced and reinforced as described below; and in this case additionally reinforced by pre-stressing wires, rods or cables 24 and 26. These blocks are of usual form with core holes 27 to reduce the weight.

In this structure, the layer 22b on the bottom serves both as an attractive ceiling and as a tensile member which, combined with the compressionally strong and rigid body of blocks 20a provides a strong deck. The layer 22 on the top makes a smooth, tough wear-resisting floor surface, and also provides a tensile strength against a reversal of stress such as may occur in bombing, earthquake or tornado, etc. Reinforcing wires 24 may serve to hold the structural members securely together and may also pre-stress the concrete body in compression.

FIGURES 9-11 show an apparatus useful for making blocks, beams or slab portions of the type shown in FIGURES 1-5.

As shown pre-cast concrete blocks 20a are stock-piled adjacent one side (left as shown in FIGURE 10) of a laminating machine.

At the feed end, of the machine 28 is a supply of reinforcing fiberglass mat or fabric 30, and in this case a second mat 32 of a strong, but more stretchable, fiber such as sisal. Either or both of these may carry fillers, resin, and/or other ingredients which go to make up the reinforcing layer; these being applied to the fabric at the factory and carried thereby in the reels. In the case illustrated, however, these bonding and compounding ingredients are supplied separately, the resin as a syrupy liquid from the resin tanks 34 and 36, respectively, and the filler, pigments, and any other ingredients supplied in dry powder or granular form, from one or more hoppers represented at 38.

The endless conveyor belt 40 may serve as the pallet or mold surface. In such case it is advantageously surfaced with a metal which forms a continuous surface along the entire beam; and, when treated in the usual way with mold release agents, will allow removal without damage of the molded facing 22 or 22b. This surface

may be sheet metal laminated to the conveyor belt, or, most advantageously, if single blocks are to be made, individual pallets 42 may be carried on the belt.

Onto this molding surface is first applied the facing fabric 32 and the facing resin composition which has previously been impregnated and saturated into the fabric in the tank 36. Next, the fiber glass 30, impregnated and saturated with resin composition from the tank 34 is applied over the facing fabric 32. Onto this, dry ingredients of the resin composition which is to impregnate, and bond into, the porous block are added from the hopper 38 through the chute 44 by which they are spread evenly onto and sink into the liquid resin.

The conveyor 40 moves this composite web slowly or intermittently through a heating chamber 46 wherein the web is heated by batteries of infra-red (radiant heat) lamps 48. The time of each part of the web in the chamber 46 and the intensity of heating by the lamps 48 are regulated so that the resin is gelled, i.e., partially cured to a tacky adhesive state.

The conveyor continues the movement of the partially cured web into the next zone or station where concrete blocks are moved up from one side, having first been preheated in a heat chamber 49. This heating evacuates most of the water which is ordinarily present in capillary spaces in the concrete block, so that the dried block can be easily permeated by the resin, which penetrates into the body of the concrete. The hot blocks are then coated with polyester resin composition on the face which is to be laminated with the fiber-reinforced resin. Advantageously a deep penetrating and permeating resin is used, to secure maximum bond strength.

By designing the capillary structure to secure penetration and permeation of the concrete body, plastic resin can be placed into and upon the concrete structure to provide anchorage suitable for a balanced design.

The hot concrete blocks thus coated are then placed with their coated faces down against the tacky resin-saturated web and press the reinforced plastic layer 22 down against the pallet 42 while the whole assembly is allowed to complete the cure at the required temperature—in this example 250° F. to a hard surfaced, strong, tough layer.

I have observed plastic resins pass up within five minutes or less, from a pan on a heated platen into a one and one-half inch concrete slab portion of a concrete block placed thereon, the block having been preheated and dried as above described. By pulling out the air through the concrete body the plastic resin can be drawn up into the body, where it sets in the pores, filling capillary spaces to make a unitary reinforcement within the concrete body. Use of even a partial vacuum aids in making such reinforced structural bodies. Pressure exerted on the face of the still fluid resin has a like result.

When the block is cured completely, it is moved sideways by conveyor tracks 50 and stockpiled.

Cross sections of such finished blocks are shown in FIGURES 1-4, 7 and 11. This illustrates the bonding and laminating of concrete block with fiberglass reinforcement, all thermally set and laminated and bonded to make the pre-stressed concrete building components.

The shrinkage stresses of the resin composition that come about by setting or other chemical reactions, as well as thermal shrinkage, introduce pre-stress forces into the block or other building construction or structural component, thus making a stronger, more resilient composite structure better suited for its end use. The transfer of stress into the pre-cast concrete component is accomplished by contact of the plastic resins that reach into the interstices and porous holes, gripping and bonding together the concrete with the fiberglass, plastics, etc., of the surface layer.

When it is desired thus to laminate three or four sides of a reinforced concrete component, a form pallet 42 with hinged or removable sides, as shown in FIGURE 11, 75

is placed over conveyor 40 and the plastic resins and reinforcing fiber are supplied onto this pallet while the sides are spread out flat as shown in full lines on FIG. 11. The resin is then gelled sufficiently to retain shape but still be soft and tacky. A concrete block coated on its bottom and side faces with polyester resins (or other plastic resins) is placed on the central part (bottom) and the side portions of the pallet, as shown in FIGURE 11. After a brief, preliminary partial cure to a tacky condition, the side members 52 of the pallet carrying the just gelled resin are raised to a vertical position (as shown in broken lines on FIG. 11) and pressed against the sides of the block, and the whole is then allowed to cure completely.

If the blocks are to be secured and bonded to one another into a beam or panel, etc., a sheet of fiber glass mat reinforcement is impregnated with plastic resin and inserted as shown at 54 into each joint between adjacent blocks. Small flows or jets of the resin plastic may be flowed into the joints between the blocks for securing and bonding them together, whether or not the fiberglass mats are used in the joints. The resin on these mats and/or on the blocks in the present example, is partially cured to a tacky condition; and then integrally engages the adjacent ends of two blocks permeating and penetrating in the same way that the layer of fiber-reinforced resin is laminated onto the outer faces of the blocks as described above. Such joints when tested by a recognized testing procedure have shown 2000 p.s.i. in direct shear.

The blocks in such case are pressed together longitudinally of the beam, at the same time forcing some of the resin into the pores of the concrete, by means of cables 26 and hydraulic jacks 56 acting between the cables and the blocks 20a. A plurality of such assemblies may be likewise assembled side by side, bonded and pressed together while setting the bond to make broader structural elements such as panels, even entire walls or floors.

The cables 26 pass from reel 62 along the conveyor 40 to a pre-stressing means 34, which is here shown as hydraulic jack 56 engaging between frame 58 and the cables 26 to stretch the cables to the desired prestress before they are bonded into or otherwise secured to the blocks 20a. The prestress tension is recorded on gauge 64 of the hydraulic jack. These cables 26, in such case, are stretched along the conveyor 40 as shown in FIGURES 9 and 10, and the blocks, preheated and with their bottom faces loaded with the just gelled resin, are lowered into place with grooves 60 each receiving one of the cables. The preheating of the blocks evacuates most of the water contained in the capillary pores of the concrete blocks, so that the resin can easily permeate and penetrate the concrete bodies. The heat thus left in the concrete hastens polymerization of the resin when applied on the hot block.

The blocks are then pressed down on the resin-saturated fiberglass reinforcement layer 22 and the cables 26, and thus are laminated with the partially cured and prepared resin composition until the whole fiber-reinforced component layer, consisting of the blocks 20a, the fiberglass 30, the sisal fiber 32, the resin composition, and the prestressing cables 26, are compressed together and cured. To this end, the temperature is maintained at the curing temperature, e.g., 250° F. until the cure of the resin is completed.

Meanwhile, the beam thus formed is engaged between the head frame 58 and the jack 56 and hydraulic pressure is applied to the jack to prestress the blocks in compression by reaction against the tension of the cables 26.

By thus incorporating in the composite structural element a plurality of energy-absorbing and dissipating joints, they serve to localize the effects of shock waves on structures into which they are built, and locally dissipate the energy of such shocks, thereby protecting against failure. The laminating materials used have the inherent ability to absorb shock waves. This is due to their ability to

take deformation resiliently, either in the body or surface components of the laminate.

The joints between the blocks thus bonded and cushioned together and the resulting articulated beam or other structure, are further described and claimed in my co-pending applications, Serial Nos. 210,803, 211,011, 211,705, filed February 14, 15, 19, 1951, respectively, said patent applications having been abandoned as to their specifications but the inventions disclosed therein not being abandoned and being claimed in subsequent patent applications of record in the U.S. Patent Office. The present application is a continuation-in-part to my co-pending applications Serial No. 229,852, filed June 4, 1951, and a portion of which is now Patent No. 2,850,890, Serial No. 340,642, filed January 16, 1953, and copending application Serial No. 345,084, filed March 27, 1953, said Serial No. 340,642, filed January 16, 1953, being of issue to a portion of its disclosure in my Patent No. 2,951,006. The invention here claimed is concerned with the combination of the reinforced plastic with the building unit, e.g., a concrete block, concrete slab, concrete wall, ceiling, floor, roof, beam, column, or other building component; and the nature of such combinations, whether in single units or multiple joined units wherein the surface is improved and the structural strengths and resistances of the units are greatly enhanced.

With the articulated beam structure built up as shown in FIGURES 9-11, when curing is complete the prestressing cables 25 can be cut, or released from the jacks 56, so that their tension is imposed on the blocks through the resin bond in the grooves 60.

The use of a bonded series of blocks in a floor or roof slab is shown in FIGURE 3; in this case, however, reinforcing rods or cables 24 extend centrally through the blocks tying together the beams made as above described and thus forming a strong tight floor or roof. The prestressed reinforcement members 26 are shown running longitudinally of the beams in grooves 60. Advantageously, these beams are also bonded together into larger slabs during the prestressing by laminating and bonding the concrete with fiberglass mat and polyester resin and other components as in the joints between the longitudinal series of blocks.

The steel cables whose ultimate strength is the order of 220,000 p.s.i. may be prestressed in tension at 102,000 p.s.i., allowing for a factor of safety required by good design, and bonded into the fiberglass and resin of the laminate in a prestressing machine which may be arranged to serve as a platen for thermal setting of the polyester resin in the fiber mat, thus producing a prestressed concrete slab which, when surface laminates are used, as above described, will be at least as strong as mild steel about 20,000 p.s.i., both in tension and in compression).

At least some of the holes 66 through the blocks are kept open by having aligned holes in any joint material used between the blocks, so that service pipes and wires, etc., may be located in them.

The layer 22b on the bottom forms a finished ceiling surface without further work. The beams or columns may be encased in the fiber-reinforced plastic 22 covering all outer surfaces thereof. Because of the greatly increased strength of the laminated concrete structural unit, increased loads can be carried on a given cross section, or reduced cubage, area and reduced reinforcement requirements are derived from the plastic and fiber reinforced structural components.

In other cases, the steel reinforcement is not required and will be omitted, the tensile strength requirements being satisfied by the fiber-reinforced plastic laminated to the concrete. This is especially effective when this reinforced plastic bonded to the concrete takes a form resembling I beam, T-, Z-, angle, round, rectangular or other beam section, thus serving both the function of a joint to bond adjacent blocks or other structural members and also the function of a rigid, high tensile strength beam.

The plastic saturated and bonded fiberglass joints form strong webs between the blocks which are kept strong even in case of fire by the thermal protection afforded by the porous bodies on either side, especially when such exterior bodies are made with pumice, "Rocklite" or other fire-resisting concrete mixtures.

Reference has been made to the heating chamber 46 for curing the resin composition. Although it is possible to cure resins without heat, especially if polymerization or vulcanization catalysts are used, or in the presence of light or other radiant energy, it is most advantageous under factory conditions to use both heat and catalysts to hasten the curing reactions.

Heating the materials in this invention can be by convection and/or radiation from burning fuels, by ovens, heated platens, heated molds, heating blankets or electrical heating pads, e.g., sheets of silicone rubber, fabric reinforced or fiber reinforced which contain the heating elements, induction heating devices, and in general any available heating means.

The heating means is advantageously used together with a pressure means, including pressure of atmospheric air against a vacuum, or of compressed air, or mechanically applied pressure.

Under factory conditions, heating and pressing by means of a heated platen is most advantageous. Apparatus for such use is shown in FIGURES 12 and 13, in which a cast reinforced concrete footing slab, as indicated at 68, is provided with walls 70 and 72.

Hydraulic jack press 56f is securely mounted on the slab 68 and is fastened to cross beam 74 which travels on a frame 76. Pull and push rods 78 connect the pressure cross beam 74 with sliding guide heads 80. A cross shaft 82 is fastened to and extends between the sliding heads 80; and the cable-like and belt-like, plastic-insulated fiberglass reinforcing means 26f are looped over the shaft 82 for pre-stressing.

On opposite sides of rod 78 the walls 70 form abutments against which bearing beams 84 and 86 transfer prestressing loads derived from hydraulic jack presses 56f and 56f' through pressure cross beams 74 and 88.

At the opposite end of the machine, the walls extend upward to form an abutment 72 opposite to that at 70. A pressure beam 88 when secured by abutment 72, opposes the force applied by hydraulic jack 56f' through the series of blocks 20a which are braced against pressure beam 88. Pump 92 provides pressure for hydraulic jack presses 56f and 56f'; and gauge 64f records the pressure.

Between the walls 70 and 72 is a heated platen 90 which serves as a support for the pallets or mold pans 42f of polished, stainless steel sheet, chromium-plated sheet metal, aluminum sheet or plastic sheet or lining.

Guides 94 at the end of platen 90 and tail shaft 96 provide for anchoring one end of the reinforcing members while the other end is engaged by shaft 82 and pulled by the hydraulic jack press 56f.

A pressure beam 98 above the platen 90 is provided with press means 100 (shown here diagrammatically as screw jacks) by which beam 98 presses the blocks 20a against their pallets or pans 42f.

Mechanically or electrically operated hoists 102 are mounted to roll on track beam 104 above the platen 90 for use in removing the heavy beams or panels which may be made when multiple assemblies of blocks are bonded together as above described. When blocks are treated individually to apply the molded fiber-reinforced plastic, they are ordinarily removed manually.

In use of this machine, the press beam 98 is raised, a series of mold pallets 42f are filled with settable resin composition and reinforcing fiber and the blocks 20a placed on top. With a series of blocks thus assembled on the heated platen 90, the press beam 98 is lowered onto the blocks and forced down, pressing the blocks against the facing and reinforcing material on the pans

or pallets. The blocks remain thus for a time sufficient to cure the resin.

When multiple assemblies of blocks are to be integrated into a reinforced beam or panel, etc., a roll of packaged reinforcement 30f is mounted on axle 105 and the packaged material drawn out from the roll through the guides 94 across the platen 90 above the pallet 42f. The ends of this reinforcement are engaged on shafts 82 and 96, and if the packaged material has a wrapper, it is removed or prepared for bonding to the block. The hydraulic jack press 56f is operated to pre-stress the reinforcement, and blocks 20a are placed thereon in alignment separated by fiber mats 54f impregnated with plastic resins suitable for polymerizing into yielding resistant resilient joints securely bonding adjacent faces of the blocks.

The desired compression forces are exerted on the series of blocks by hydraulic jack press 56f and tensile stress on the reinforcement by hydraulic jack press 56f. When the required amount of prestress is put into the reinforcement, the hydraulic forces in hydraulic jack presses 56f and 56f' are maintained until the polymerization reaction is complete and the pre-stress is fixed by the bond and augmented by chemically induced forces due to shrinkage occurring during the polymerization reaction.

The machine shown in FIGURES 12 and 13 is also adapted for use of stock materials. Various rolls of reinforcing mat and/or woven fabric can be mounted on axles like 96 in any one or more of the holes 106; drums 108 of resin, filler and other ingredients stored overhead on frame 110, from which these materials can be fed by gravity to a work table where the reinforcement and the resin, etc., are placed on the pallets in proper order and proportions, after which the blocks are pressed into the thus assembled material and heated on platen 90 until cured to a tough, strong and durable layer.

This machine is also adapted for making individual blocks as well as beams and slabs using multiple assemblies of blocks bonded together. Such individual blocks are shown, for example, in FIGURES 4, 5, 6 and 7. The body of the block 20a is of concrete and it is covered with a laminated reinforcement layer 22, which is molded in mold pans as shown in FIGURES 4 and 7 to form the layer 22 not only on the face but extending into an overhanging lip 112 along the side and end edges.

This lip may be made with an undercut to serve as an additional anchorage for mortar or other bond between blocks as shown in FIGURE 4. This lip may overhang the block on all sides of the face by $\frac{3}{16}$ ", thus providing a $\frac{3}{8}$ " space for mortar joint with the lips on adjacent blocks contacting or in thin line joints which are both structurally desirable and decorative. Greater or less overhang can be used where structural or design considerations require it. The lip may also be roughened or grooved for a suitable bond or gasket 113. Such gasket can serve both as a bond and reinforcing member strengthening the wall and rendering it impermeable at the joints, and to this end may be a cable-like reinforcement of glass fiber bonded and insulated with resin, e.g., as described and claimed in my copending application Serial No. 345,084, filed March 27, 1953.

One important feature of my invention is shown in FIGURES 1, 4, 7 and 8, namely, the integration of the resin composition layer with the concrete. As stated above, the resin, under the influence of external pressure or suction exerted through the block and/or capillary action, is extended into the interstices of the concrete, thereby reaching around and gripping the grains and particles of the concrete, like fingers, and at the same time adhesively bonding said particles and grains into a strong, composite cemented stone. The capillary action of the preheated concrete on the resin compositions, as given herein, is very strong.

In FIGURE 1 the scale is enlarged to show what one sees with a magnifying glass when a structural unit according to my invention is sawed with an abrasive wheel and washed clean. In this figure, grains of sand and aggregate are shown at 114, these are bonded by a more or less continuous film or mass of Portland cement bond 116, but having pores and interstices 115 into which the resin extensions 118 have entered, adhering to the grains 114 directly, or indirectly by bonding to the cement 116. In the smaller scale FIGURES 4, 7 and 8, the finger-like extensions are represented diagrammatically by lines extending into the body of the concrete.

The pores may be filled completely as shown at 118' or the resin may be porous as shown at 118". The latter is preferred and can be achieved according to my invention by including in the resin composition a solvent or blowing agent or a substance which is volatile under the conditions encountered within the block, so that bubbles or channels are blown by gas or vapor released by the heat of the block when the resin is still fluent. In the formulas given below, monostyrene serves this function as well as cross-bonding the polyester. The escaping styrene vapors push the fluent resin along the walls of the larger pores and into the smaller pores.

This filling and/or lining of the pores of the body of structural material not only integrates the surface high tensile layer, but also greatly increases the strength of the structural body itself in the zone of penetration—in tensile, shear and torsion as well as in compression. This integrated structure can be extended to any desired depth up to several inches, and advantageously is at least $\frac{1}{3}$ the thickness of the facing layer and should be at least $\frac{1}{32}$ " in depth, and for best results should be at least $\frac{1}{4}$ ". In general, the depth of engagement of the finger-like extensions should be greater than the diameter of at least one-third of the grains in the concrete body.

Fibers for use in the reinforced plastic layers may be selected on the basis of stress analysis and each use will dictate selection based on cost, availability and strength characteristics; but fiberglass has outstanding and surprising advantages when combined with concrete according to the present invention.

The fiber best adapted for use adjacent the concrete surface according to this invention is fiberglass, i.e., very fine strands of glass which may be applied in any form; loose, in roving or in woven form. Long filaments are best, but chopped fibers or staple yarn can be used, as the impregnation with adhesive resin will secure them to one another and insulate them against mechanical injury. The high tensile strength and very high elasticity and low elongation of the fiber glass bring it into supporting relation to the concrete before the latter can be strained to failure. Fibers with greater stretch can be used if pre-stressed; and, where several layers of fiber are used, those of greater stretch are advantageously used farther from the surface of the concrete.

Any fiber may be used in the reinforced plastic layer if it has the required strength, compatibility with the other materials used in said layer, and permanence under the conditions of use; but no other fiber is fully equivalent to fiberglass for such use. Among such other fibers or strands which one may use are fine metallic wires, cotton, wool, linen and other textile fibers, hemp, sisal, and other rope fibers, bamboo fibers, burlap, nylon, Orlon, Dacron, vinyon, rayon and other synthetic fibers, wood fibers, etc. In lieu of the fiberglass, or in addition to it, but with somewhat less advantage, other mineral fibers may be used. Fused quartz fibers may be used to give high strength, low stretch, and heat resistance no less than ordinary fiberglass, but its cost is excessive for most uses. Asbestos and other volcanic glass fibers as well as rock wool can be similarly used, but the fiber length is limited and characteristics are less uniformly under control.

The fibers are most advantageously used in the form of mat, bat or roving, but may be woven cloth or other

form. The fibers in such fabrics may be unidirectional, multi-directional, oriented or disoriented to any extent, depending upon the stresses to be encountered by the structural unit being formed. At least some of the fibers should be parallel to the direction of greatest stress and if there is a direction in which major stress may always be expected, the fibers are oriented along that direction, e.g. by use of unidirectional mat or roving.

The resin gives much latitude for choice, depending upon the conditions to which the completed structure is subjected. If strength under high temperature is not essential and if expected tensile loading at higher temperatures is not in excess of the strength of the concrete and its non-plastic reinforcement, thermoplastic resins can be used. Soluble rigid resins which are not thermoplastic can be applied in solution and the solvent evaporated when adhesion and penetration have been established.

Where the strength of the resin is relied upon for structural strength of the member, setting resins give important advantages and I have found most advantageous for this purpose the unsaturated polyesters cross-bonded with an active unsaturated monomer "vulcanizing" agent, such as styrene or vinyl toluene, etc.

Rigid plastics are most advantageous because they can bring their own tensile strength to bear in reinforcement of the concrete. More stretchable set plastics, like rubber, and especially the stiffer synthetic rubbers, although they may not of themselves afford much tensile support to the concrete before it is stressed to failure, nevertheless may be used to bond reinforcing fibers such as fiberglass to the concrete.

Among the various resins which I have found most useful for this invention are the following:

Polyester resins
Alkyd resins
Polyester resins containing triallyl cyanurate to give heat resistance
Polyester resins made from triallyl cyanurate and modified maleic alkyd
Polyester resins containing fireproofing additions such as antimony oxide and Chlorowax 70
Epoxy resins
Phenol aldehyde resins
Amino aldehyde resins
Silicone resins

Among the best thermoplastic resins for this invention there may be mentioned:

Vinyl resins
Poly tetra fluoro ethylene resins (Teflon)
Poly chloro tri fluoro ethylene resins (Kel-F)
Polyamide resins (nylon)
Polystyrene

Among the rubber (elastometric) resins useful as mentioned above are:

Buna, Perbunam, GRS, etc., Butadiene polymers and copolymers, especially the stiff long chain cross-bonded resins
Pliofilm (rubber hydrochloride)
Neoprene (polymeric chloroprene)
Thiokol (polysulfide rubbers)

It is also advantageous to use compatible combinations of thermosetting and thermoplastic resins, e.g., melamine-nylon and phenolic-nylon combinations.

Generally, the resins as directly supplied by manufacturers for other uses do not have the required toughness and the desired limited stretch; and I find that addition of styrene monomer or other materials such as vinyl toluene, or non-rigid unsaturated polyester resins like Pittsburgh Plate Glass Co. #5208 when added to harder, tougher unsaturated polyester resins like Pittsburgh Plate Glass Co. #5003, provide the kind of a mix that results in a good product.

Combinations of compatible resins may be used, for example, by assembling such resins respectively in several successive layers in the mold form or on the pallet and in the fiber and on the concrete body. Thus, one resin best suited for the purpose may be used for impregnating and adhesion to the concrete to strengthen it and bond the fiber glass layer; another may be used to impregnate and adhere to the fiber glass and to insulate the fibers from one another; a third may carry the filler and pigment for molding the face and giving it a desired color and appearance; while still another may be used at the surface as a hard glaze for wear and good appearance. Ordinarily, two or at most three different resins will be used, although frequently the compounding of the resin will be different for different layers. Thus, a monostyrene with suitable catalyst and with or without reinforcing pigment or diluent can be used in the concrete as an integral tensile reinforcement, while unsaturated polyester with styrene therein as a cross-linking vulcanizing agent is used in the fiber glass mat and for most of the thickness of the surface layer, and an alkyd resin with or without a fine particle silica pigment is used at the surface to give a hard scratch-resistant finish.

The resin used in my invention is advantageously liquid. It may be in various viscous states or may be a paste resin or even a powdered resin. The resin catalyst, such as benzoyl peroxide and other peroxides, persalts or hydroperoxides (Lupersol DDM etc.), and for epoxy resins, dicyandiamide or phenylene diamines, may also be liquid, paste or powder and may be incorporated directly into the resin in intimate mixture or can be in fusible or crushable capsules from which it is released or expelled by heat or pressure of the molding operation.

Fillers, pigments and other ingredients may be used according to the ordinary principles of plastic compounding, and special effects can be attained as set forth in my copending applications. The fillers thus used are many and varied. Some control shrinkage of plastic resins; some extend the resins to reduce cost of the final product; some impart toughness or other strength characteristics; some, like silica, impart surface hardness, texture and stone-like finish. Clays of various kinds impart smooth surface with reduced sheen and glare. Pulverized or granular rocks and minerals give various surface design effects, colors, textures and hardness. Among the many fillers available and useful in my invention, a few of those which can be used with advantage are calcium carbonate, clay, onyx dust or granules, silica, pumice, obsidian, grits, pulverized colored aggregates, minerals, dry colors, wood flour and other pulverized fibers, colors, etc.

Increased use of fillers in the face layer over and above the amounts commonly used in reinforced plastics production have improved properties and lowered costs for my purposes. 40% to 60% by weight of the resin content of a given mix has been considered heretofore a high filler content; whereas I have used as much as three times by weight of graded mixtures of filler in a resin mix. Whitaker, Clark and Daniels "Snowflake" is one CaCO_3 which I find can be used in workable mixes of three to one of the resin.

Following are a number of examples of formulations according to my invention.

Example I

Ordinary so-called 4" x 4" x 16" concrete blocks made of high quality concrete lightweight aggregate. The actual dimensions of such blocks are about $\frac{3}{8}$ " less, to allow for mortar joints.

Mold pans of stainless steel measuring 3 $\frac{3}{4}$ " x 15 $\frac{3}{4}$ " inside, with side edges $\frac{3}{8}$ " high, were made of 18-gauge stainless steel.

Inside surfaces of the pans were treated with a mold parting agent for polyester resin, for example, that available on the market as "Mitchell Rand #1894EXS" a pro-

prietary wax mixture parting agent and surplus parting agent wiped out with a rag to leave a uniform waxy film over the entire inner surface.

A thin uniform film of the facing resin was brushed onto the pan thus treated. This facing resin being prepared as follows:

600 parts by weight of polyester resin (Vibrin VX 1058C or Vibrin #151 unsaturated polyester resins made by Naugatuck Chemical Division of the U.S. Rubber Co.)
12 parts benzoyl peroxide as a catalyst

3 parts of peroxide catalyst "Lupersol DDM" made by Novadel-Agene Corp.

50 parts styrene monomer

2 parts of mold release agent, #5918 a proprietary mold release agent having wax-like properties and also useful as internal lubricant for release purposes when added to unsaturated polyester resins as is known in the art, made by Pittsburgh Plate Glass Co.

This mix tends to thicken at low temperatures and should be applied in a room temperature between 65 and 75° F. It can be thinned, if necessary, with up to 20% additional styrene.

Onto this facing film, place a thin fiberglass mat cut to the size of the form. For this I have used "surfacing mat .010" polyester bond of Owens-Corning Fiberglass Corp. This mat is worked down or allowed to settle down into the facing layer of resin using care to avoid trapping air bubbles.

Into the pans, on this facing layer, is added, in a uniform layer, 75 grams of body resin mix made as follows:

544 parts by weight of liquid polyester resin (Vibrin VX1058C or Vibrin #151—a mixture of unsaturated polyester with monostyrene)

110 parts styrene monomer

587 parts calcium carbonate pigment ("Snowflake" brand from Whitaker, Clark & Daniels)

62.5 parts of Chlorowax C-70 a chlorinated wax containing 70% chlorine from Diamond Alkali Co. as fireproofing agent

62.5 parts antimony trioxide powder, as fireproofing agent

5 parts green pigment ("Laminac #600" of American Cyanamid Co., or "Hunter Green" from Claremont Pigment Dispersion Co.)

11 parts benzoyl peroxide crystals, as a catalyst (or 22 parts "ATC Lupersol Paste" of Novadel-Agene Corp.)

500 parts of the resin was first put into the bowl of a mixer and 500 parts of calcium carbonate pigment added and thoroughly stirred in by the mixer while adding styrene from time to time as required to keep a creamy flowable consistency. 10 parts of the styrene is saved out and mixed with the catalyst and this mixture then added to the resin-pigment mixture in the bowl.

The remaining 44 parts of resin are mixed with the color and the mixture added to the other ingredients in the mixer bowl. Mixing all these ingredients is continued for from one to four hours until they are well blended, and the resulting mix is de-aerated by standing with not over 10" depth for at least 12 hours at about 72° F. (a shorter time if subjected to vacuum).

A .75 oz. reinforcing fiberglass mat "Treatment #18" from Owens-Corning Fiberglass Corp., is cut to fit in the pans and placed onto the layer of body resin and left at least one hour to soak up the resin and settle into it. Ordinarily, this period will be extended to about 4 hours.

Concrete blocks are prepared by grinding true (as shown in my Patent No. 2,805,448) their faces and edges, which are to be covered with plastic. These blocks are then baked out in a tunnel kiln at temperature of 220° F. until thoroughly dry to a depth of at least 1/2" from the face which is to be covered. The blocks when taken from the tunnel are placed immediately into the mold pans previously filled as above described, so that not more than 15° F. temperature drop occurs at the face of the

block before it contacts the resin. The block and pans are then immediately put into the press and gradually (i.e., without impact) pressed with 40 lbs. p.s.i. on the face of the block. (This may be 5-40 lbs., p.s.i. with other block depending upon its porosity factor.) The lower platen of the press in contact with the pan is heated to 250° F. and accurately maintained within $\pm 10^\circ$ F. The pressure and temperature are maintained for 6 minutes, after which the press is opened and the blocks removed.

Each block is transferred quickly from the press to a post-curing oven, still in its mold pan, and there held at 250° F. $\pm 10^\circ$ F. for about 1/2 hour, and then taken out of the oven and removed from the mold pans.

Example II

8" x 16" concrete blocks are made with "Rocklite" aggregate, a Ventura, California, clay expanded during kiln firing at 1900° F. to 2100° F. giving lightweight aggregate varying in size from sand to 3/8".

Mixed polyester resin composition is made as follows: Mix 0.1575 lb. benzoyl peroxide with 0.5 lb. styrene monomer.

Mix 25 lbs. Selectron 5003, polyester resin manufactured by Pittsburgh Plate Glass Co. with 2.5 lbs. of Selectron 5208 resin (also P.P.G. Co.). Add 7 lbs. "Perdonyx" limestone powder (up to #30 mesh) of analysis, 90% CaCO₃ and 2% MgCO₃. Then add .5 lb. 325 mesh Georgia Kaolin (44% SiO₂, 40% Al₂O₃, 0.5% Fe₂O₃, 0.5% CaO, 1% TiO₂, moisture 0.25, loss on ignition 13.0%) and 0.1 lb. Pittsburgh Plate Glass Co. mold release agent #5219 and mix thoroughly. Then add the mixture of styrene and benzoyl peroxide. Continue mixing in a pony mixer at room temperature (60-77° F.) for from 1 to 4 hours. The mix is left at a temperature of about 68° F. and is used up within 8 hours, mixing before each use.

200 grams of this mix is placed in each of the stainless steel pans 8" x 16" x 1/4" deep. More resin is required if the block is more porous than average. The filled pans are left standing in the open for 15-30 minutes during which some settling of heavier particles occurs. Then place a mat of 2-oz. fiberglass Owens-Corning Tr. 16 cut to fit freely in the mold pan. Pan is left until mat has settled into the resin or this may be hastened by vibrating.

After the mat has settled into the resin, heated block dried and hot as in Example I is lowered gently onto the mat in the pan and placed on the heated (250° F.) platen of the press. Bring pressure up immediately to 15 p.s.i. and maintain pressure for 5 minutes. If no pressure, or low pressure, is used during cure, voids will remain near or at the surface giving an effect like that of travertine.

Remove the block from the press and lift and strip off the pan. The block can be used with care as soon as it is cool, but advantageously will be stored for several days before shipping to the building site. The surface of the cured block has a Barcol hardness in the range 30-60.

The mold pans when new, even if highly polished, should be treated before each use with a suitable mold release agent, e.g. Mitchell Rand #1894 EXL, but after about 50 uses it is ordinarily sufficient to clean the pans and recoat with release agent once a day.

Example III

1 kg. Bakelite polyester resin BRS #203 and 0.2 kg. U.S. Rubber Co.'s Vibrin polyester resin #151 and 0.1 kg. vinyl toluene are thoroughly mixed in a glass or stainless steel bowl. Add 0.5 kg. of #19 silica pigment, 325 mesh; and, when it is well mixed in, add 0.2 kg. #F6844 ground pumice, 100 g. Champlain Red Granite ground to 100 mesh and 50 g. mineral brown pigment Hoover #3094. Continue mixing in a poly mixer for about 2

hours; then add 70 grams Lupersol ATC catalyst, and continue mixing for 1 more hour. At 68° F., the "pot life" of the mix should be about 1 hour (i.e., each batch should be used within the "pot life" time), but as variations in ingredients may occur, the gel time and cure time are preferably determined by a small sample from each mix. Variations in gel time can be controlled to required limits by varying the amount of catalyst and/or accelerator or inhibitor in the mix.

With the mineral particles well dispersed, place 225 grams of the mix into each 8" x 16" mold pan. Allow to stand for 5 minutes in the pan; then place 0.10" surfacing mat of fiberglass onto the mix and let stand until the mat absorbs the liquid resin mix. Place a second layer of similar glass mat but pre-dyed red (which dye will "bleed" into the resin) and allow this to absorb the resin mix. Then place a layer of 0.75 oz. Owens-Corning Tr. 18 fiberglass mat on the second layer; then a 2 oz. unidirectional, silane treated type fiberglass mat in the pan. Each mat should settle into the liquid resin mix and become saturated with it without pressing, which would entrain bubbles in the mix, before going on to the next step. A sufficient surplus of the mix should be present to be pressed up into the porous block to the extent of at least 1/4 inch.

Next, 8" x 16" concrete blocks made with "Rocklite" aggregate, a fire-expanded Ventura clay concrete aggregate as in Example II, are preheated to 275° F. in tunnel kiln, heating quickly but avoiding both excessive heat and prolonged holding at the high temperature. Blocks, when heated to 275° F., are quickly transferred with as little loss of temperature as feasible into the mold pan where they are lowered gently onto the saturated mats. The assembly in the mold pan is then transferred immediately to the heated platen of the press and pressed for about 5 minutes at 27 p.s.i. pressure, which is built up gradually in a hydraulic press over a period of about 4 seconds. After this cure period, blocks are promptly removed from the press and the pans immediately stripped off.

Example IV

Instead of brushing or flowing the facing resin mix into the mold pans, it may be sprayed in with a sprayer such as is used for applying resin finishes to automobile bodies or other surfaces. This permits achieving special finish effects by variations in the application techniques and also provides a desirable method of distributing the resin over the surfaces of the pans.

Since the resin compositions used for spraying will ordinarily have volatile constituents such as monostyrene and acetone, it is important to provide for removal of vapors from the work space and in a manner which avoids explosion and fire hazards. This is a problem common to spray application of various finishes and is well understood in the art and generally governed by local regulation.

As one example, a facing mix comprised of the following is placed into the material tank:

- 600 parts by weight of polyester resin fluid (e.g., Vibrin #151, or Vibrin #117, or Vibrin #142 all unsaturated polyester resins as made by Naugatuck Chemical Division of U.S. Rubber Co., or unsaturated polyester resins Selectron #5003—75% plus Selectron #5208—25% as made by Pittsburgh Plate Glass Co., or American Cyanamid Co.'s #4116—70% plus #4134—30% or American Cyanamid Co.'s #4116—75% plus P.O. Co. #5208—25%)
- 12 parts of benzoyl peroxide as catalyst
- 3 parts by weight of Lupersol DM (This may be more or less depending upon the system and time of cure required.)
- 10 parts of styrene monomer
- 2 parts of Pittsburgh Plate Glass Co. #5918 mold release agent

This mixture is kept at 65° F. to 75° F. If humidity goes over 50% (e.g., on cold rainy days) add small amount acetone, up to 20% by volume to aid in spraying. At higher temperatures avoid getting the mixture too thin. As deposited from the spray gun, the material should stay put and not form "weepy" globules or runs.

The Lupersol DDM is a catalyst which must be used with care. It or the accelerator, e.g., cobalt naphthenate (6%), should be kept separate from the rest of the mix until it is sprayed. It is better not to mix the catalyst with the resin before spraying so that all danger of setting the resin in the spraying apparatus will be avoided. To this end, the catalyst is put into a glass jar and thinned with 40 parts of the styrene monomer and the whole is then placed in the catalyst dispensing pressure tank.

As apparatus suitable for the spraying, the following may be used:

Catalyst "gun" Binks Manufacturing Co.'s No. 18 (63Bx 66 PE) complete with the following:

- "D-5666" two-gallon pressure tank with regulator and gauge
- "D-5667" two-gallon pressure tank with regulator and gauge
- "D 1901" Stainless steel adaptor
- "D 1902" Stainless steel tube
- "PA-50" Stainless steel nipple
- "H 106" Air hose and connections
- "H 208" Material hose and connections
- 3/16" neoprene hose with stainless steel connections
- Glass jar for holding catalyst inside of a pressure tank

The air pressure is regulated in relation to the viscosity of the mixture, its temperature, the ambient temperature, the specific gravity of the mixture, the orifice size used and the condition of the equipment (especially how long it has been used since cleaning and accumulation material around the spray orifice, etc.). Ordinarily, a pressure of 7-15 p.s.i. is used on the resin mix delivered through the material hose and 40-70 p.s.i. on the atomizing air in the #18 spray gun. The air is advantageously dried by an oil and water separator and extractor. The pressures and orifices used on the material (resin mix) spray and on the catalyst and/or promoter spray are adjusted to each other to give the desired gel time to the applied resin. The resin mix may be designed to gel in open air at ambient temperature, but I find it preferable to heat it in a tank or oven as described above.

All utensils should be kept clean and abide by temperatures set if clear sparkling laminates are desired. Clouded mixes impair the decorative value of the underlying layers.

After the mold pans are spray coated with this finish resin mix, the body resin, reinforcing fiber and concrete block can be the same as in Example I and can be added and the whole pressed and cured as described in connection with FIGURES 9-11. This should be done before the facing layer has so far set as to impair integration with the following layers of body mix but advantageously after the facing resin has partially gelled. This condition can be attained in two minutes if the pans are heated to 200-220° F.

Instead of the clear resin mix for the facing it may be tinted, e.g., for green with Selectron Green #5572, for blue with Selectron #5571, for yellow with Selectron #5568 (Selectron being the trademark of Pittsburgh Plate Glass Co.).

The resin mix may also be made thixotropic by addition of 0.5% to 2% of fine clay (99.6% capable of passing through a 325 mesh screen) or of Santocel CX (a trademark of Monsanto Chemical Co.). Such a mix can be sprayed as described above.

Example V

If a block wall, beam or panel is to be exposed to different temperatures on opposite sides, it is desirable that a side which is continually exposed to the colder temperature be previous to water vapor so that if any air which leaks or diffuses into the body of the block should come close to the dew point, the moisture can escape to air of lower relative humidity outside the wall.

A plastic layer for this purpose can be made as follows:

To the facing resin mix of Example IV add the following:

120 parts of a white Cyptocrystalline Silica —325 mesh
5 grams Laminac 600 green pigment ("Laminac" is the trademark of American Cyanamid Co.)

60 parts of CaCO_3 —(Whitaker, Clark & Daniels "Snowflake")

50 parts acetone

Mix for four hours before addition of Lupersol DDM followed by one hour mixing of the total resin mix. Add the acetone just prior to use. Spray on the faces of mold surfaces prepared with mold release. Keep each pass of gun moving equally across the face of the mold and try and cover the mold in three passes. The body resin mix and reinforcing fiber are added and the whole used as in Example IV.

The high proportion of silica pigment in this facing resin gives greater abrasive and scratch resistance to the molded surface.

Example VI

To obtain textured or matte surfaces and also at the same time provide a protective cover to the finished face I use a non-compatible resin such as cellulose acetate as the first coat placed in the mold pan. Dilute cellulose acetate in acetone until it is watery consistence. Place in an ordinary type spray gun and spray the liquid cellulose acetate mix onto the mold. By varying the intensity of the spray, its viscosity and the number of passes, it is possible to build up a variety of textures. As the acetone evaporates rapidly, the layer appears as a white film. When the film is complete to your satisfaction as to grain or texture, proceed as in Example V.

Example VII

For multi-color work use a stencil, or perforated, or open fabric, screen of the pattern desired. This is laid over the mold face before spraying starts. Spray the first colored resin mix and allow to gel. Remove the stencil and spray the second color resin mix and allow it to gel. Mixtures as made in Examples IV and V may be used and completed as in Example I for the complete element.

Example VIII

Some very interesting architectural effects are obtained by using discrete particles of stone, glass, quartz, marbles, onyx or the like. White silica sand or colored sands also make good decorative as well as good wearing surfaces. I have used single mesh sized materials such as 50 screen size red Champlain granite particles, onyx dust graded from very fine to $\frac{1}{16}$ " to $\frac{1}{8}$ " size granules. Tourmaline waste wherein the crystal formations are broken but still discernible as long crystals; crushed Arizona pink Tufa, crushed black and white quartz, Mexican golden onyx, all the colored marbles crushed to fines; the volcanic glasses, pumice and pumicite, vermiculite, petrified wood from Grand Canyon country, gem stone waste from Pala, California, and ocean sand all when used as fillers and decorative elements have produced unbelievable beauty.

Using the same facing resin mix as Example IV and

preparing mold pans with it in a gelled condition, I have taken for example the following:

10 parts of onyx dust—to 50 mesh

10 parts of crushed black and white quartz—to 30 mesh

10 parts of #30 silica sand

200 parts of white silica—325 mesh to 400 mesh

This dry mix was placed in a shaker hopper screen and the pre-gelled facing resin mix in the pans was passed under the hopper while an uneven layer of the dry mix was allowed to shake through onto the gelled surface. Next I sprayed in about 200 grams per 8" x 16" pan of an opaque body resin mix, taking care not to move the particles or get opaque resin all around them to obscure them from view, i.e., from the finished face. Next I laid in a layer of Owens-Corning Tr. 16—2 oz. mat and allowed the resin to permeate the mat, as in Example I. When the body resin mixture appeared through the mat, I placed a heated block upon the mat and then placed the mold and its contents in a press at a mold temperature of 240 F. and gradually applied pressure to 20 lbs. per square inch.

Example IX

The making of wall panel out of ordinary yard stock 8" x 8" x 16" concrete blocks is accomplished in the following manner:

As an example a number of panels 8" x 16" x 96" were made. The mold pan was made of 16 gauge polished surface stainless steel $\frac{1}{2}$ " deep x 16" x 96". Mold release was liberally applied and then rubbed into the steel with all surplus removed. A facing mixture as in Example V was sprayed onto the long mold and allowed to pre-gel. Next a quantity of body resin such as in Example I was placed into the mold pan equal to about 250 grams per square foot of mold area. Next twelve pieces of 8" x 8" x 16" Rocklite concrete block were dried in an oven to a temperature of 280° F. and placed into the mold pan one at a time. As a block was placed, I placed vertically across the mold and against the block a piece of 8" x 16" —2 oz. Owens-Corning Tr. 16 mat. a random chopped strand fiber glass mat which had previously been saturated with the body resin mix, after which I pressed a second block against the vertical piece of mat. This formed a joint between the two blocks. Proceeding thus, all the twelve blocks were assembled and pressed together longitudinally. At the time I placed the body resin into the mold pan, I also placed a layer 16" x 96" of Owens-Corning Tr. 16 mat on top of the resin, allowing the resin to permeate through it. Also, I placed on top of the previous layers in the pan a piece of 3 oz. special unidirectional mat which had been previously impregnated with a silane treatment and a polyester resin. The unidirectional mat was stressed longitudinally in placing so that the full value of its fiber strength could be obtained lengthwise of the panel.

The assembled blocks were next put under pressure both vertically and horizontally, forcing the blocks into adjacent close contact horizontally and the whole assembly down into the pan so that the laminated layer could integrally join the assembled blocks and joints. The resin was set while thus pressed. The resultant structural panel was a prestressed unit.

Next I placed the assembly in a holding device and turned the unit over and applied facing and reinforcing layers to the other side in the same way, so that when complete I had a strong panel of 8" x 16" x 96" with two sides finished.

Example X

The making of a long beam similar in function to prestressed concrete beams and using both conventional prestressed constructions and my inventions is accomplished as follows:

Precast concrete blocks made as in a Besser Block

machine of concrete of 3000 p.s.i. strength when tested in the conventional known manner are provided to the desired length of beam. Special end blocks solid in nature except for holding holes for the prestressed cable fittings are also provided. In this case I used two 1" 5
Roebbling cables standard to Roebbling's standards and fitted with Roebbling's end screw fittings.

A casting pan similar to the one used in Example IX fifty feet long is provided upon a heating platen. A facing mixture as used in Example V was sprayed on the mold release treated pan face and allowed to gel. 10
A layer of 2 oz. Owens-Corning fiber glass mat previously impregnated with a catalyzed mixture of Pittsburgh Plate Glass Co. #5003 unsaturated polyester resin was interposed between each joint of the blocks, same being 15
fitted over the two cables which had been previously pulled through the assembly in a loose manner. The joinery material in place, next I connected the two cables to the prestressing device and hydraulic jacks and placed the cables in tension to the desired preload and the concrete and the joints therebetween into compression. Heretofore, precast concrete blocks when made into a beam had either to be ground to a smooth face to face fit or had to be joined with a bed of mortar to insure equal bearing in all contact faces between blocks. 20
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The expense and delay of grinding blocks is serious. Mortar joints are relatively weak and need considerable time for setting of mortar. In my invention it is not necessary to have the face of the concrete block truly 30
planar, as the resin-filled fiber glass mat accommodates irregularities and, when the mat is cured, exerts a prestressing force upon the adjacent concrete. The irregularity of the joint contact surfaces is an advantage when the joint is placed in shear loading because of the frictional resistance of an irregular face. Some of my joints have been tested successfully in excess of 2000 lbs. per sq. in. in direct shear. 35

With the beam members joined together into a unit fifty feet long I next placed in the casting pan a quantity of reinforcing fiber glass which is multidirectional as a mat and of about 4 oz. per sq. ft. weight. Upon this mat I poured a quantity of resin mix equal to about 500 grams per square foot and allowed the multidirectional mat to become saturated. 40

Next I rolled out a prepared pre-impregnated unidirectional mat which is as wide as the beam, i.e., eight inches, and placed this mat in the casting pan on top of the previous layers. There must be a sufficiency of resin present to insure complete coverage of the glass fibers. In this case I used fiber glass roving at 20 rovings to the inch. The correct amount is a structural engineering problem and calculable by known engineering art. The unidirectional mat made up into an endless belt-like construction as shown in my copending application Serial No. 345,084 is placed in the mat stressing device shown in this application and the desired amount of preloading imposed thereon. The entire assembly of blocks, cables and resin filled fiber glass reinforcements is then pressed against the mold pan and heated by the platen thereunder at a temperature of 250° F. for about 6 minutes. The preload previously obtained by the hydraulic jacks in tensioning the cables is now fixed permanently in place by the integrated thermosetting concrete and resin mix. The preload is also augmented in amount by shrinkage forces occurring within the laminated body when the resins polymerize. 45
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Obviously, the beam can be finished on all exposed sides or fewer as desired. The additional reinforcement placed on the sides of such a beam give it much more strength. 60

The reinforcing beams such as just described can be placed next adjacent one another to form a solid deck of great strength. The assembly of such a deck is facilitated by pulling prestressing cables through previously 65
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prepared holes in a series of beams wherein the joints are made of the above described packaged materials. These joints can be bonded for added strength.

Example XI

The body resin may also be applied to the block by spraying, using special precautions to control penetration by the resin. If this is then cured without use of molds, the surfaces follow the contour of the concrete body or block. Such finished surfaces generally have a better value in the the control of acoustics and do please certain aesthetic tastes. As one example, concrete blocks were dried in an oven and heated to a temperature of about 230° F. A layer of penetrating and permeating resin made as follows was sprayed on the hot block:

500 parts of Pittsburgh Plate Glass Co. #5003 unsaturated polyester resin
122 parts of Pittsburgh Plate Glass Co. #5208 unsaturated polyester resin
75 parts of styrene monomer
7 parts of benzoyl peroxide as catalyst
3 parts of Lupersol DDM, a benzoyl peroxide catalyst fluid-type catalyst
100 parts of Surfex MM precipitated calcium carbonate
5 parts of mineral green pigment powder 25

The materials were mixed in an enameled iron kettle. This took about an hour. The spray pot of an ordinary spray gun was filled with the mixture which was then sprayed onto the upper face of the heated blocks. The catalyzing of the mix and the temperature of the block were adjusted so that the resin partly gelled before it soaked down too deep. By waiting between passes of the gun for about 30 seconds once or twice the resin mixture partially gelled and bridged over even the larger holes to finally form a solid resin-concrete layer. A layer of .010 fiber glass surfacing mat placed thereon materially strengthens and closes the film pores when the surfacing mat is allowed to sink down into the resin layer. By hand sprinkling fine sand in between the passes of the spray gun, I also was able to make a very interesting surface. By adding more Surfex MM I was able to get quicker covering of the surface but had to keep the amount below that which would stop up the spray gun. 30
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Example XII

The spray gun provides another method that is fast and economical to use if non-planar surfaces are wanted. A mixture as in the following served to make very attractive blocks. 50

500 parts of Clarocast resin, an unsaturated polyester resin as furnished by Fry Plastics Co.
25 parts of aluminum powder
5 parts of green mineral color
5 parts of Clarocast resin benzoyl peroxide accelerator 55

This mixture was sprayed on blocks heated to about 250° F. and immediately a layer of fiber glass surfacing mat 0.10 mil thickness was laid over the resin-coated blocks and allowed to settle by itself into the resin. The capillary action of the resin in permeating the concrete pulled the glass to the face. As it started to gel, additional resin mix was applied by two more passes of the spray gun over the surface and found on curing that the surface was practically smooth and free from holes and in general followed the contour of the block face. The resin then set to a hard tough surface. 60
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As a variation of this method, one may use pre-impregnated ready-to-use laminations of fiberglass and resin materials which are unrolled onto the surface of the concrete blocks after spraying as above, the resin penetrating and permeating the heated blocks and bonding the fiberglass. 70

Blocks made in this way can be inverted before the resin is fully gelled and pressed into a molding surface 75

with or without addition of other facing and/or reinforcing and/or decorative materials.

Example XIII

The use of epoxy resins such as Shell Epon 1004 when combined with styrene monomer makes a very durable exterior finish to my inventions. One such formula is as follows:

	Parts by weight
Epon 1004	30.0
Soy bean fatty acids	29.3
Dehydrated castor acids	7.4
Styrene monomer	33.3

This formula makes a spray finish for applying to hot concrete blocks as above described and can be set to a hard finish by baking.

As variations which may occur in the materials used or in operating techniques of the men who perform these steps may affect the curing time or the viscosity of the resin, compensating changes may be required to thin the resin by additional styrene or increased temperature and/or by varying the time or temperature of cure.

Although, as indicated above, thermoplastic resins can be used where maintenance of structural strength under high temperature conditions is not essential, the resins used should generally be thermosetting resins having high temperature resistance and which are liquid, or can be made liquid by suitable compounding, so that the resin can thoroughly saturate and adhere to the reinforcing fiber and the porous structure of the concrete block or other base. Phenol aldehyde resins, epoxy resins, silicone resins and polyester resins offer the best combination of desired properties; and of these the unsaturated polyesters cross-bonded with styrene or other unsaturated monomer are at present most practical.

The resins selected for use in this invention should be those having high stiffness, toughness and tensile strength. Highly plasticized resins will, in general, be too easily stretched—i.e., will not offer a major part of its ultimate strength in support of the concrete until the latter has been stretched beyond its failure point. High shrinkage will, to some extent, offset high stretch by prestressing the plastic in tension and thus bringing the operating range higher on its stress/strain characteristic. Even such softer resin, however, will improve the compressive strength of the concrete.

In the zone of impregnation, the product of Example 1 showed on test compressive strength more than one-third greater than the same block without the plastic. Tensile strength, as already indicated above, is increased many fold. The fiberglass reinforced plastic layer above the surface of the concrete has compressive strength of the order of ten thousand pounds per square inch.

It is not necessary for these improvements that the voids in the concrete be filled with the resin, and in fact I prefer not to completely fill them but to surround and tie together all individual pieces of the aggregate, so far as possible, with a continuum of resin. One advantage of the use of hot block, as described above, I have demonstrated to be in its vaporization of some of the styrene with the result that the resin is driven up through interstices of the concrete and into the minute crevices between particles.

The pressure applied to the mold pan drives the resin into the pores of the concrete, tending to fill them completely adjacent to the surface, but such externally applied pressure necessarily drops sharply with depth beneath the surface of the block. If the block is heated and/or subjected to vacuum sufficiently so that the resin mixture at its maximum exothermic heating is above the critical temperature of monostyrene, it will produce sudden vaporization within the pores. By the resulting dynamic flow of the resin over the hot surfaces of the concrete, the resin is both driven farther into the pores—in some cases entirely through the concrete wall into the

core holes 21—and is pressed and flowed into intimate adhesive engagement with the interior surfaces of the pores and voids in the concrete. The dynamic flow effect of vaporization in the pores, and the depth of impregnation of the resin can be increased by imposing a vacuum on the uncoated sides and back of the blocks. The wetting of internal surfaces of the concrete adds capillary action to the forces which tend to impregnate the resin more deeply into the block. This impregnation of the concrete with the resin produces not only a very great increase in tensile strength, but also increases substantially shear, torsional and compressive strengths. Using polyester resin as in the above examples and cutting off the fiber reinforced plastic layer from the face and the unimpregnated concrete from the body, the remaining plastic impregnated concrete showed 30–40% increase in compressive strength as tested by a recognized testing laboratory.

The compounding of the resin for the above examples may include a variety of materials, for example, extenders, fillers, reinforcing pigments, decorating elements such as dyes, pigments and aggregate designed to give pleasing or desired surface effects.

Fillers and extenders may include either, or both, inorganic and organic materials which are inert to the resin and the concrete; for example, talc, gypsum, calcite, fluorite, apatite, feldspar, quartz, corundum and even dust and chips of gem stones. Use of the harder stones in chip or powder gives a hard surface more resistant to scratching. With softer materials like gypsum, the hardness of the resin will generally control the scratchability. High proportions of filler may be used because in the combination with the concrete the plastic is largely protected against compressive loading and elongation beyond the point of failure of the concrete is not to be expected. However, excessive proportions of filler may reduce the shrinkage so as to reduce the amount of prestressing set forth above.

The resin surface may be polished with very fine abrasive to expose and polish chips of decorative or very hard materials such as onyx, quartz, obsidian, etc.

I claim:

1. A composite prestressed structure which comprises a preformed porous body of relatively high compressive strength and relatively low tensile strength, and an integrally bonded reinforced plastic composition layer, and having as a component of said combination, a high impact resistant set polymeric resin composition providing force systems, said force systems providing a state of internal stress, said reinforced plastic composition layer being bonded in and to said porous body at its surface interface by portions of said set polymeric resin composition in a state of internal stress, and said reinforced plastic composition being additionally bonded by projecting portions of said set polymeric resin composition extending into portions of said porous body and integrally permeated, penetrated, anchored, and bonded in a state of internal stress into pores and interstices of said porous body structure to a depth of at least $\frac{1}{32}$ of an inch, and reaching around and gripping the grains and particles of said porous body material in compressive stress, like fingers, substantially increasing the impact strength of the porous body material, said polymeric resin composition having a high stiffness, toughness, and tensile strength in its cured state and having a low order of shrinkage during set, and in which said porous body has an induced compressive prestressed preload provided by mechanical means prior to combination with the said polymeric resin composition, said polymeric resin composition and said reinforced plastic composition layer providing tensile strength reinforcement at least in excess of the compressive strength of the porous body and said induced compressive prestressed preload provided by mechanical means prior to combination with said reinforced plastic composition layer is substantially held in the body of said com-

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posite structure by said set high tensile strength polymeric resin composition after the removal of said mechanical means, whereby said combination of materials and force systems provides said composite prestressed structure.

2. A composite prestressed structure as in claim 1 wherein said integrally bonded reinforced plastic resin composition layer which includes said high impact resistant polymeric resin composition has a co-polymerizable substance and setting agent therefore.

3. A composite prestressed structure as in claim 1 wherein said polymeric resin composition comprises at least two discrete polymeric resins.

4. A composite prestressed structure as in claim 1 wherein said porous body is provided in a substantially dry state having its said pores and interstices discretely expanded by thermal means, said thermal means providing in combination additional force systems as component of said induced compressive prestressed preload.

5. A composite prestressed structure as in claim 1 wherein said polymeric resin composition contains a discrete mineral filler.

6. A composite prestressed structure as in claim 1 wherein said polymeric resin composition includes an unsaturated polyester resin composition having a styrene monomer as co-polymerizable portion thereof and a benzoyl peroxide catalyst.

7. A composite prestressed structure as in claim 1 wherein said polymeric resin composition includes an epoxy resin and a curing agent therefor.

8. A composite prestressed structure as in claim 1 wherein said polymeric resin composition includes a thermosetting resin composition selected from the group of thermosetting resins consisting of polyester resins, epoxy resins, phenol aldehyde resins, amino aldehyde resins, silicone resins and polyurethane resins.

9. A composite prestressed structure as in claim 1 wherein said polymeric resin composition comprises a thermosetting resin composition and a thermoplastic resin composition, said thermoplastic resin composition selected from the group consisting of vinyl resins, poly-tetra-fluoro-ethylene resins, poly-chloro-tri-fluoro-ethylene resins, polyamide resins, and polystyrene resins.

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10. A composite prestressed structure as in claim 1 wherein said polymeric resin composition comprises a thermosetting resin composition and an elastomeric resin composition, said elastomeric resin composition selected from the group consisting of butadiene polymeric resins, rubber hydrochloride, polymeric chloroprene rubbers, and polysulfide rubbers.

11. A composite prestressed structure as in claim 1 wherein said polymeric resin composition comprises a thermosetting resin composition and a nylon resin composition.

12. A composite prestressed structure as in claim 1 wherein said polymeric resin composition comprises a thermosetting resin composition and a melamine-nylon resin composition.

13. A composite prestressed structure as in claim 1 wherein said polymeric resin composition comprises a thermosetting resin composition and a phenolic-nylon resin composition.

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