Feb. 14, 1961 P. GRAHAM **2,971,237**

FLEXIBLE BUILDING PANEL FORM

Filed Jan. 6, 1959 3 Sheets-Sheet 1

FIG. 1

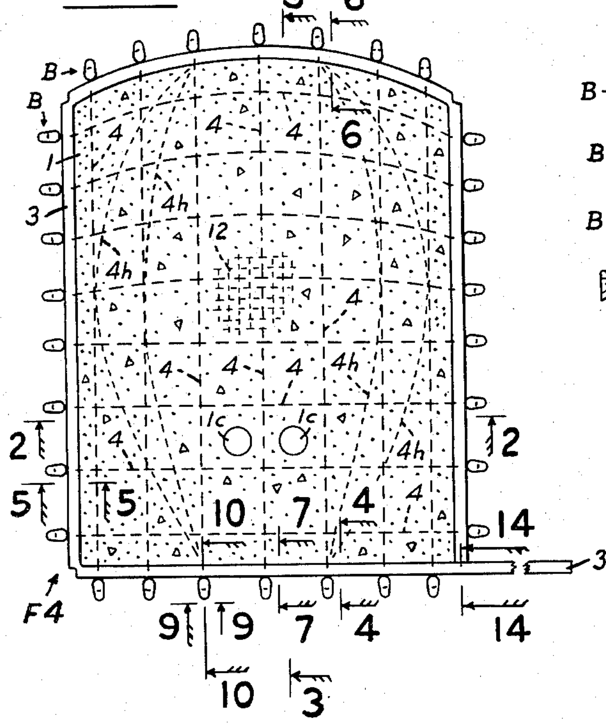


FIG. 4

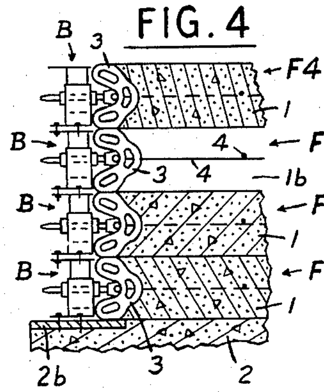


FIG. 5

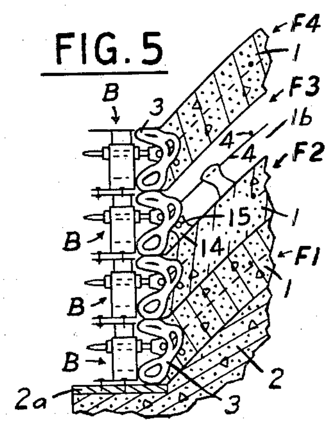


FIG. 2

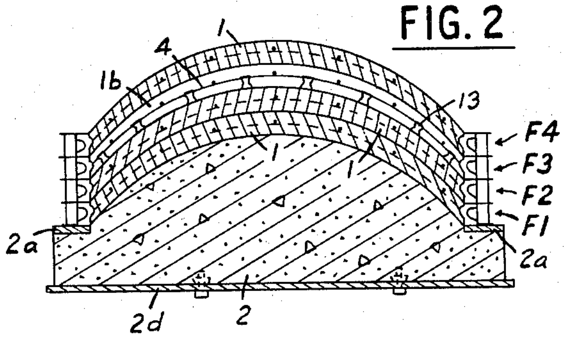


FIG. 6

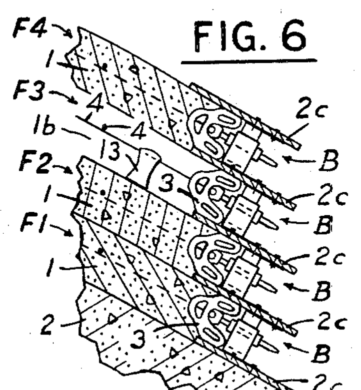
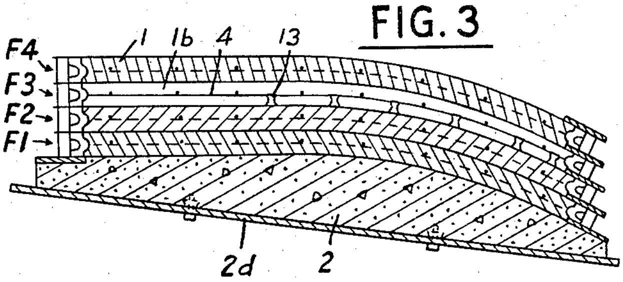


FIG. 3



INVENTOR.

Phillip Graham

BY William J. Ruano

ATTORNEY

Feb. 14, 1961 P. GRAHAM **2,971,237**

FLEXIBLE BUILDING PANEL FORM

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FIG. 7

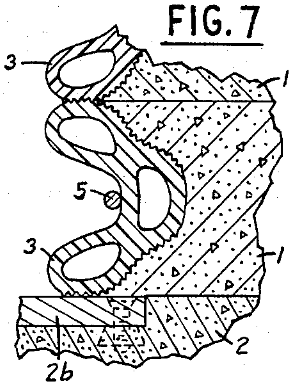


FIG. 8D

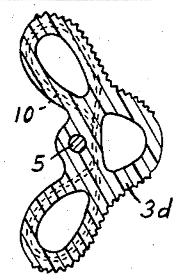


FIG. 11

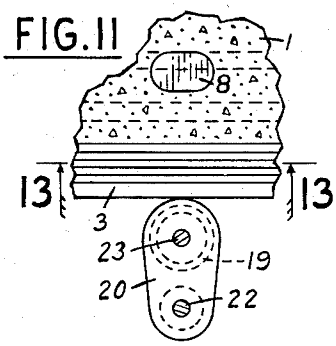


FIG. 8A

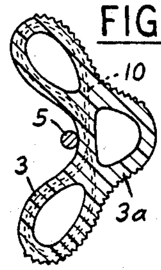


FIG. 9

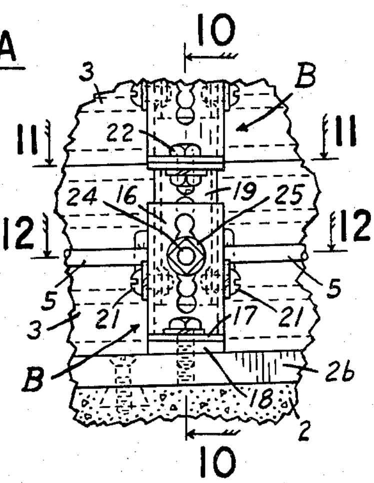


FIG. 12

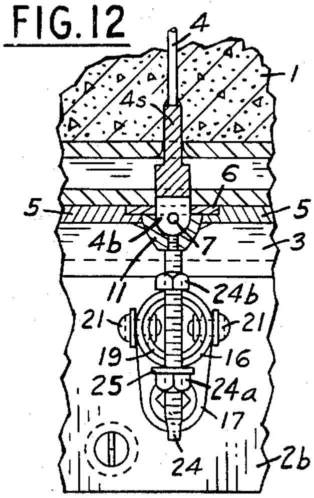


FIG. 8B

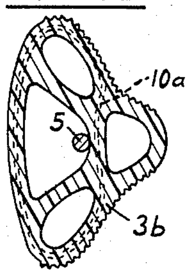


FIG. 13

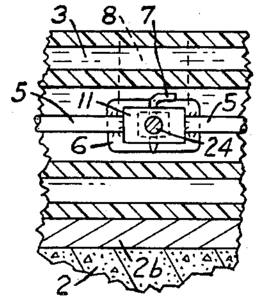


FIG. 10

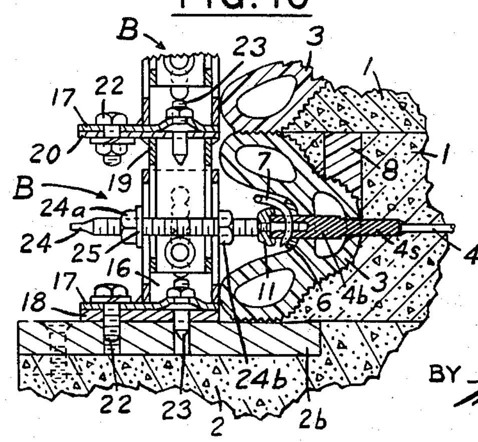
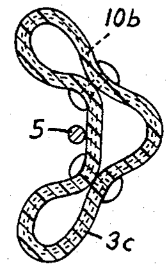


FIG. 8C



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FLEXIBLE BUILDING PANEL FORM

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FIG. 14

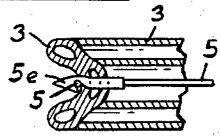


FIG. 19

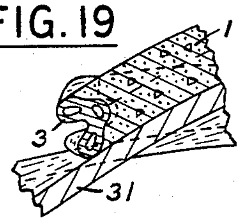


FIG. 24

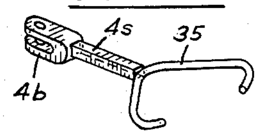


FIG. 15A

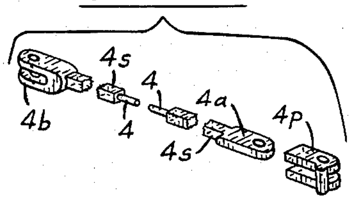


FIG. 20

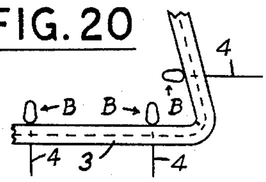


FIG. 25

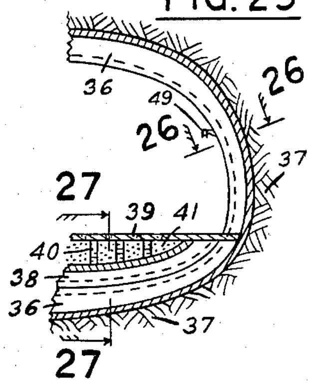


FIG. 15B

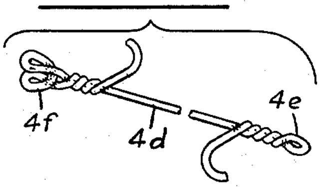


FIG. 21

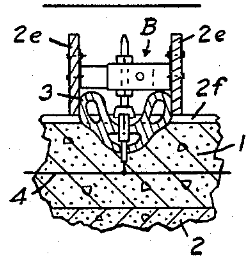


FIG. 26

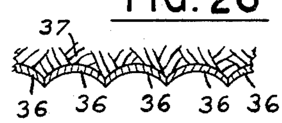


FIG. 16

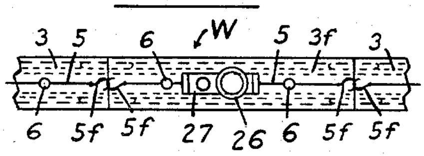


FIG. 27

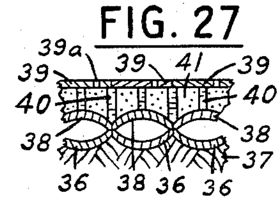


FIG. 22

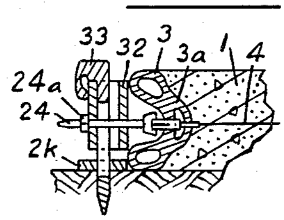


FIG. 17

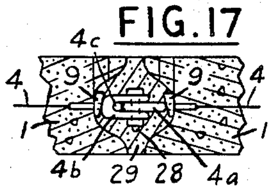


FIG. 28

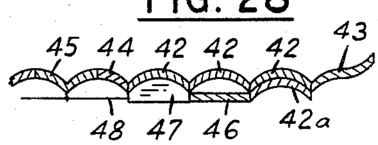


FIG. 18

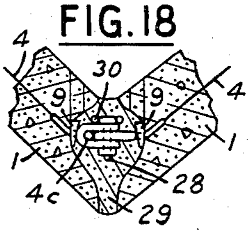
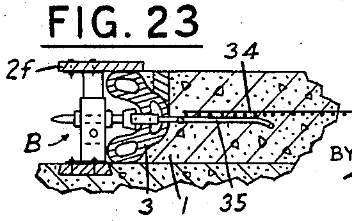


FIG. 23



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United States Patent Office

2,971,237

Patented Feb. 14, 1961

2,971,237

FLEXIBLE BUILDING PANEL FORM

Phillip Graham, 2825 Glenmore Ave., Pittsburgh, Pa.

Filed Jan. 6, 1959, Ser. No. 785,273

11 Claims. (Cl. 25—121)

This invention relates to improvements in forms for molding building panels, including adjustable flexible elastic edge forms which can be used to cast curved and flat, thin shell, reinforced panel sections of cementitious materials and plastics, which panel sections can be readily interlocked or bonded together to obtain an integral building shell of great strength. This invention is a continuation-in-part of my co-pending applications: Serial No. 456,684, now abandoned, filed September 17, 1954, entitled Flexible Building Panel Form, and Serial No. 259,354, now Patent No. 2,897,688, filed December 1, 1951, entitled Building Construction.

This invention particularly refers to adjustable forming means that has durable elastic flexible edge forms that allow low cost, quick, and accurate molding of various shapes and sizes of curved, and flat, precast, prestressed, reinforced thin shell concrete panel sections. The panel sections are suitable for use to speedily construct low cost, blast resistant, corrugated shelled houses and other buildings that are made pleasingly attractive and have far greater strength and durability than other types of buildings using equal amounts of material, so as to provide security for the occupants against the terrifically violent forces of atomic-H-blasts (in fringe areas), as well as other violent forces, such as those from hurricane-like winds, earthquakes, explosions, floods, avalanches and fires.

The lack of a suitable, low cost form means for use in molding sections for constructing bomb shelters and the like has prevented the building of such structures. Small arched shelters made with corrugated precast concrete sections are suitable for general use since they are strong and durable. Such buildings are not being built in this country because with present day building methods and equipment, the cost of the forms and the labor costs are prohibitive. Other countries with great masses of cheap labor have used thin shell types of construction to build strong buildings.

The optimum use of concrete and reinforcing materials is made with corrugated thin shell construction by using dished precast concrete sections. The sections are made with multiple curved forms. Such forms of wood or steel when made with conventional methods, are very costly to make as they require a large amount of material and a very large amount of skilled labor. Such forms deteriorate rapidly, therefore they can only be used a few times. They cannot be readily converted to mold sections that are differently curved. Such forms, for large scale shelter construction, would require large quantities of steel or lumber, which would be scarce and unobtainable during warlike times when forms would be needed most.

The form means embodied in this invention can be used to economically mold multiple curved thin shell, precast concrete sections, thus allowing bomb shelters and the like to be constructed with the precast sections at an economically low cost. The form means allows accurate positioning of fasteners on the precast sections. This fastening means allows precast sections to be erected dry

with pins during inclement weather—the grout mortar being inserted in the joints at a later suitable period. The forms and the concrete building sections require very little strategic materials—also the manufacturing and use of the forms and concrete building sections require very little labor compared to that needed for conventional forms. The forms and precast construction means are nearly foolproof, thus unskilled labor may be used to make and use the construction means. Therefore persons unskilled in the construction field, such as unemployed persons, including those of frail stature, may be used in public works projects during business recessions to build bomb shelters or make precast sections that can be stock-piled for future building of bomb shelters.

The elastic forms can be used many times to mold many differently shaped building panels without materially deteriorating. Non-elastic panel portions of the form may be made of concrete. These non-elastic portions may be used as building panels after they have outlived their usefulness as forms.

The form means embodied in this invention is an improvement over the form means described in my co-pending application Serial No. 459,684, as it is simpler, stronger, easier to use, easier to manufacture, and it would cost less to manufacture. The flexible form means embodied in this invention is an improvement over the form means described in my Patent No. 2,897,668, as it is flexible so it can be bent to mold panels of various curvature, whereas Patent No. 2,897,668 has rigid forms that cannot be bent to other curvatures.

Suitable building designs that supplement this thin shell forming and construction means are my U.S. Design Patents No. D. 171,889, and No. D. 174,122 which show corrugated shell arched buildings which are very strong, durable, and able to resist violent blasts. These shelter buildings can be quickly closed-up to make them airtight so they will offer security to the occupants against air raids in which poisonous gas or deadly bacteria are dropped. The corrugated arched construction uses curved precast concrete panels in compression principally, which is concrete's best characteristic. Very little reinforcing metal is needed. The compressive force of the arches squeezes cracks shut, thus eliminating water-pockets that allow freezing and spalling. The arches and corrugaitons of arched buildings can bow outwardly and inwardly slightly to allow for expansion and contraction. Thus objectionable cracking is eliminated and such building shells can be made water-tight with silicones and other waterproofing materials. Rain and slush will tend to quickly drain off such arched buildings. Dirt and fallout would be flushed off such buildings by rains or a spray. Buildings such as those shown in the above design patents can be covered with earth in critical areas during warlike times to increase their value as bomb shelters. Similar buildings may be built underground to be used as bomb shelters. Another suitable building design for thin shell precast concrete panel construction is shown in my U.S. Design Patent No. D. 174,175. It is a related type of structure to the two arched building designs, is not as strong as the arched buildings but is stronger and more durable than most conventional structures in its field. This building design bridges the gap between straight walled rectangular buildings and curved walled buildings. Thus it may be the means to create construction projects of thin shell concrete structures, so as to put the form means into use so that manufacturing facilities, construction facilities, and know-how will be available for future construction of shelters for military installations, and for civil defense.

My U.S. Patent No. 2,897,668 describes thin shell precast panels that may be cast with the elastic forms described in the present invention. Since the buildings as shown in the designs are of light-weight construction, I have provided a design for a low cost light-weight "General Portable Utility Crane" (U.S. Patent No. 2,763,218), for use in lifting and moving the thin shell forms and the precast concrete sections to eliminate heavy manual work, thus allowing the use of workers that are of frail build. This crane eliminates the need of a large costly conventional mobile crane.

Conventional doors and shutters lack the characteristics that are needed for closures on blast resistant buildings such as those shown in my design patents. My Patents No. 2,770,850, No. 2,826,787, and No. 2,826,788 describe strong, thin, curved cushionable doors and shutters that are blast resistant and they may be used effectively with the thin shell panel type of construction. Furthermore my U. S. Patent No. 2,877,517, entitled Jalousies, describes strong, curved, durable cushionable windows to thus provide a blast resistant type of window for thin shell panel type of construction.

An object of my invention is to provide a curvable, elastic, flexible, plastic edge form strip that is able to accurately mold the edges of straight and curved, reinforced thin shell precast cementitious sections of various suitable widths, lengths and thicknesses including tapered thicknesses—furthermore, to provide means to position and prestress the reinforcing, also means to position connectors on the ends of the reinforcing.

Another object is to provide a curvable, flexible rubber-like plastic edge form strip that is superimposed onto a base form consisting of a similar elastic edge form that is securely bonded to the edge of a cementitious reinforced form panel to accurately mold the bottom and the edge of a precast concrete building panel that is like the form panel.

Other objects of my invention will become more apparent from the following description taken with the accompanying drawings wherein:

Fig. 1 is a plan view showing forms being used to mold thin multiple curved reinforced concrete sections;

Fig. 2 is a sectional view taken along line 2—2 of Fig. 1;

Fig. 3 is a sectional view taken along line 3—3 of Fig. 1;

Fig. 4 is an enlarged, fragmentary sectional view taken along line 4—4 of Fig. 1;

Fig. 5 is an enlarged, fragmentary sectional view taken along line 5—5 of Fig. 1;

Fig. 6 is an enlarged, fragmentary sectional view taken along line 6—6 of Fig. 1;

Fig. 7 is an enlarged, fragmentary sectional view taken along line 7—7 of Fig. 1;

Fig. 8A is an enlarged, cross-sectional view taken through an unrestrained, elastic flexible edge form and spacer strand whose usefulness is an important part of this invention;

Figs. 8B, 8C, and 8D are views similar to Fig. 8A, showing modified forms;

Fig. 9 is an enlarged, fragmentary view taken along lines 9—9 of Fig. 1;

Fig. 10 is an enlarged, fragmentary, sectional view, taken along line 10—10 of Figs. 1 and 9;

Fig. 11 is a fragmentary, sectional view taken along line 11—11 of Fig. 9;

Fig. 12 is a fragmentary, sectional view taken along line 12—12 of Fig. 9;

Fig. 13 is a fragmentary, sectional view taken along line 13—13 of Fig. 11;

Fig. 14 is an enlarged, fragmentary sectional view taken along line 14—14 of Fig. 1;

Fig. 15A is an exploded, perspective view showing details of a metal reinforcing strand;

Fig. 15B is a view similar to Fig. 15A showing modified reinforcing;

Fig. 16 is a fragmentary view showing typical splicing

means and a typical access opening insert for the elastic forms;

Fig. 17 is a fragmentary, sectional view, taken through a joint of a building shell made of thin precast concrete sections that can be molded with the forms described in this invention;

Fig. 18 is a fragmentary, sectional view taken through a side joint of a thin corrugated building shell showing concrete sections that can be molded with the forms described;

Fig. 19 is a fragmentary, sectional view showing an elastic form that is twisted to follow the contour of a warped shaped molding section;

Fig. 20 is a fragmentary, plan view showing an elastic form that is bent inwardly;

Fig. 21 is a fragmentary, sectional view showing an elastic form arranged to mold a groove and position reinforcing connectors in an intermediate face portion of a panel;

Fig. 22 is a fragmentary, sectional view similar to Fig. 10, showing an arrangement for molding a panel with an elastic form that is staked to the ground;

Fig. 23 is a fragmentary, sectional view similar to Fig. 10, showing an arrangement for molding a panel which has modified reinforcing;

Fig. 24 is an isometric view showing details of the modified reinforcing for use in the arrangement shown in Fig. 23;

Fig. 25 is a fragmentary, sectional view taken through a bomb shelter made of precast concrete sections that are molded with the forms described in this invention;

Fig. 26 is a fragmentary, sectional view taken along line 26—26 of Fig. 25;

Fig. 27 is a fragmentary, sectional view taken along line 27—27 of Fig. 25;

Fig. 28 is a sectional view taken through a building shell showing various types of related panels that may be molded with the form means.

Referring to the drawings, Figs. 1 to 6 inclusive show assemblies F1, F2, F3, and F4 in an arrangement for molding crescent-like shaped, two-way curved dished or corrugated precast, prestressed, reinforced concrete panel sections 1. The assemblies are stacked on the base form 2. The assemblies F1, F2, F3, and F4 will be identical after the casting operations have been completed. The space 1b in assembly F3 illustrates the typical shape to be filled with concrete to mold a panel like panel 1. The assembly F1 would have such a space 1b before a panel 1 is formed in it.

Figs. 7 to 16 inclusive show details of an assembly F1 and the like. These intricately shaped panels 1 can be accurately molded at low cost with little effort due to the flexible adjustable elastic and resilient plastic or rubber edge form strip 3. The strip 3 may have one or more longitudinal holes or cavities, as shown in Fig. 7. The forms 3 are the edge moldings of the assemblies. An assembly may be stripped of its form 3 so the panel 1 may be used as a building panel. An assembly may also be kept with its form 3 intact with the panel 1, so the assembly may be used as a form until the panel portion deteriorates from usage or is no longer needed as a form—then the panel 1 may be used as a building panel. The stacked casting means allows the molding of accurate duplications of an intricately curved panel surface such as that of the base form 2 and a panel 1. A panel 1 for use as a portion of an additional form assembly may be molded on the form 2, the top surface of the panel 1 may be shaped with a screed or scraper.

When an original curved surface of the base form 2 is made, it may be duplicated in reverse by casting a female form on it, thus obtaining male and female forms which may be used to mold additional forms or building panels. The lower facing of a panel 1 is usable as a female form. When the curved panels to be molded are identical to panels that are being made elsewhere, effort can be saved by obtaining a few of the assemblies with the identical panels still attached to the forms 3. One of these assemblies can be used as a base instead of making a base form 2. The second of these assemblies can be used as a top member or cap above an edging form 3 that has been superimposed on the base.

When numerous identical building panels are to be made during a short period, assemblies may be used to arrange and mold identical assemblies, so that many stacks of assemblies can be used simultaneously to mold additional sections for use as building panels or panel portions of form assemblies. Thus, intricately curved form assemblies with their elastic edging strips secured to the concrete panel form may be used as seed-like means to reproduce duplicate panel sections at a very low cost as compared to other casting methods. Precision casting means can most effectively be maintained by reusing the most accurate assemblies for molding purposes. Slightly objectionable discrepancies will develop in panels 1 that are molded from other than the original form means.

The casting means shown causes the molding of identical curvatures to the surfaces of the panel faces, except that the top surface of the panel is convex and bottom surface is concave. The width contour of a panel 1 has equal radii but with different centers spaced vertically. The side edge radii are identical. The identical curvature of the surfaces of the panel faces provides a constant thickness, this thickness being parallel to the tiers of forms 3 as shown in Figs. 4 and 5, except when the panels are to be tapered in thickness. The panel thickness is uniform along spaced, vertical parallel lines as distinguished from uniform radial thickness as obtained from a common center. The identical curvature of the faces of each panel allows identically curved building panels to be laminated to each other where additional building shell section is required for strength or insulation. The identical curvature allows a thin layer of moisture resistant substance to be sandwiched between two such concrete panels to form a moisture barrier. These curved panels 1 have substantially the same cross sectional area and weight as would a flat panel of the same vertical thickness that could span the chord of a corrugation.

Fig. 2 shows the standard curvature across the width of panels 1. The panel width becomes progressively, radially thicker towards the center, similar to a crescent. Curved panels four feet wide are the standard used for the example shown as it is a widely used standard for building panels, and it is suitable for constructing small buildings. Other standard widths of panels and other curvatures may be used, including those varying the width curvature to obtain deeper corrugations and corrugations that are tapered in depth. The four foot panel width is also the chord of the width curve. The length of the width curve arc is fifty-six inches. The panel width has a radius that is roughly thirty inches and the middle ordinate is roughly twelve inches. While I have described the curvatures as arcuate, they also may be made with irregular curves.

The crescent shaped panels 1 are particularly well suited for arched roof and/or arched floor construction, since the concrete and reinforcing is so distributed that it will effectively resist bending caused by unequal loads on the arch of the roof and floor or a concentrated impact load on the center portion of the panel width.

Dome shaped arched buildings may be made with segmental shaped panels that are similar to panels 1.

A series of straight corrugated panels similar to panel 1, placed side by side and joined, would be highly efficient when used to act as simple beams and the like, since the thick center portion of the corrugation is near the extreme top, thus the thick concrete can efficiently resist high compressive forces—the reinforcing wires near the side portions resisting the tensional stresses.

The identically shaped panels 1 allow low cost casting, low cost handling, and low cost storage, since they can be nested tightly together to conserve space—also because the panels are light in weight. When the cured curved panels are nested together, they have little tendency to bend and break during shipping and handling because the curved panel shape is very strong, and a stack of the curved panels acts as a strong unit. The identical curvatures provide adequate bearing surfaces between the sections to cause them to act as a unit. No blocking is required between panels when they are stacked, and the dished panels have little tendency to slide or shift apart in transit. A stack of these panels may be lifted as a unit with little danger of breakage or shifting while being lifted. Assemblies whose panel sections 1 are to be used as building panels may be kept intact in stacks so the assemblies are fastened together for safety and ease in handling as a unit during shipping and storage; furthermore the forms 3 protect the fragile concrete edges and the reinforcing connections from being damaged. The form 3 also shields the panel edges from mud, ice and other objectionable elements. The forms 3 and their supplementary metal fasteners are so low in cost that they could be used economically to protect building panels that are stored for long periods since they would not tie up much capital.

These nesting and strength characteristics make the panels particularly suitable for shipping by barges and ships, as well as trucks and railroads. This method of stacking forms in tiers and casting leaves less chance of errors in making duplicate panels. The stacking method requires little space for casting and curing, and it allows the forms to be set up quickly with unskilled labor.

There are spaced fastener parts along the edges of the panel 1 to allow low cost joining of the panels at erection. A typical end splice or joint is shown in Fig. 17; a typical side splice or joint is shown in Fig. 18. Materials other than concrete may be used for the panel portions of the form assemblies. These materials include plaster, metal, and wood. Such panel forms would have little value after they are no longer needed as forms, whereas discarded concrete panel forms would have great value as building panels.

The base form 2 may be made of concrete, plaster, or other suitable materials. The surface of the base form 2 makes a neat finish for the underside of the concrete panel 1 of the assembly F1. The top of the base 2 is preferably covered with a thin coating or covering that will prevent the fresh concrete from adhering to it. A thin rubber sheet or an elastic plastic sheet may be used since it strips easily from the concrete. A similar covering should be applied to the molding surface of a cured form panel 1 that is being used as a mold. The base form 2 has anchored to it a framework made of template bar forms *2a*, *2b*, and *2c*. The base 2 is anchored to the base plate *2d*. The arrangement of the base 2 on the base plate *2d* is a simple means to support the forms for casting. It allows the casting means to be portable. The plate *2d* may be supported on a conveyor to allow the whole assembly to be moved to a pouring position where the concrete, is inserted in the assemblies, vibrated, moved to a vacuum chamber for partial curing and then be moved to the curing site. The whole assembly may be suitably tilted while casting to insure against voids forming in the side surfaces of the concrete panels, by diverting air pockets to edges where they can be eliminated or be compensated for with more grouting in the field joint. The template bars *2a*, *2b*, and *2c* have accurately spaced holes that are used to align and hold the assembly F1 to the base 2. These template bars are a means to accurately and quickly position the assembly F1. The bars may be omitted if it is preferred to fasten the assembly F1 direct to the base 2, with bolts penetrating the concrete base to hold the assembly.

The concrete for panel 1 of the assembly F1 can be poured within the confines of form 3 with the top surface of the panel being leveled with a screed, or the top surface may be molded by placing a completed assembly F2 on top of the assembly F1. When the top surface of a panel 1 is to be shaped with a screed, the top portion of the form 3 may be depressed with a top member similar to the arrangement shown in Fig. 23.

The form 3 and supplementary metal parts can be positioned to allow them to be used to mold concrete panels of various widths and various lengths in multiples of eight inch or other suitable modular units—also in various curvatures as well as flat shapes; furthermore, the panels can be molded in various thicknesses with the form 3. The form 3 and its supplementary parts may be arranged for molding non-rectangular panels such as curved or flat segmental panels and curved or flat round panels. The maximum panel size is limited only by the limitations of the equipment used for economically handling, shipping and erecting the panels. The form 3 may be compressed to taper it to allow it to mold a tapered panel. The form 3 may be compressed to allow a range of depths for molding panels of suitable thicknesses for thin shell building construction. For example, a form 3 with an unrestrained depth of two and a quarter inches that may be compressed to one and a half inches, would allow its use in molding a wide range of panels. Smaller and larger sized forms 3 may be made, such as smaller sizes for very thin type panels that are to be laminated.

A panel of double thickness may be cast within the confines of the edge forms of assemblies F2 and F3. A panel of triple thickness may be cast within the confines of the edge forms 3 of assemblies F1, F2 and F3. Such thick panels, particularly flat panels, would usually need the reinforcing near each face to resist bending forces. The triple thick panel would usually not have reinforcing within its center portion that is molded by the assembly F2. The two grid systems of a thick panel would be tied to each other with short metal strands.

There is accurate modular spacing means for spacing the reinforcing strands or wires 4 and the support fasteners B. There is connector means for connecting the reinforcing strands 4 to the support fasteners B. A strand 4 has a connector welded to each end, the connectors being an eyelet or eye connector *4a* on one end and a clevis connector *4b* on the other end, as shown in Fig. 15A. The connectors *4a* and *4b* are means to anchor the strand 4. The connectors *4a* and *4b* provide a clevis-like pin connected interlocking means for joining building panels to each other as shown in Figs. 17 and 18. This anchoring means allows tensioning of the reinforcing 4. All the ends of the strands 4 on one side edge and one end edge of a rectangular panel each have an eye *4a*. The ends of strands 4 on the other side edge and the other end edge of the panel each have a clevis *4b*. Slightly less foolproof panels may be made with all of the ends of the wires 4 having eyes *4a* and clevises *4b* spaced alternately around the periphery of the panel. That is, having every other connector an eye *4a* with clevises *4b* between the eyes. Such alternate spacing would require more effort during manufacturing to determine when an eye *4a* is to be the first or second connector along a particular panel edge. During erection, such alternate spacing of eyes and clevises would cause confusion, because panels would have to be studied to determine which side would match the panel edging to which the panel is to be joined.

The modular unit for the spacing of the reinforcing and the sizing of the panel are standardized for various types of construction on which it is to be used. Such a module as eight inches is a desirable size. It is a module used in the Modular System of building dimensional standardization. The standard reinforcing module for the examples shown is eight inches. An eight inch module also is a suitable unit to use for matching thin

shell panel reinforcing to concrete block reinforcing since eight inch modular sizing is widely used for blocks. Eight inch modularly spaced reinforcing is practical for corrugated thin shell arched span type of construction, since the building shell is principally in compression and there is little tension stress, thus little reinforcing is needed. When thin shell panels are to be used for non-arched spans, a smaller module for the metal reinforcing spacing may be used since it would prevent objectionable cracking and resist the tension forces. When closer reinforcing spacing is required, the module may be four inches.

A form means with a four inch module may be used. It would allow desirable combinations, such as eight, twelve, and sixteen inches, by plugging the spaced holes in the form 3 that are not in use. Such skipping of holes would be done when it is preferred to use wire mesh to control the shrinkage cracks and to use a few wires 4 where reinforcing is needed to resist tension forces.

Only a half module space is used from the corners of the panel 1 and the like to the first uniformly spaced reinforcing strand so that when erected, half module spaces on adjoining panels form a whole module space. This feature allows an intermediate edge portion of a panel to straddle the end of a joint.

The edge form 3 may be made at low cost with a continuous extrusion process. Holes for the reinforcing strands may then be pierced through the form 3. This method of manufacturing allows the standard blank form 3 to be pierced to suit different modules, including those spaced in inches and those spaced to a metric system module. The edge form 3 is elastic to allow it to be depressed, bent, curved, or twisted to mold various shaped panels. The form 3 is light in weight. It can be coiled for ease in handling, shipping, and storing. As shown in Fig. 14, an end of the form 3 is coped to allow it to be tightly fitted to an intermediate portion of the form strand to close or encase a space for casting a panel. The end of the spacer wire 5 has a hook *5e* securely attached to its end. The hook *5e* may be pointed to allow it to pierce the form 3 to allow it to engage the wire 5. The hook *5e* allows a ready means of coupling and uncoupling portions of a form strand. Pieces of form 3 may be readily hooked together to make any length of form strand desired.

A typical splice for joining sections of form 3 is shown in Fig. 16. Hooks *5f* are attached to wires 5, the ends of the forms 3 are pressed tightly together to depress the plastic, which allows the hooks *5f* to be engaged to couple the pieces of forms 3 together. Flexible dowels may be used to engage the longitudinal holes in the forms 3 at the splices. The plastic in form 3 may be readily cut with a knife to allow suitable splicing, mitering, slitting, trimming, and such needed operations. Old slits in form 3 tend to be self-sealing by the elasticity of the plastic. These elastic forms 3 do not require oil on their contact surfaces to prevent adhesion with the concrete. Such oil is a detriment to proper bonding of the mortar grout used to key sections together.

The elastic form 3 can yield slightly to break its bonding effect to the cured concrete, thus allowing easier stripping. The elastic form could be stripped noiselessly. The stripping action would not damage either the concrete panel edging or the elastic form. Since the forms 3, when in use, would usually be depressed to such a shape as that shown in Fig. 7, it would tend to spring away from the concrete in panel 1 and be more readily strippable when the depressing means is removed. The non-depressed shape of the form 3 is shown in Fig. 8A. The form 3 may be made of elastic plastic that is stiff enough so the upper portion of the form will not sag from its own weight. The form 3 may be made of a more elastic, weaker plastic that is reinforced with spring steel wire 10, as shown in Fig. 8A. The wire 10 may be continuous with loops in the upper and lower portions. The loops may be welded to make the reinforcing strong. The form 3 may be thin and be inflated to stiffen it.

When properly used, the elasticity of form 3 tends to cause the form to seal its contact surfaces with the abutting form 3 of the adjacent assembly—also its contact surfaces which engage template bar forms 2*a*, 2*b*, and 2*c*. The sealing action tends to eliminate open cracks and thus tends to prevent fresh concrete from seeping out. Friction tends to prevent movement between two stacked forms 3 or between a form 3 and bars 2*a*, 2*b*, and 2*c*. There are small longitudinal grooves on the portions of the surface of the form 3 that are to engage abutting surfaces above and below it. The bars 2*a*, 2*b*, and 2*c* may also have such grooves. The grooves create more friction to prevent objectionable outward movement of the form 3. There also are small grooves on the portion of the surface of the form 3 that engage the panel 1. These grooves mold a roughened surface on the edge of the panel 1. The roughened surface allows keying grout to bond better.

The forms 3 do not stain the concrete as would rusted metal forms. The form 3 would be durable as it is noncorrosive, non-absorbent, and termites and such pests would not harm it. The form 3 does not warp from moisture as would wooden forms. The form 3 has little value except as a form, thus it would be less likely to be stolen for other uses, as would wood or metal forms. The form 3 may be coiled into a compact arrangement when it is not in use, thus it can be kept in a locked construction chest or small locked building.

Most of the panel sections to be cast require keying grooves in all their edges, so that panels can be keyed together with mortar grout at the time of erection. The form 3 has a protruding medial portion which is the groove mold offset 3*a*. The offset 3*a* molds the keying groove. Modified form sections, similar to form 3 but with a smaller groove mold offset 3*a* or no groove mold, may be made so they can be readily spliced to other form sections when needed. A very small groove may be required in an otherwise flat edge of a panel for receiving a metal window member and the like.

The modified form 3*b* shown in Fig. 8B differs from form 3 by having a wall on its left side. The wall restrains the top and bottom portions of the form from yielding towards each other due to the pressure of fresh concrete. The form wall has spaced holes to allow access for fastening the reinforcing strands 4. Wire reinforcing 10*a* may be used to stiffen the plastic, like the wire 10 is used to stiffen the form 3.

The modified form 3*c* shown in Fig. 8C differs from form 3 by being made as a single tube and by being riveted, sewed or otherwise held to a shape like form 3. Reinforcing wire 10*b* may be used to stiffen the plastic.

The modified form 3*d* shown in Fig. 8D differs from form 3 by having the spacer wires 5 embedded in the plastic. Wire 10 may be used to stiffen the plastic.

Fabric reinforcing may be used to reinforce the forms 3, 3*b*, 3*c*, and 3*d*.

The form 3 for the assembly F1 and the like is slit and bent at three of the corners. The spacer wires 5 are attached to the connectors 6 by welding or by other suitable means to form an accurate pliable metal spacing strand. The spacer strand is shown positioned along the full length of the form strip 3 at substantially the central portion of the form. The connectors 6 are short curved steel plates. The connectors 6 are accurately spaced a module apart. There are holes through the form 3 in alignment with holes in the connectors 6. The ends of the reinforcing strands 4 are pushed through the holes in form 3 and the connectors 6, curved pins 7 are projected through the clevises 4*b* and the eyes 4*a* to anchor the reinforcing strands 4. The end of each pin 7 is tapered so it acts as a wedge to force the clevis 4*b*, or the eye 4*a*, into position. The outer end of the pin 7 is bent to the right as shown in Fig. 13, so the end may be gripped with a tool to allow the pin 7 to be inserted or be removed with a motion like the motion used to turn a corkscrew. The spacer strand formed by wires 5 and connectors 6 maintain the modular spacing for the reinforcing wires 4. It also prevents the form 3 from stretching in length from the pressure of green concrete against it. The metal wire 5 does not stretch or contract materially from temperature variations as would soft plastic in the form, thus the wires 5 maintain accuracy of the form means. The wire 5 is centered, thus the plastic form 3 may be bent or twisted without objectionably varying the spacing of the holes in the form. The wires 5 may be made of high carbon spring steel so they will straighten out when unrestrained. Panels of limited accuracy may be molded with forms 3 without spacer wires 5—the wires 4 being anchored to the connectors 6 with pins 7. Fasteners B may be used to accurately space the ends of the reinforcing wires 4, particularly when spacer wires 5 are omitted. The elasticity of the form 3 causes the form to grip the reinforcing strands restraining the form from objectionably buckling inwardly before the concrete is poured. When the concrete is poured it pressures the form outwardly. The elasticity of the form 3 gripping the reinforcing strands forms a seal around each strand hole in the form to prevent fresh concrete from seeping through the strand hole.

There is a rectangular hole in each connector 6 to position the clevis 4*b* or an eye 4*a*. Since the eye 4*a* is thinner than the clevis 4*b*, an adapter 4*p*, shown in Fig. 15A, is slid onto the eye 4*a* so the parts snugly fit the hole in the connector 6. A V-shaped nut or coupling 11 is welded to the connector 6. The nut 11 is shaped so it restrains the clevis 4*b* to prevent it from tilting or moving outwardly too far through the connector 6 before the wires 4 are tightened to tension them. The connector 6 and the nut 11 may be combined in a single forging. The spacer strands may be coiled and dipped in oil or paint to give them a protective coating before they are assembled with the form 3 and put to use.

The clevis 4*b* and the eye 4*a* are shown with long stem portions 4*s*, the wire 4 being welded to the stems. The stem portions 4*s* are thicker and stronger than the wires 4. The stems being strong resist forces caused by rough handling that tend to bend the clevises and eyes out of alignment. During erection, the strong stem portions 4*s* resist dead load forces that tend to bend them before grout is inserted to key adjoining panels together. The stem portions 4*s* may be bent with tools to shape them for receiving the wires 4 from an angle for conditions such as that shown in Fig. 5. The stem portions 4*s* may be rectangular in shape as shown, so the cured concrete encasing their end portions will restrain them from twisting due to rough handling, thus tending to maintain alignment of the apertures of the eyes 4*a* and the clevises 4*b*. When the wire strands 4 are thick and strong enough to resist the various bending forces, the stem portions 4*s* may be omitted.

Near the ends of each strand 4 an elastic mold 8 may be fastened to the form 3 with an adhesive. A mold 8 is shown in Figs. 10 and 11. After curing the panel 1 and exposing its top surface, the top portion of the mold 8 is pried loose from the concrete. The mold 8 is gripped with tongs and pulled free of the panel 1 by breaking its bond with the concrete and the form 3. Molds 8 are used to form access holes in the panel 1. The access holes allow forked wedges 9 to be inserted and be driven between the cured concrete and the wide shoulder portions of the connectors 4*a* and 4*b*. The wedges are forked so they can straddle the stem portions 4*s*. The wedges 9 are shown positioned in Figs. 17 and 18. When a wedge 9 is inserted and driven, it forces the adjacent portion of the form 3 away from the concrete. The wedges 9 are used to maintain the pretensioning of the wires 4 or to pretension the wires 4. After the wedges 9 have been driven, the access holes may be filled with grout. The wedges 9 may be driven without using access holes by prying back the form 3 from the concrete adjacent to the connectors and driving the wedges at an angle. Such wedges would be curved so they would bear against the concrete.

The form assemblies F1 and the like are usable in different ways for prestressing the reinforcing strands 4 in the precast panels 1. Prestressing is the term commonly used when referring to pretensioning reinforcing before the loads are applied which the concrete section is to carry. The tensioning straightens the reinforcing strands 4 and then stretches the metal slightly. Therefore when loads tend to bend such a prestressed panel 1, there is no slack to take up in the reinforcing 4; the pretensioned strands 4 act immediately to resist tensional stresses. A simple means to pretension or prestress the reinforcing 4 is by stretching the strands 4 by take-up means on the support fasteners B, and by using conventional prepared iron particles in the concrete mix. The iron oxidizes and expands to compensate for the normal shrinkage of the concrete. Such panels are of limited value because the rust of the iron discolors the concrete and it is difficult to exactly compensate for the shrinkage factors. The compound with the iron particles is used extensively for grouting under machinery. It is more costly than common concrete but, since these panels contain little concrete, the iron compound would add little to the cost.

The precast panels in general would be made strong and dense by using the minimum amount of water and by allowing the concrete to cure properly. Conventional fillers may be used to reduce the porosity of the concrete and thus the amount of water needed, to thus reduce shrinkage.

The panel 1 may be molded by the assembly F3 and be prestressed effectively even though the concrete does not contain means to prevent shrinkage, and normal shrinkage occurs for this type of construction. This prestressing means includes coating the strands 4 with a soft plastic or the like, so the concrete does not adhere to the strands. The strands 4 are highly tensioned with the support fasteners B, then the concrete is poured and allowed to cure. The assembly F4 is then removed, the wedges 9 are then driven so the strands 4 remain tensioned. The wedges 9 may be driven after the strands 4 have been uncoupled from the fasteners B. With this means the tension force is released by the uncoupling, then the strands 4 are repretensioned by driving in the wedges 9.

When the wires 4 are thickly coated with an elastic plastic or the like, and the shrinkage of the concrete is controlled to keep it small, the wires 4 may be welded together where they intersect. The elastic coating on the wires 4 would compress enough when pressured by the shrinking concrete so it would not restrain the concrete from shrinking. Therefore the welded grid of wires 4 is suitable for small prestressed panels. When large panels are to be made in which the shrinkage is more than can be economically compensated for by compressing the coating of the wires 4, the wires 4 may be joined where they intersect with short tie wires that allow each wire 4 to move slightly in its relationship to the other wire 4. This tieing means is like the tieing means shown for wire chairs in my Patent No. 2,897,668.

The panels 1 may be made without prestressing the wires 4. Such panels would be suitable for much construction work, particularly when the panels are to be used in arch construction and there is little or no tension stresses. Wire mesh or fabric 12 may be stretched and attached to the wires 4, as shown in Fig. 1. The mesh 12 would be highly suitable for use in non-prestressed panels. The mesh 12 would control the shrinkage cracks and cracks from expansion and contractions, causing the cracks to be small. Small cracks in these thin concrete panels can be filled to a large degree by forcing cementitious water-proofing compounds into the cracks from both sides of the panel. The mesh 12 may be coated with soft plastic and the like so it may be used in prestressed panels. The wire strands *4h* and the like that are arced across the length of panel 1 may be used effectively on straight, crescent shaped panels to resist bending stresses.

The length of reinforcing strands 4 for flat panels and for those spanning the width of panels 1 are made in the modular multiples of eight inches to conform to the standard module established. The distance between centers of holes of a reinforcing strand 4 is accurate. The reinforcing strands 4 may be fabricated in a shop, using jigs and machines for economical cutting and welding of the wires 4 to the eyes *4a* and the clevises *4b*, and gaging of the lengths.

The wires 4 across the width of the panels 1 are identical for all curved width panels of any given standard that is set up. Therefore large quantities are required, which would allow automation in fabricating the wire to its eye *4a* and its clevis *4b*. The longitudinal wires 4 on the panels 1 are not in modules of eight inches, since they vary in length due to their various longitudinal radii which step up from the side edges where the modular spacing of the side connections is eight inches. The various longitudinal wires 4 of the panel 1 may be different in size and/or composition to allow them to take the different degrees of stress to which they would be subjected. Corrugated panels like panels 1 may have additional longitudinal wires 4 spaced with closer modules, such as four inch modules, near the side edges of the panel and/or at the center portion of the panel to cause the reinforcing to work more effectively.

Fig. 15B shows a modified wire reinforcing strand *4d*. One end of the wire is looped to form an eyelet or eye *4e*—the other end has two loops to form a clevis *4f*. The crotch of the clevis should be welded to make it strong and accurate.

When the curved wires 4 are positioned above the base 2 or above the convex surface of a cured form panel 1, they are supported by the chairs 13. The straight portions of tight longitudinal wires 4 do not require chairs 13. The chairs 13 may be slightly resilient to cause them to pressure the wires 4 to tighten and tension them. Resilient chairs 13 may be coiled springs to furnish enough pressure against the wires 4 to tension them to a high degree. The fluid concrete would fill the cavity inside the coiled chair. Chairs 13 may be made of stiff resilient rubber or resilient plastic.

Such chairs can easily be removed before erection to allow the chair cavities to be filled with grout. Conventional threaded metal inserts may be grouted into the chair cavities. Such inserts are used as connecting means for utility fixtures and construction members. Non-resilient chairs 13 may be made of concrete and the like. Concrete chairs remain in the panel. Threaded metal inserts may be used as chairs where inserts are required, such chairs may be welded to the wires 4. A panel 1 may have some resilient chairs 13 and some non-resilient chairs 13. The resilient chairs 13 can most effectively tension the wires 4 when they are positioned on all wires midway between the intersections of the wires.

As shown in Fig. 5 in the assembly F3, the offset *3a* on form 3 yields to bend upwardly due to the position of the reinforcing strand 4. Chairs 14 which are similar to chairs 13 are positioned to bear against the offset *3a* to eliminate any downwad bulging of the form 3. There is a thin lower lip of the panel below the offset *3a*. It is relatively weak in its resistance to breakage from rough handling, so reinforcing wire 15 is positioned in this space to eliminate breakage. The wire 15 may be corrugated to spread it through the lip. Reinforcing may also be used in the upper thin lip, although breakage of the upper lip is not so important since this lip can be patched easily at erection.

The support fasteners B are used to accurately position and hold the ends of the reinforcing wires 4, also to tighten and thus tension the reinforcing. Furthermore, the fasteners are used to selectively gauge the effective depth of the form 3 and thus the thickness of the panel 1. The fasteners B restrain the form 3 from tilting. The support fasteners B align and support the assemblies F1, F2, F3, and F4 with the template bars 2*a*, 2*b*, and 2*c*. Details of a fastener B are shown in Figs. 9, 10, 11, and 12.

A fastener B has a lower vertical stiff tube 16. The tube 16 has a base plate 17 welded to it. A beveled washer 18 is engaged to the bar 2*b* and the plate 17. Beveled washers 18 are used for conditions such as that shown in Fig. 4. An upper tube 19 has a slidable engagement with the upper portion of the tube 16. The tube 19 has a cap 20 welded to it. The sides of the tube 16 have spaced notches in slots to allow machine screws 21 to project into threaded flanged holes in the tube 19. The tubes 16 and 19 are telescoped to allow them to slide to adjust their combined overall height.

After the fasteners B are adjusted, the screws 21 are inserted and tightened to maintain the setting. There are lock washers under the heads of the screws 21. The base plate 17 and the washer 18 are fastened to the bar 2*b* with a bolt 22 and a lock washer. A dowel 23 may also be used to position the plate 17 to the bar 2*b*. The dowel 23 is bolted to the plate 17. The inverted countersunk head of the dowel 23 engages the underside of the plate 17. The plain dowel shank projects below the head. Bolts 22 may be used to attach and align the fasteners B of the assembly F1 to the fasteners B of the assembly F2. Dowels 23 align the upper and lower fasteners B. The pointed dowels 23 are self-centering with the holes in the adjacent form assembly. A headless bolt 24 projects through one of the spaced notches in the slots in the tubes 16 and 19 and engages the nut 11. A pair of self-locking nuts 24*a* and 24*b* on the bolt 24 hold the bolt 24 securely. The nut 24*b* may be set as a limit means to gage the setting of bolt 24 and the clevis 4*b*. The bolt 24 can be adjustably set in height to suit the required elevation for the wires 4. The wires 4 are positioned below the center of a flat precast floor panel to efficiently use the wire for resisting tension. The notched slots in the tubes 16 and 19 that engage the bolt 24 and the notched slots in tubes 16 that engage the screws 21 may be filed to lengthen notches when adjusting means requires intermediate non-notched positioning. The bolt 24 has a flattened end, which may be gripped with a socket wrench to turn the bolt or to hold the the bolt while tightening its nuts. The nut 24*a* can be turned to tighten the wire 4 to pull the clevis 4*b* into alignment and to tension the wire. Straight wires 4 for a flat portion of a concrete panel may be tensioned with the nuts 24*a*. The bolts 24 may be pre-set accurately along two adjoining edges of an assembly. The bolts 24 that are on the fasteners B along the other two edges are tightened to tighten the wires 4. Thus the eyes 4*a* and clevises 4*b* are not pulled out of alignment. The nuts 24*b* may be loosened and the bolts 24 may be turned to disengage them from the nuts 11 so they may be retracted from the recess in the form 3, so the panel 1 and the attached form 3 may be lifted from the confines of the fasteners B without disturbing the remaining portions of the fasteners. Thus partial assembly set-ups may be maintained to allow low cost duplication in molding panels. Washer 25 may be tack welded to the tube 16 to maintain a temporary elevated position for the bolt 24. Temporary form connections and settings may be made in general with tack welds rather than the bolts, nuts, screws, and dowels. Non-adjustable support fasteners may be made by permanently welding parts together.

After a panel has cured to an extent in the assembly F3, the assembly F4 may be raised slightly to create a gap between the assemblies. The nuts on the bolts 22 would be loosened so the assemblies may be wedged or jacked apart. The dowels 23 and the bolts 22 would hold the two assemblies in alignment. The gap between the assemblies allows the surface of the curing panel to be reached by steam and air while curing.

When the form assemblies are used to mold panels that are tapered in thickness, the form assemblies used to mold the top and bottom surfaces of the tapered panel are variably spread apart—the form 3 being depressed to a tapered shape. The fasteners B would be suitably adjusted to support the titled form assemblies to maintain the selective variable thicknesses due to the tilting. The tapering means allows thickening of concrete panel sections where loads are greater, particularly to compensate for the loss of sectional area at window openings and the like. A form 3 may be extremely tapered by cutting away a portion of it where it cannot be depressed enough for the tapering required.

The fluid concrete for a panel 1 may be inserted into a form assembly by various means. The concrete may be inserted through the access holes 1*c* that are cored in the panels 1. Concrete can be deposited within the confines of the form 3 of an assembly before a complete form assembly is used to cap the fluid concrete. The excess concrete is forced out of the holes 1*c*. The holes 1*c* may also be used for inserting vibrators. The green concrete in the holes 1*c* is removed after the concrete has slightly hardened. If preferred, an elastic access unit W may be used to insert fluid concrete and a vibrator through the elastic edge form when an assembly is to have a panel 1 cast within it and there is a complete form assembly capping it. The access unit W is shown in Fig. 16. It has a short elastic edge form 3*f* which is similar to form 3. Form 3*f* has a hole through it for a threaded tube 26. A spacer strand has wires 5 that are welded to connectors 6, tube 26 and end hooks 5*f*. Hooks 5*f* on the unit W engage hooks 5*f* on the adjoining spacer strands. The form 3*f* tightly engages the tube 26. The tube 26 has a slot for the sliding orifice plate 27. There is an off-centered hole in the plate 27. The access means is opened when plate 27 is slid so that all the holes are in registry. The exterior end of the tube 26 is threaded to allow a threaded engagement for a hose connection to allow the fluid concrete or vibrator to pass through the form 3*f*. After the fluid concrete has been inserted, this sliding plate 27 is slid to block the passage, preventing the concrete from backing out. After the concrete has cured slightly, the plate 27 is pushed to the open position to allow air to enter and escape so moisture can pass through the form edging. There would be a suitable number of units W inserted in an assembly form.

Fig. 6 shows how the curved ends of the assemblies F1, F2, F3, and F4 are stepped. The template bars 2*c* have spaced holes that engage the bolts and dowels that engage the base plates 17 on the tubes 16 of the supports B. There are spaced slots in the bars 2*c* to engage bolts and dowels that engage the caps 20 on the tubes 19 of the supports B. The slots are an adjusting means to allow variable stepping to suit set-ups for molding panels that have different longitudinal curvature. The bars 2*c* depress the forms 3.

Holes like holes 1*c* may be cored in the panels to allow panels to be bolted together to make laminated panel shells. Laminated panels are suitable for combining sections of various types such as strength, insulation, annd water resistance. Large holes for window openings may be molded in the panels by inserting sponge rubber panel molds in the assembly.

Fig. 17 is a fragmentary section through a typical end joint of the interlocked panels 1. It is also a typical joint through a floor. The wedges 9 maintain tension in the strands 4 of the panels 1. The pin or bolt 28 connects the eye 4a and the clevis 4b that are attached to the reinforcing 4. The ends of the reinforcing strands may be welded together if preferred to make a low cost connection of the panels. The pin 28 is inserted through the joint gap. The pin 28 may have a narrow head to allow it to be inserted into a narrow joint. The panels 1 are keyed together with the grout mortar 29. The pin 28 may be tapered near the end of its shank so it may be driven into the clevis means to lock the eye 4a to the clevis 4b to prestress the reinforcing strand where it spans the joint.

The grout 29 is inserted during the erection of panels or later to key and bond the panels together. The engaged reinforcing at the joints keeps the panels in alignment. This allows the panels to be erected without the grout 29 during cold or rainy weather, the grout 29 being inserted later when suitable weather prevails. Therefore, the panels means allows speedier and lower cost constructions since it eliminates lost time due to inclement weather.

After the grout 29 is inserted and cured, it restrains the pin 28 from moving out of place if the pin does not have a nut. A strand of reinforcing wire 4c may be placed in the joint in the crotch of the clevis. It keeps the shrinkage cracks small in the grout 29 and acts efficiently to resist bending tendencies. The grout 29 may have iron particles in its mix to cause the grout to swell to maintain its volume, thus compensating for the shrinkage tendencies of the concrete.

Fig. 18 is a sectional view taken through a typical side joint formed by the interlocked panels 1. The panel sides form a V-shaped valley at the joint. This V-shape acts like a strong structural member. Although the panels 1 are thinner in radial directions along the side portions that form the V-shape than they are in the central intermediate portions, the thin V-shape is adequate. The V-shaped portions of the roof paneling that act as gutters may be made more water resistant by placing a corrugated reinforcing wire 30 in the joint. The wire 30 would keep shrinkage cracks in the joint small, particularly those that are parallel to the joint. The wires 30 may be welded to the clevis or be partially wrapped around the pin 28.

Figs. 19 and 20 are fragmentary views showing some of the flexible characteristics of the form 3 and the adjustable means of the support fasteners B. Fig. 19 is a sectional view showing a form 3 which has been twisted to allow it to follow the contour of a warped panel 31 to allow the molding of another panel that is to have a portion that is the same curvature as the panel 31. Fig. 20 is a plan view showing the form 3 bent inwardly. The form 3 is notched at the corner to form a mitered joint.

Fig. 21 shows a rigid means to support and compress a form 3 that is being used to mold a keying groove and position reinforcing in the face of a panel, thus providing a means to join panels that are at right angles to each other. Template bars 2e are fastened to the support fasteners B. The bars 2e compress the form 3. The ends of the template bars 2e may be welded to bars 2f, the bars 2f being arranged similar to their arrangement shown in Fig. 23. The concrete is leveled with a screed or scraper for this arrangement.

Fig. 22 shows a form assembly that may be used to mold flat panels of limited accuracy at low cost. This arrangement includes a ground surface that may be covered with a thin waterproof plastic sheet, a form 3, a spacer strand formed by wires 5 and connectors 6, reinforcing wires 4 and template bars 2k. The bars 2k are accurately positioned. A metal tube 32 has a metal stake 33 projected through it and the bar 2k. Stakes 33 are then driven into the soil. A bolt 24 is inserted through the holes in the sides of tube 32 and the slot in the stake 33—then the nut 24a is adjusted on the bolt 24. The bottom portion of the form 3 may be depressed by selective lowering of the stake 33. The wires 4 are slightly tensioned with this arrangement due to the form filling outwardly from the pressure of the fresh concrete against it. A slit in the underside of the head of the stake 33 engages the top of the tube 32 to prevent the tube from tilting.

The stakes 33, bars 2k, and tubes 32 may be omitted in more limited arrangements, but then the form 3 must be weighted down to restrain it from rising from the pressure of the fresh concrete against the underside of the form offset 3a. The arrangement shown in Fig. 22 illustrates a means to use the elastic form 3 for molding cast-in-place floor slab panels and the like. The forms 3 may be used with the support fasteners B for cast-in-place molding of panels; the fasteners B may be arranged similar to the arrangement shown in Fig. 23.

As shown in Fig. 23, wire mesh fabric 34 may be used for reinforcing rather than wires 4. Reinforcing rod anchors 35 are welded to clevises 4b and eyes 4a to provide continuity of reinforcing and fastening means to allow panels to be interlocked. My Patent No. 2,920,475 thoroughly describes a mesh reinforced panel. Fig. 24 shows an anchor 35 that is welded to a clevis 4b. The wire fabric 34 may be stretched and be fastened to the anchors 35, then the support fasteners B may be used to pretension the fabric 34. Conventional wire fabric 34 is suitable as reinforcing for flat panels and panels that are only curved in one direction. With this arrangement, each strong clevis 4b and each strong eye 4a act for many small strands of the fabric 34 to allow the reinforcing to act efficiently like the reinforcing strands 4 act.

Form arrangements similar to that shown in Fig. 22 and 23 are useful in molding precast concrete floor sections that have terrazo chips added after the concrete has set slightly.

Figs. 25, 26, and 27 show how corrugated thin shell concrete panels that may be molded with the form means can be used to build low cost underground structures including bomb shelters, explosive storage structures, hangars, supply depots, and factories for vital industry.

The shell of the structure, shown in Fig. 25, is made of crescent shaped panels 36. These panels are similar to panels 1. The corrugations are tapered in depth. The arched roof shell of the structure is pressured by the soil 37. The soil confining the shell would prevent the arch from distorting to an objectionable degree. Since the arch is confined, it has little bending tendency, as it acts almost solely in compression. Therefore, such a thin light-weight corrugated shell would be capable of resisting a great soil pressure. The confined arch would require very little reinforcing metal. The compression of arched concrete would tend to close any small cracks, thus tending to make the building shell water-resistant.

The outer shell below the floor line has an inverted arched shape; it has the same characteristics as the arch of the upper portion of the shelter. The shape of the lower portion of the shell forms a strong light-weight, water resistant, floating foundation. Panels 38 may be placed above the panels 36 to form oval shaped duct-like spaces in the lower portion of the structure. Such oval spaces allow air to be circulated adjacent to the bottom of the structure to eliminate dampness. The oval spaces would provide access crawl space for cleaning and water-proofing maintenance work. The floor slab panels 39 have reinforcing like that of the panels 1. The panels 39 are shown supported by the supports 40. The space between panels 38 and panels 39 may be used to circulate air 41 under the floor of the shelter. The structure may have an air duct from the ground level to these duct-like spaces. The floor panels 39 may have spaced bleeder holes 39a through them to allow fresh air to be inserted into the shelter; the fresh air may be conditioned to heat or cool it.

The panels 38 may be omitted, allowing the bottom panels 36 to support the panels 39.

The arched ceiling may have interior precast cementitious panels laminated to strong exterior panels. The interior panels may contain suitable aggregate to provide panels having sound absorbing characteristics, along with fire resisting and insulating characteristics.

Hidden conventional electrical wiring means are not highly suitable for use in thin shell concrete buildings, so I have shown an exposed inverted trough-shaped conduit 49. The conduit 49 is supported by wall brackets. Lamps, pictures and drapes may be hung from the conduit. The conduit 49 may be a pleasingly attractive aluminum extrusion, with sloping fins in its interior to support wires. The bottom of the conduit 49 may have short removable closure strips to which siwtches and outlets may be attached. The wires in the conduit 49 would be easily accessible. The switches may have long ball-chains, the chains being pulled to operate the switches. Electric cords would be plugged into the outlets so they could be yanked out of their sockets in case of a short circuit emergency. The electric cords would be out of reach from small children, pets, and water being used to clean floors. The isolated conduit 49 would be out of reach of rodents, flood waters, and heat in the floor system. Short circuits in the conduit would be isolated, confined and easily discovered, thus lessening fire risks.

Fig. 28 is a sectional view through a building shell showing various types of precast panels that can be molded with the form means. The panels are useful for corrugated, thin shell type of construction. The panels are similar in construction to panel 1. Panels 42 are similar to panel 1. A serpentine or S-shaped panel 43 is attached to the adjacent panel 42. A curved panel 44 is like half a panel 42. A winged-bird shaped panel 45 is attached to panel 44. A panel 42*a* is attached to the underside of an identical panel 42 to form a laminated shell portion. A panel 46 has a straight cross-section like panel 39. The panel 46 is attached to the panels 42 so as to form a duct-like arrangement. A flat panel 47 has a segmental-like shape. The panel 47 may be used to restrain a panel 42 from buckling in width. A metal strand 48 is attached across the chord of a corrugation to prevent the chord width of the corrugation from spreading.

Means to build hollow walled structures with thin shell panels is shown in my Patent No. 2,897,668.

Thus it will be seen that I have provided economical building form means that is capable of performing a wide variety of operations to suit many conditions.

While I have illustrated and described several embodiments of my invention, it will be understood that these are by way of illustration only, and that various changes and modifications may be made within the contemplation of my invention and within the scope of the following claims.

I claim:

1. A form for molding a precast cementitious building panel having metal reinforcing strands positioned in grid formation, said form comprising an elongated elastic strip, a base for supporting said strip, said strip being sufficiently rigid so as to prevent sagging of its top portion when supported on said base, said strip having an effective height substantially equal to the thickness of the building panel to be cast, said strip having a length at least sufficient to enclose the periphery of said molded building panel, said strip being bent to the shape of the contour of the edging of the said building panel and being sufficiently flexible so as to be bendable in all directions to allow it to follow the contours of curved and flat planes, said strip having an offset portion substantially centrally of the height of said strip extending throughout its length and protruding inwardly towards the said building panel for molding a keying groove in the edging of said building panel, said strip confining the fresh cementitious aggregate of said panel deposited onto said base and defining its shape, said strip having uniformly spaced transverse holes through an intermediate portion of its height and substantially parallel to the plane of the said base, said reinforcing strands of said building panel having end portions extending through said holes, and fastener means disposed along the periphery of said strip for fastening said strip to said base and for anchoring the ends of said reinforcing strands.

2. A form for molding a precast cementitious building panel having metal reinforcing strands positioned in grid formation, said form comprising an elongated elastic strip, a base for supporting said strip, said strip being sufficiently rigid so as to prevent sagging of its top portion when supported on said base, said strip having an effective height substantially equal to the thickness of the building panel to be cast, said strip having a length at least sufficient to enclose the periphery of said molded building panel, said strip being bent to the shape of the contour of the edging of the said building panel, said strip being sufficiently flexible so as to be bendable in all directions to allow it to follow the contours of curved and flat planes, said strip having an offset portion substantially centrally of the height of said strip extending throughout its length and protruding towards the said building panel for molding a keying groove in the edging of said building panel, said strip confining the fresh cementitious aggregate of said panel deposited onto said base and defining its shape, said strip having uniformly spaced transverse holes through an intermediate portion of its height and substantially parallel to the plane of the said base, said reinforcing strands of said building panel having end portions extending through said holes, and fastener means for fastening said strip at uniformly spaced intervals to said base, the spacing of said fastener means coinciding with said spaced holes in said strip, said fastener means being disposed along the periphery of said strip and including means to anchor said ends of said reinforcing strands.

3. A form as recited in claim 1 wherein said strip has at least one longitudinal hole extending throughout its entire length.

4. A form as recited in claim 1 together with a longitudinally extending, flexible metallic spacing wire means mounted substantially centrally of the height of said strip, said spacing wire means being bendable in every direction and uniformly spacing the said end portions of said reinforcing strands, said spacing wire means also restraining said strip from stretching or contracting in length.

5. A form as recited in claim 4, said spacing wire means being mounted so as to extend longitudinally of, and closely adjacent to, said strip.

6. A form as recited in claim 1 together with a longitudinally extending, flexible metallic spacing wire means embedded in substantially the central portion of the cross section of said strip, said spacing wire means being bendable in every direction and uniformly spacing the said end portions of said reinforcing strands, said spacing wire means also restraining said strip from stretching or contracting in length.

7. A form as recited in claim 4 wherein said end portions of the said reinforcing strands of said building panels include connector means, the said connector means including a clevis on one of said end portions, and an eye on the other of said end portions of each of said reinforcing strands, said clevis and said eye each having an aperture, said fastener means including means for accurately positioning said connector means to said form and so that the apertures face towards the planes of the panel's major surfaces, whereby said connector means on like building panels to be joined together will align easily and quickly at erection so they can be interlocked with pins.

8. A form as recited in claim 1 wherein said fastener means includes means for prestressing said reinforcing strands.

9. A form as recited in claim 1 wherein said fastener

means includes means to selectively adjust the distance between said end portions of the reinforcing strands and said base, thereby allowing the positioning of the said reinforcing strands close to the bottom of said panel to allow the reinforcing strands to effectively resist tensional stresses in panels used as floor slabs.

10. A form as recited in claim 1 together with a top member engageable with the top surface of said strip to effect compression and depress the top portion of said strip, said fastener means being engageable with the underside of said top member to limit the depression of said strip, for gaging the thickness of said panel.

11. A form as recited in claim 10 wherein said fastener means includes adjusting means for selectively varying the spacing between said top member and said base to vary the thickness of said panel.

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