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2,826,521

LIGHT WEIGHT SHELL STRUCTURES OF HIGH STRENGTH-WEIGHT RATIO

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Fig. 1

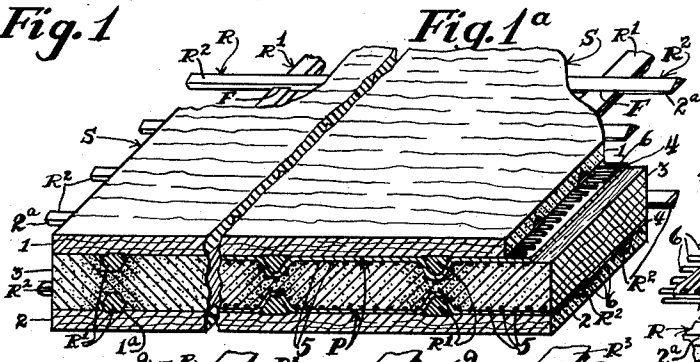


Fig. 1^a

Fig. 2

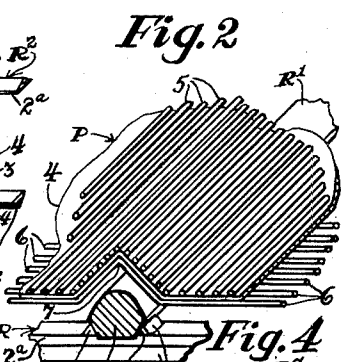


Fig. 3



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LIGHT WEIGHT SHELL STRUCTURES OF HIGH STRENGTH-WEIGHT RATIO

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5 Claims. (Cl. 154—45.9)

This invention relates to improvements in strongly reinforced light weight shells or sheathings for structural purposes and particularly where a minimum of weight and high structural strength, disclosed in my co-pending applications, Serial No. 455,350, filed August 19, 1942, now abandoned; Serial No. 492,914, filed June 30, 1943, and issued as U. S. Patent No. 2,593,714; and Serial No. 545,630, filed July 19, 1944, and issued as U. S. Patent No. 2,626,804. It relates particularly to laminated structures adhesively integrated under pressure and the novel combination of relatively cheap materials such as wood veneers and/or resin treated paper, etc., with a skeletonized continuous metal reinforcement so as to provide great strength with light weight and at small cost. It provides thin shells which can be facily and economically formed in mass production and uniquely installed for a wide variety of structural and ornamental uses.

One of the prime purposes of this invention among others is to provide a new and extensive use for commercially plentiful electrically fused or welded metal fabric, long in common use for reinforcement in concrete masses, by novelly clothing same with impressed wood veneers and in harmonious relation with the general grain structure of the latter; to reinforce at strategic points the weaker fibers of the wood with embedded elongated tensile members and also filaments of high tensile strength and superior physical properties, not possessed by the wood fibers; and furthermore to reinforce the metal fabric with strong sheet material.

Similarly, a further purpose is to provide new fields for plywood panels and sheathing by so giving new and greatly enhanced strength and physical properties to this long employed and relatively cheap material by so changing its structural character and strength-weight ratio and making it particularly desirable for a wide field of usages where these considerations are uppermost; and to provide a light weight wall-board and sheathing material of exceptional tensile strength and ruggedness.

A further purpose is to provide strong structural sheets or films in combination with high tensile filaments and in combination with other wood, metal or other laminations after the manner of applicant's disclosures in his above noted co-pending application Ser. No. 455,350 of which this may be considered a continuing and divisional application with regard to disclosures common to both applications.

Still another purpose of this invention is to provide improved and novel forms of electrically welded fabric and with particularly advantageous features for combination with applicant's fibrous and cellular laminations.

The many other objects and advantages of my invention will be better understood by reference to the following specifications when considered in connection with the accompanying drawings illustrating certain embodiments thereof in which:

Figure 1 is a fragmentary sectional perspective view of a reinforced laminated shell.

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Figure 1a is a similar fragmentary sectional perspective view of the reinforced shell, the same as Figure 1 but with the inclusion of supporting structural sheets with filaments imposed on the central core.

Figure 2 is a fragmentary perspective view of such a structural sheet with filaments, as employed in Figure 1a, and showing in somewhat diagrammatic relation the metal reinforcement in position to be combined with same.

Figure 3 is a fragmentary sectional perspective view of another reinforced laminated shell with a modified form of metal fabric.

Figure 4 is a diagrammatic comparison and end view of reinforcement similar to that used in Figure 3 in relation to other and less advantageous cross sections of metal.

Figure 5 is a fragmentary sectional perspective view of another reinforced shell in which the reinforcement is exposed to view on its two faces.

Figure 6 is a fragmentary sectional perspective view of a reinforced shell similar to that of Figure 5 but employing a slightly different cross section of metal.

Figure 7 is a fragmentary sectional perspective view of a reinforced shell with exposed metal members and a protected highly cellular core.

Figure 8 is a fragmentary sectional perspective view showing a combination of reinforcement and a covering of structural sheets with filaments.

Figure 9 is an elevation showing a reinforced shell in place, as in a building structure, and method of installing same under tension.

Figure 10 is a fragmentary elevation showing a plurality of reinforced shells in place, as for fencing, partitioning and the like, and method of installing same under tension.

In Figures 1-1a are shown adhesively laminated light weight shells S, of typical balanced sandwich construction using an odd number of laminations, as is preferred in preventing warpage. Outer wood veneers 1 and 2 form the facings for the central core 3, the general axis of the grain of the facings extending longitudinally and that of the wood core 3, crosswise thereof, the grain directions being indicated somewhat diagrammatically. The core member is of softer wood and facings of harder wood, although my invention is not limited to such arrangement or to such materials where other combinations are preferred for various reasons. In order to develop extra strength through thickness (which varies as the square of the depth) the core member 3 is relatively thick in relation to the facings 1 and 2. At the same time in order to maintain lightness of weight with this increased or greater thickness, a wood of low density, as for example balsa wood, is preferably used for the core. However, other light weight material, wood or synthetic cellular material or the like may be likewise so employed.

In order to give the plywood shell so formed with these materials exceptional strength, I introduce a strong tensile reinforcement R between the core 3 and the faces 1 and 2. This reinforcement is in each case a single, molecularly continuous element presenting a meshed but unwoven formation, the integral members of which extending in one direction have at least the greater part of same in a different plane from those extending crosswise thereof, at least the greater part of which are in an adjacent plane. In Figs. 1-1a, the reinforcements R are formed with the cross members R1 molecularly continuous with the longitudinal members R2, both being formed of high tensile drawn wire made into a molecular unit by electric fusion. Such metal members produce a tensile strength of some 70,000 lbs. p. s. i. with ordinary drawn steel. Where still greater strengths are wanted, special steel alloys can be used, heat treated and tem-

pered and with strengths two or more times the above. Such fabricated reinforcement drawn with ordinary steel, known originally as "Clinton Wire Cloth" and welded wire fabric has been produced commercially for the last 40 or 50 years and has been in common use these many years for reinforcing concrete in which it is cast. Notwithstanding that fact, the use of such metal units, uniquely impressed into assemblages of wood veneers in accordance with this applicant's disclosure has been unknown to the art and never been hit upon in this extensive art's history as evidenced by the patent records.

In applicant's novel construction, this ordinary commercial welded wire fabric which is made with round wires may be employed for these elements R. However, I prefer in the prefabricating of these high tensile units to employ specially drawn wires of shapes I have devised for better serving the several and peculiar functions of my new combination. Thus in Figs. 1-1a, instead of the standard round wire for the members R1, the wire is drawn to something of a triangular shape with the outer point to present a suitably rounded bearing surface for impressing in the soft core 3. The width of this rounded bearing surface will best be determined by the nature and hardness of the core in which it is to be introduced under pressure by which the laminated shell is formed. With a harder core wood I correspondingly narrow or make more pointed this outer penetrating and bearing surface. To further grip the core and mechanically interbond these members R1 with same, I also preferably undercut the lower and under sides of same, as at 1a, so that in the process of impression the compressed wood expands back under these undercut portions to provide this mechanical interlocking. With the thinner and harder veneer facings 1 and 2, the metal members R2 are correspondingly smaller and drawn to a penetrating triangular point at the outer edge while the under or base edges are likewise undercut at 2a for the mechanical bond. The form and relationship of these members R1 and R2 are shown in larger scale in Fig. 2 for greater clarity. Therein it will be seen how the members are electrically fused together which occurs at all crossing points in the various forms of the reinforcements R. Normally, as indicated in Fig. 2 the crossing members will slightly countersink with regard to each other and small metal shoulders will form as indicated in the fusion F, the whole structure becoming in the process a molecular unit of great strength throughout. In connection with assemblage of the various laminations for the proposed shell, I preferably dip, spray or otherwise combine the reinforcements R with suitable adhesive material so that the bond with the wood or other surrounding material is adhesively improved in addition to mechanical bonding. While my undercuttings as 1a and 2a can be omitted in drawings of these tensile members I prefer to include them while at the same time keeping a broad contact and fusion base for the molecular union of the crossing members which my special shapes provide as in distinct contrast to the tangent crossings of round wires, while at the same time requiring a lesser amount of metal even though overall dimensions of height and breadth are kept the same as that of a round cross-section, and so as to offer strong resistance to bending moments in either direction and either in the fabric by itself or in the reinforced shells S. A particular feature of the invention is to proportion, as noted, the cross-sections of the members as R1 and R2 in direct relation to the materials with which each respectively is to be combined in pressure penetration, both in consideration of so facilitating the pressure impressing and still more to secure thereafter a bearing base for the reinforcement proportioned to the softness or hardness of the wood or similar bearing material. Thus in Figs. 1-1a where a large soft core of balsa wood or the like is provided, the large cross-section of the members R1 secures a large bearing base for the metal member under stressing.

Furthermore the large size of the members R1 causes so much greater compression of the fibres of the wood surrounding these members following impression with a so-increased density of the supporting core wood at these points, as indicated in the drawings. By this means, and by further centering the opposite members R1 impressed in the opposed faces of the core member 3 in vertical alignment, as shown in Figs. 1-1a, a column of harder denser compressed wood or material is built up between and about the opposed members R1 so as to form, within the core, an I-beam construction on spaced apart centers and in conjunction with the metal members R1 forming a part of same. Also, it will be noted with a sufficiently harder material, this large size of metal cross-section would not be feasible for facile impression so that in my novel combination the sizes and shapes of my reinforcement members are not only determined by the nature of the respective lamination with which each is to combine in the structural shell formed, for considerations of strength, but, furthermore, for considerations of facile pressure forming and integrating of the shell.

As will be noted in Fig. 1a, when desired, I augment the aforesaid bearing surface of the soft core 3 for the reinforcement members R1 by further including bearing sheets or structural films P, positioned on the surfaces of the core 3 in the preliminary assemblage of the several laminations of the contemplated shell and so that these bearing sheets P intervene between the members of the reinforcement R and the core 3 and so support the reinforcement in the stressing of the finished shell by acting as a saddle for same to sit in and so distribute bearing stresses across and all over the soft core instead of permitting otherwise concentration of same directly under the members R1. The nature of these structural and reinforcing sheets P, which are further disclosed in my above noted co-pending applications, is better shown in Fig. 2 wherein a sheet or film 4 has combined with it suitable adhesive material, preferably a thermo-setting plastic, such as phenol-formaldehyde. Impregnated structural paper of the "papg" type which is capable of developing remarkable physical properties with tensile strengths of 35,000-40,000 lbs. p. s. i. when given final cure under heat and pressure is a preferable base film or sheet and in any desired number of ply. On this I have applied in manufacture and while the impregnating and/or coating resin is in a sticky state substantially parallel rows of strong tensile filaments, as 5 and 6, which are so made to adhere to the surfaces of the paper in the preliminary setting of the resin adhesive. While a variety of strong fibers or strands, organic, inorganic or synthetic may be used for these filaments, I preferably employ glass filaments where the greatest strength and other high physical and desirable properties are of prime importance. As these are in themselves non-porous and so, I find, are harder to bond adhesively to other laminations when presenting a solidly covered glass fiber front or surface, I preferably space these filaments slightly apart in sticking them on the sheet, film or papreg so that each filament by itself is free to impress itself into the wood grain or other material of the lamination with which the structural sheet element P is combined under pressure, as in Fig. 1a. Also, to so best impress with and into the wood grain of crossing wood veneers, as 1 and 3, or 2 and 3, in Fig. 1a, I apply the filaments on one surface, as 5, in one direction and filaments on the opposite or underside in crosswise direction so that both will approximately conform to the grain axis of the veneers into which each is to be impressed in the assembled laminated shell as in Fig. 1a. These directional arrangements of the so applied filaments may be greatly varied to suit the arrangement of the veneers of the intended shell and be crosswise of each other at any angle as well as right angles as shown, so as to suit wood layers so arranged; or they may be laid in the same di-

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rection on both of the sheet 4 surfaces, or again they may be applied to only one of the surfaces. Also a ply of many such sheets and with filaments on each ply in any of such arrangements may be built up preliminarily and for such use as P in Fig. 1a.

To further make it possible to combine these sheets P with the reinforcement R, as R1—R2, and press same together as shown in Fig. 1a and without thereby fracturing or overstraining these sheets by otherwise stretching them to conform to the extended contour created by the presence of the metal members (as compared with the area of a flat sheet laid upon same for the pressure integrating), I provide creased ribs or folds 7 in the prepared sheets P, spaced apart to match the spaced centers of the metal members, as R1. The size of these ribs 7 is calculated in relation to the size of the members as R1 with which the sheets are to be used and of such dimension that the sheet P is drawn properly and to the desired tightness when the reinforcement R is impressed upon it. By this means, also, a slight and desired tension can be given the sheet as it is so impressed so as to remove any desired remaining stretch and give same the highest tension reaction in the integrated and hardened shell, and this without over-stretching the sheet. Instead of a single rib or fold allowed for each member as R1, a plurality of smaller ribs or folds or indentations may be provided which will equal the same increased area for the required expansion. It also is not necessary that in assemblage exact register be had between the ribs as 7 and the members R1 as in the pressure joining the excess sheet material, so provided, will be drawn out in any case and to the contour of the so indented core 3. In cases where the wire or metal members of R are so small that undue stretch will not be brought to bear on the sheets P in the above noted pressure assemblage and integrating, these ribs or folds can be omitted.

In preliminary assemblage for the forming of the shells S, it will be understood that the several elements forming the laminations are loosely imposed one on the other in the proper order in the press which may be of the hydraulic or other mechanical type or one operating with fluid bag pressure or a combination of both. The contacting surfaces of the veneers are coated or otherwise associated with suitable adhesive, as is also preferably provided on the reinforcement as well. When the component elements are all in proper position, the pressure, and heat when required for the adhesive employed, are applied for the proper period and the reinforcement R thereby forced into the grain of the wood veneers or layers, the wood so compressed about the reinforcement and the whole laminated shell so integrated with the final curing or hardening of the adhesive. Single sectional or continuous shells can be so formed in a matter of minutes in mass press production. It will also be understood that in the gluing or adhesive bonding of the laminations the structural sheets P, when used, also provide in themselves an adhesive bonding agent similar to impregnated tissue known in the trade as "Tego" and made for bonding veneers together. Where the high structural strength of the papreg material is not required, my filaments 5 and 6 can be similarly embodied in such tissue bonding material as Tego in its manufacture so that my filaments may be impressed into the grain of the wood to supply the necessary reinforcing strength while the impregnated or otherwise adhesively treated tissue or film supplies the gluing agent for the contacting laminations. In the figures the joint or contacting lines of the several component laminations and the metal to non-metallic material may be considered as glue lines or surfaces adhesively treated for bonding. It should also be noted that as indicated or shown in Figs. 1-1a and others, the members of the metal reinforcement R can extend outward of the edges of the

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shells for providing ready metallic means for facile connection of shells to each other or to framing or other anchorages, preferably by welding of metal to metal. When not so wanted they may be cut off or the shells manufactured with flush edges in whole or part. Both arrangements are shown among the several figures.

In Fig. 3 is shown a modified form of applicant's 3 ply shell wherein the reinforcement R is similar to that of Figs. 1-1a with mesh forming molecularly continuous members R3 and R4 drawn to a unique shape having a barbed like and undercut head designed to readily penetrate the wood laminations and embed in same when the loose assemblage is subjected to pressure integrating as already described. The outer veneer facings 9 and 10 are thereby adhesively bonded to the core wood 8 as well as being mechanically bonded throughout by undercut anchoring A of the reinforcement members R3 and R4. The R3 members are of larger cross section for embedding in the thicker softer core wood 8 while the R4 members are proportioned to a smaller cross section as determined by the hardness and/or thickness of the facing veneers 9 and 10. In this instance the members R3 of one layer of the reinforcement element are in staggered instead of directly opposing relation to the corresponding members of the other layer of reinforcement impressed in the other face of the core 3 and all reinforcement members embed, as always, in directional harmony with the general grain axis of the engaged lamination.

The special cross sectional shape of these special reinforcing members as R3 are more clearly illustrated in the larger scale Figure 4 and in somewhat diagrammatic comparison with other shapes of relatively less efficiency for the intended purposes. While ordinary welded fabric formed of round wires may be used in applicant's shells, as already noted, the round wires as indicated in dotted cross sectional shape W present many disadvantages. Among these it will be readily observed from the figure that the blunt round face of W is not adapted to penetrating the wood as compared with the barred head of applicant's member R3 and while the latter has the same over-all dimensions of height and breadth for stiffening resistance to bending moments applied in either direction as compared with W, a much smaller quantity of metal and weight is employed in R3. Likewise while R3 has the same width to sustain itself in pressure on the wood lamination, (as 3 of Fig. 3), this is located at the base where it does not interfere with the impression of the member in the wood as does the same width of metal in W which is spaced away from the base or at the center axis of the circle. Furthermore R3 grips the wood relatively deep therein with its undercut A whereas the only grip for mechanical bond which W presents is on the underside of the circle and so at the more nearly surface portion of the wood, with corresponding weakness. Again where W presents only a tangent surface for fusion welding with cross members, R3 (and R4) each present their broadest width at the base for a broad fusion and bearing surface and to stiffly resist bending stresses. To further resist these and provide as well a large section of metal for fusion applicant preferably provides these members as R3 and R4 with a thickened base B, as shown. In fusion, producing the metal molecularly continuous element, the opposed members as R3 and R4, the same as R1 and R2 of Figs. 1-1a and 2, will have their contacting bases slightly countersunk with regard to each other in the normal union and so making a particularly strong cross section at such points but where this is not preferred the countersinking can be avoided by lighter or spot-welded union. As a further alternate, where the bond of the undercut A is not required, my wire shapes may be drawn with the undercuts omitted and the sides those of a simple triangle as indicated by the dotted lines W1. Also when

desired the sharper point of the shapes as R3 and R4 may be blunted to any desired terminal curvature as C1 for example. My special fabric employing any of these shapes is not only particularly adapted to my shell structures but also, it will be readily seen, has distinct advantages of strength and stiffness and with a reduced amount of metal as compared with the common commercial welded fabric and very particularly for fencing as well as reinforcement.

In Figure 5, I combine my reinforcement R, using the barbed members R5 and R6 similar to Figs. 3 and 4, with thinner veneers to make a two ply structural shell S in which the metal members are so exposed to view on both surfaces with veneer strips exposed between same and adhesively and mechanically bonded while held by the undercuts A under which the veneers 11 and 12 are forced, compressed and held. By being so compressed, subsequent shrinkage of the wood veneers, if occurring will not present an open and unsightly joint. At the same time by using handsome metal, as chrome or stainless steel, or even copper, or aluminum alloys, etc., and combined with choice and beautiful veneer woods, new and unusual architectural effects may be had for partitioning, sheathing and a great variety of ornamental as well as structural purposes. The veneers 11 and 12 cut to individual widths slightly wider than their occupied spans may be forced between the metal members in the pressing assemblage and as such separate veneer units. However, advantage may instead be taken of the special cutting points C provided by the members R5 and R6 so that whole veneer sheets formed in widths to cover the span or broad sections of the whole shell may be layed up with the reinforcement R in the preliminary assemblage and the veneer then forced onto the cutting points C of the members R5 and R6, by press or rollers, so as to crease and cut same and force the so cut veneer strips down between the reinforcement and under the undercuts A, the veneer sheets being of course first treated or coated with adhesive so as to form a completely and adhesively bonded shell under the pressure treatment so applied. It will be noted, of course, that the cutting points C, crease and cut the veneer along the grain axis with a corresponding minimum of resistance, and it will be further understood that the cutting angle of C is made, in the fabrication of the metal, to best suit its intended purpose.

In Figure 6 is shown a similar shell to that of Fig. 5 with the exception that in connection with the reinforcement R, its metal members R7 and R8 are drawn to a simpler cross section with undercut sides for locking the veneers 13 and 14, as shown, and forming a pentagonal cross section with the creasing and cutting edge C and with a broad bearing and fusion base but not as large in proportion as that of R5 and R6 of Fig. 5.

Figure 7 shows a modified shell where the central core lamination 15 is preferably a light cellular sound deadening and insulating member used in place of the balsa or soft core of Figs. 1-1a. While a variety of materials may be used for this cellular filler or core member, cellular cellulose acetate, known as "Strux" and weighing only 6-7 lbs. per cubic foot while having exceptional strength for its low weight, is particularly suitable for this lamination. In the structure of Fig. 7, this highly cellular core is not used to embed and support directly the metal reinforcement R. Instead, as shown, the members thereof, R9 and R10, combine directly with the veneers 16 and 17, on the one side, and similarly 18 and 19 on the other side of the shell S, these veneers being denser and forming a strong bearing plate for supporting the reinforcement R and covering the softer core 15. Where further supporting strength is desired, my reinforcing and sustaining bonding and structural sheets P, with or without my filaments 5 and 6, are interposed between the veneer plates and the faces of the core 15, the so multiple laminated shell assemblage be-

ing adhesively integrated throughout in connection with the pressure forming of same, as in the case of all my other structural shells S. In Fig. 7, it will be noted, I show another special shape for the reinforcement members R9 in fused molecular union with members R10, in this case of simple triangular section although other forms are optional. However, the members R9 are made to present flat flush metal surfaces between the strips of veneers 16-16 and likewise 18-18 which are mechanically locked in by the undercut cross section of the metal with its outer flanged-like lips R9F as well as being adhesively joined to the metal. These veneer strips 16, and correspondingly 18 are forced between the metal members R9 under compression, as from a preliminary arched position between same and when the shell is completed, a very fine ornamental effect may be had with many selections of handsome woods to interpose between polished metal surfaces provided by the members R9. The latter are in fused molecular union with the cross members R10 which are impressed in cross veneers 17 and 18 respectively after the manner already described in the preceding figures. It should be especially noted that when desired in combining architectural and structural effects, and further to reduce costs, I make the members R10 of different metal from R9. Thus the exposed members R9 may be of expensive chrome steel and the members R10 of ordinary cheaper steel. Similarly ornamental but weaker copper may be used for the R9 portions in fused union with stronger steel forming the R10 portions. A great variety of combinations may so be made in a thus entirely new and highly useful form of welded fabric unknown to the present art. This may apply likewise to the reinforcement R of Figs. 5 and 6 where the two opposite and exposed sides of the shell or panel can be made to present different effects and when joined in an extended shell or partition can so present alternating architectural effects. Similarly in shells as in Figs. 1-1a, and 3, where the reinforcement R is concealed as regards both members, greater strength when desired can be introduced into one set of members or lower cost of metal in another set of members by using higher strength and more costly steel alloy in one set of members and lower cost weaker steel in the cross members molecularly joined therein as the situation may recommend. In addition to applicant's shells S being made with metal members projecting from one or more or all edges as desired as well as finished flush, as already noted, these shells may be formed with mechanically interlocking edges, as tongue and grooved, and Fig. 7 shows such an arrangement whereby extended assemblages of finished shells may be set up in such interlocked and closed relation with the matching tongue and grooves adhesively joined while being forced together. It will be understood that in Fig. 7 the bearing plates formed by the sheets P or and the harder veneers 17-16 or 19-18 serve to distribute over the entire surface and body of the softer cellular core 15 the otherwise more locally applied stresses arising from the stressing of the sustaining metal skeletons provided by the reinforcements R. It should also be understood that a highly cellular material of synthetic or other creation may also be used for the core members of the shells S of Figs. 1-1a, 3 and the like, in lieu of woods or other fibrous material of any degree of softness as may be selected, as in the case of Fig. 7 and vice versa, woods and other fibrous or cellular material may be used for the core 15 of Figure 7.

Figure 8 shows a structural shell where my special structural sheets P, either singly, or in multiple groups, are applied on both sides of my reinforcement R and adhesively integrated under pressure and with or without other additional covering laminations of veneers or other suitable materials (not shown) employed as in Fig. 1a. When these sheets 4 and likewise the imposed filaments, when included, so formed about the molecularly continuous meshed but unwoven metal, are polymerized in ad-

hesive union with each other and the metal, a remarkable structure in itself is produced forming as it does thin walls of metal-like strength with cellular parallel-rows of ridges in one plane crossing and communicating with similar rows in a contiguous plane and with the so continuous connecting rows of elongated cells at the same time filled with molecularly continuous metal extending throughout all of the cell structure so formed. With a minimum of weight, it will be at once seen this multiple arch construction of the skin, crosswise in two planes as it is and containing, within, a complete and continuous metal filling skeleton, provides a unique structure of great strength and suitable for a wide field of structural uses. Applicant's imposed filaments, which can be arranged in a number of different directions to meet corresponding stresses, not only greatly increase the tensile and compression strength but also notably enhance the flexural and shock absorbing values of the shell and can further be arranged to provide directly against shear when wanted, this by including sheets with the filaments disposed at 45 degrees with the reinforcement mesh and in opposite directions, at such angle, on the opposite sides of the sheet or sheets 4 (not shown). This same applies to other of applicant's shells, as for example Fig. 7 where the filaments 5 on the core (15) side can be arranged to resist shear with one set extending at a right-hand 45 degrees and the other set extending at a left-hand 45 degrees. While any number of ply of 4 or P may be employed at will and with any combination and numbers of directions of the filaments embodied in P, two 2 ply, one on top and one underneath the reinforcement R, are shown in Fig. 8. The top two sheets 4 have their filaments 5 and 6 so oriented that both surfaces of the outer sheet and the upper surface of the under sheet have these in parallel direction with the members R11 of the reinforcement, while the under surface of the under sheet has the filaments crosswise thereof and so parallel with the direction of the reinforcement members R12. The two bottom sheets 4 have their filaments arranged directionally so that those of the outer exposed surface of the bottom sheet extend parallel with R11 while the remaining three surfaces of the two sheets have the filaments thereon extending parallel with the members R12. This also so provides for the contacting filaments 6, of the opposed surfaces in the middle of the laminated shell S, to come together parallel of and interbond in somewhat of a tongue and groove formation when the loose assemblage of sheets P and reinforcement R are finally forced together under pressure and adhesively integrated in such position therewith. As noted, the further inclusion of sheets with 45 degree filaments will further fortify the shell against shear and some or all sheets may have filaments on only one surface or none as may be predetermined in the shell design. The greater strength of uni-directional filament or an approximate approach to same, as compared with conventionally woven material has been brought out in applicant's aforesaid co-pending applications and is fully recognized as result of laboratory tests in the field of plastics. Applicant's sheets P take full advantage of this important fact. They make it possible to handle and apply unwoven uni-directional filaments in wholly unwoven form where in the field of assemblage it would be impossible or impractical to handle and employ the separate loose unwoven fibers or filaments. They also make it possible to cut these sheets with their filaments to any desired shape and size and hold the materials in position without trouble whereas, as in glass or fiber-glass cloth, the loose weaving frays and unravels and cannot be held to sharp edges or position. The unwoven filaments would of course present an even more impossible situation in such matters. It is also possible to obtain a close interbond between filaments meeting parallelly and in unwoven form where opposing sheet surfaces are bonded together, as shown in Fig. 8, whereas

the same does not occur with opposed woven filaments. Still another advantage of my structural sheets P with their filaments is that when wanted they can be polymerized or finally cured before use in laminated shells. This is important in as much as in many cases the heat and pressure that may be required for this final cure of these structural sheets is not available or employed in shops where laminated work is built up and glued with cold gluing processes and where notwithstanding these cured structural sheets of mine may still be included in gluing up the intended shells. Furthermore advantage is often gained and desired by having the filaments, as glass for example, pre-tensioned in the forming of a shell and to the proper degree, to remove stretch and increase resistance to tensile stressing. To further provide such advantage, my structural sheets can be made with the filaments readily so tensioned in the manufacturing process and where it would not be feasible or possible in the assemblage and gluing of laminated shells and under various conditions. Again, it should be noted that while I do not limit my structural sheets to any one film or sheet material or filament material or adhesive employed, my combination of impregnated paper as "papreg" with approximate strength approaching 40,000 lbs. p. s. i., with adhesively coated glass filaments developing strengths (tensile) between 100,000 to 200,000 lbs. p. s. i. or more, make shells possible of tremendous strength, of very light weight and correspondingly high strength-weight ratio.

In Figures 9 and 10 are shown somewhat diagrammatically the manner in which my various structural shells as above described can be combined, installed or erected to great advantage so as to take advantage of their embedded molecularly continuous metal skeletons forming the reinforcements R by drawing the latter into tension and then securing same by welding or other means to supporting metal frames or anchorages while the thin panels are thus taut. In Figure 9 is shown a shell S used as a partition between a floor 20 and a ceiling 21. This shell panel may have its reinforcement R concealed from view as in Figs. 1-1a, 3, 7 and 8 or may show exposed metal strips on the surfaces after the manner of Figs. 5, 6 and 7. In the present instance the vertical metal members of R have their surfaces so exposed and the horizontal or longitudinal members concealed as indicated. The latter have both their ends projecting from the shell, however, for tensioning and anchorage purposes, after the manner of R6 in Fig. 5 and these when erecting the panel are welded at one end to a metal upright as a steel channel or angle iron 22 which is securely erected in place. The reinforcement R is then temporarily secured at the other end of the panel to a gripping and tensioning device indicated in dotted line for example by a bridle or yoke Y which is made to draw the reinforcement R to the desired tension in the direction of the arrow T. While the panel and reinforcement are so tensioned, the vertical members of the reinforcement which also have their ends corresponding to those of R5 of Fig. 5 likewise properly projecting from both edges of the panel are welded or permanently anchored to steel channels, angle irons or the like, 23 and 24 (which are permanently attached to the floor 20 and the ceiling 21, respectively) at their respective ends, the various weldings being marked F. Likewise the other ends of the longitudinal members of R, held in tension are welded or otherwise secured to another erected metal upright 25, corresponding to 22 both of which serve as studs. The panel S, thus secured in tensioned position on all four edges, the tightening device Y is slackened and removed and the operation can be continued again with another panel being welded to 25 and the procedure repeated. In this way partitioning, wall structures and the like of great strength, although very thin, can be provided and with only a few supporting studs as compared with conventional practices. At the same time

highly attractive and modernistic architectural effects can be had. In this connection, by forming the shells S in square sections and erecting same as in Fig. 9 with alternate panels set vertically and the intermediate panels horizontally with respect to the exposed metal ribs or/and wood grain axes, and also with different colored metal or/and wood veneers in alternate panels. Other arrangements include alternate panels with concealed metal reinforcement as in Figs. 1-1a, 3, etc., between panels with exposed metal ribs as in Figs. 5, 6, 7 and 9. These are only some of the combinations and architectural effects which my shells make possible.

In Figure 10 is similarly shown how a series of separate shells S may be joined to each other and to an occasional post or upright as for fencing, partitioning or other structural purposes. In this instance shells of the type of Figs. 1-1a, 3 and 8 are shown and with only the longitudinal members of the reinforcement R extending and welded or anchored to holding connections. Thus the members R1 arranged longitudinally for the several shells as S1, S2 and S3 and have projecting ends, have their ends welded to connection ribs or other metal plates 26 and 27 so these panels are joined with one continuous metal reinforcement which in turn has the projecting ends of the members R1 in turn welded to a metal post or upright 28. Thereafter the continuous shell S1-S3 is tensioned with suitable device, represented by the yoke Y, and in the direction T, to the proper degree and the other projecting ends of the members R1 welded to the metal post or upright 29, the weldings throughout being indicated as F and the uprights being secured in the base or ground 30. The tensioning yoke is then released and the operation continued with additional sections of shells. It will be seen that with this tensioned installation and the great strength and light weight of the shells, long lengths of the fencing, etc., may be erected with but a small number of posts or studs while the anchored tensioned resistance will hold against strong impacts and pressure. Shells and assemblages such as these can be used for light strong roofing and the like and tensioned across the entire spans or coverings and on arched structures extending and tensioned from ground to ground, as in airdromes and the like.

It will be understood that I do not limit my invention to any particular use and that I am aware that the details of construction and method of procedure may be considerably varied without departing from the principles and spirit of my invention and I reserve the right to make all such variations as fall within the scope of the following claims.

I claim as my invention:

1. A laminated structural shell adhesively bonded together and including one lamination of wood with rows of spaced apart depressions impressed therein and extend-

ing at least approximately in the general direction of the grain of same bonded adhesively to another wood lamination also having rows of spaced apart depressions therein and which extend at least approximately in the general direction of its grain and crosswise of and communicating with said depressions impressed in the first mentioned wood lamination and a molecularly continuous metal filling occupying and common to rows of depressions in both laminations and forming a unitary meshed framework in unwoven formation with the mesh members extending in one direction superimposed on the mesh members disposed crosswise of same.

2. A laminated structural shell forming a sandwich construction having in combination two spaced apart reinforced shells of the kind described in claim 1 adhesively bonded to an intervening core member forming a softer more compressible lamination and of lower specific gravity.

3. A laminated structure as recited in claim 1 in which one of said opposed wood laminations is harder than the other and the mesh members which are impressed substantially in the general direction of and in the grain of the harder lamination are smaller in cross-section than the mesh members disposed crosswise of same and impressed substantially in the general direction of and in the grain of the opposed softer lamination.

4. A laminated structure as recited in claim 1 in which one of said opposed wood laminations is harder than the other and the mesh members which are impressed substantially in the general direction of and in the grain of the harder lamination are so shaped and have such cross-section as to more facily impress in wood as compared with the shape and cross-section of the mesh members disposed crosswise of same.

5. A laminated structural shell as recited in claim 1 with at least the mesh members extending in one direction held in tension.

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