Jan. 17, 1967 J. J. LOCKSHAW 3,298,152

INTERCONNECTED SPACED RETICULATED MEMBERS

Filed July 1, 1964 2 Sheets-Sheet 1

FIG. 1

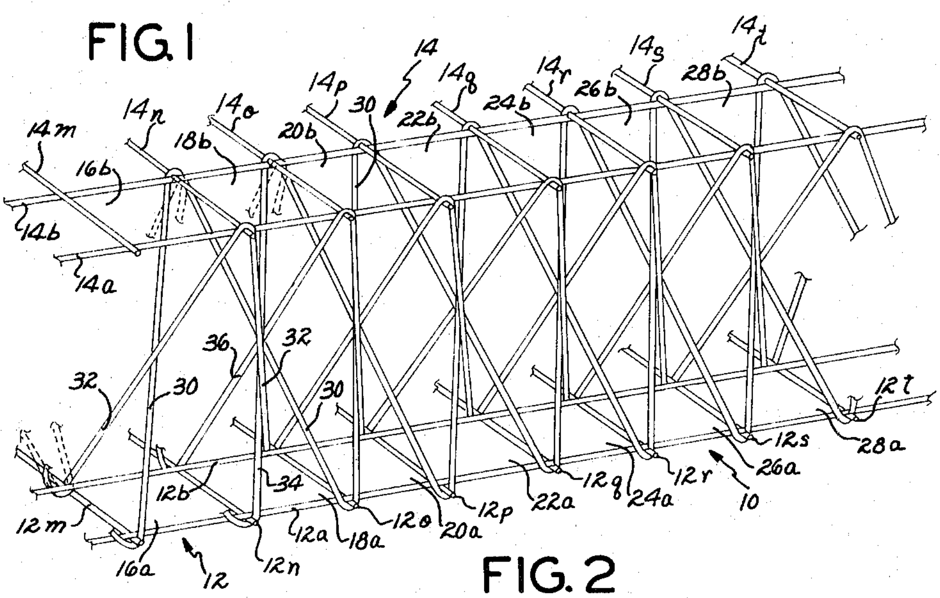
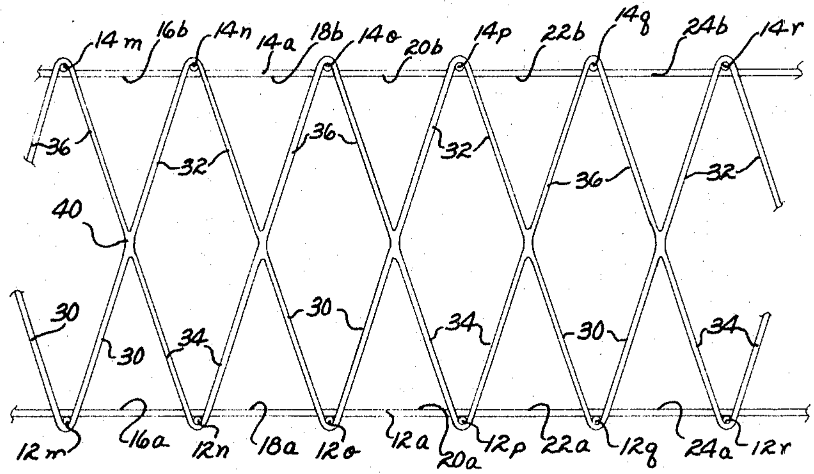


FIG. 2



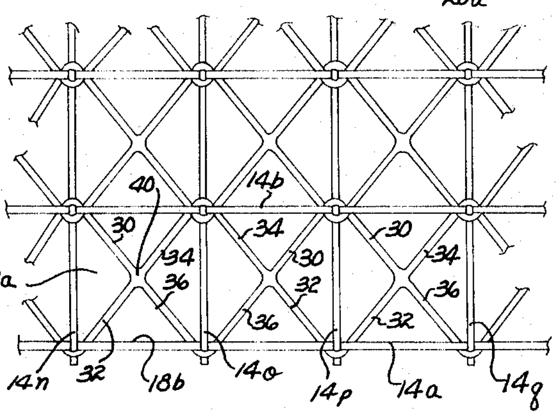


FIG. 3

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INTERCONNECTED SPACED RETICULATED MEMBERS

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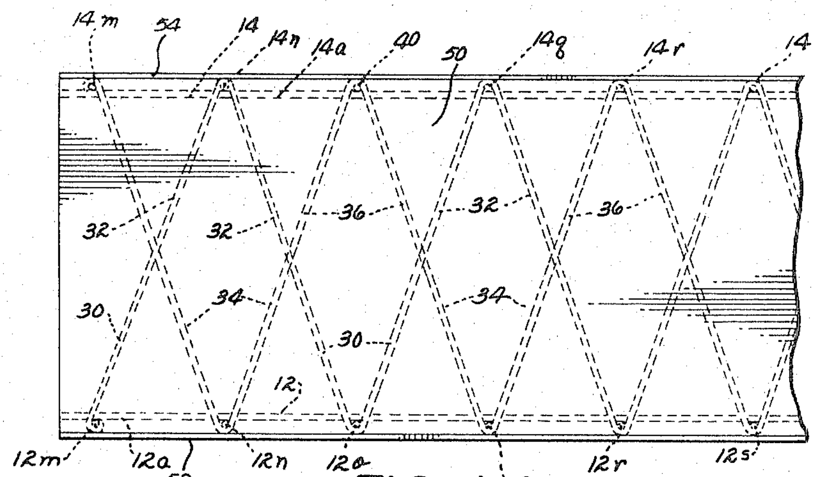

FIG. 4

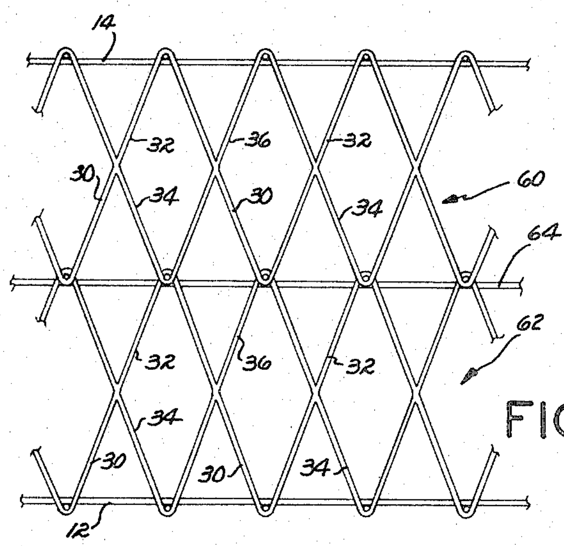

FIG. 5

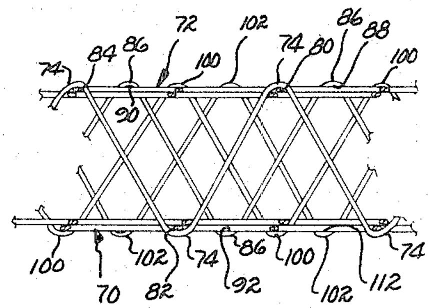

FIG. 7

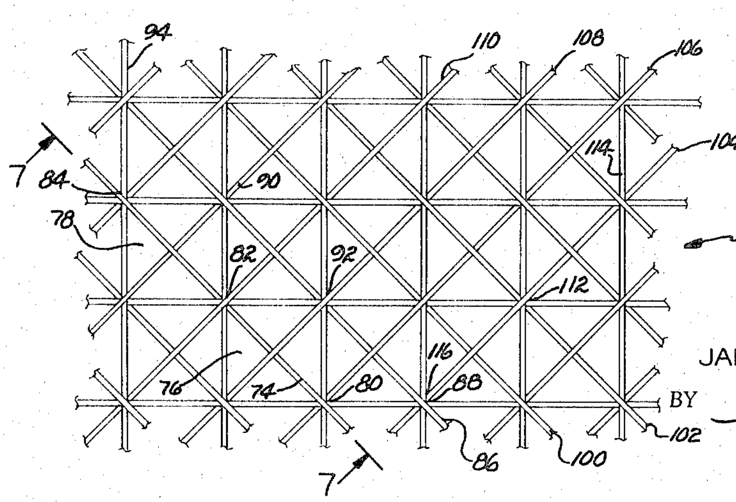

FIG. 6

72

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INTERCONNECTED SPACED RETICULATED MEMBERS

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4 Claims. (Cl. 52—650)

This is a continuation-in-part of my now abandoned application Serial Number 213,792, filed July 31, 1962 for Structural Members. The present invention relates generally to structural members and method of making same, and more particularly to lightweight members for use in constructing substantially any type of article or device.

Many industries presently employ structural members which are formed in substantially the same manner and out of the same basic materials which were used several centuries ago. This is particularly true in the building materials industry wherein structural members formed of wood, steel, or concrete are formed in substantially the same manner as was done many years ago. For instance, almost as long as man has existed he has built his shelter out of wood or similar material.

Within more recent years, however, structural members formed of steel have been used extensively in the construction of large buildings and devices. For instance, beams made of steel and provided with cross sectional configurations such as I, T, L, and the like have been found useful in providing strong structural members. Also, concrete has found considerable use in the construction of buildings for use as floors, walls and the like.

Such prior structural members, however, exhibit many shortcomings. For instance, the basic materials such as wood, steel and concrete are extremely heavy so that buildings or machines made of such materials necessarily are quite heavy. Also, such machines become particularly cumbersome due to the fact that the strength to weight ratio of the structural members used therein is extremely small.

In view of the foregoing it is an object of the present invention to provide structural members which have a very high strength to weight ratio.

Another object of the present invention is to teach the construction of structural members which can be used as compression or tension members as desired.

Another object of the present invention is to teach the construction of structural members which are formed of elongated strands woven together in a predetermined pattern.

Another object of the present invention is to teach the construction of structural members as characterized above wherein the elongated strands can be woven together by machines for that purpose.

Another object of the present invention is to provide structural members as characterized above which are constructed to withstand relatively large compressive forces.

Another object of the present invention is to provide structural members which can be shaped or contoured as desired.

Another object of the present invention is to provide structural members as characterized above which can be formed in a plurality of sections in accordance with any given strength and dimensional requirements.

Another object of the present invention is to provide structural members as characterized above which are simple and inexpensive to manufacture, and which are rugged and dependable in operation.

Another object of the present invention is to teach a method of constructing structural members having relatively high strength to weight ratio.

Another object of the present invention is to teach a method of constructing structural members by firstly weaving flexible strands in a predetermined geometric pattern and thereafter treating such strands to render them firm and strong.

A further object of the present invention is to teach a method of constructing structural members as characterized above wherein the type of geometric pattern employed renders the structural members exceptionally strong.

A still further object of the present invention is to teach a method of constructing structural members as characterized above wherein a pair of wall members, each of which is formed of a plurality of parallel and right angularly disposed strands, are held in spaced relation and double diagonal intersecting cords are weaved between such spaced wall members to form four diagonal web members between said wall members at predetermined different angles with respect thereto.

The novel features which I consider characteristic of my invention are set forth with particularity in the appended claims. The device itself, however, both as to its organization and mode of operation, together with additional objects and advantages thereof, will best be understood from the following description of specific embodiments when read in connection with the accompanying drawings, in which:

FIGURE 1 is a fragmentary perspective view of a first embodiment of the present invention;

FIGURE 2 is a fragmentary side elevational view of the embodiment of FIGURE 1;

FIGURE 3 is a fragmentary top plan view of the first embodiment;

FIGURE 4 is a fragmentary side elevational view of a second embodiment of the present invention;

FIGURE 5 is a fragmentary side elevational view of a third embodiment of the present invention;

FIGURE 6 is a fragmentary top plan view of a fourth embodiment of the present invention; and,

FIGURE 7 is a fragmentary sectional view taken substantially along line 7—7 of FIGURE 6 of the drawing.

Like reference characters indicate corresponding parts throughout the several views of the drawings.

Referring to FIGURES 1, 2 and 3 of the drawings, there is shown therein a first embodiment **10** of the present invention. This embodiment comprises a pair of spaced substantially parallel wall members **12** and **14** each of which is formed of a plurality of elongated strands which are arranged in crossed relation to provide a reticulated wall member. For instance, wall member **12** is formed of a plurality of parallel strands, as represented by strands **12***a* and **12***b*, which are disposed in spaced relation. Member **12** also includes a plurality of parallel strands represented by strands **12***m*, **12***n*, **12***o*, **12***p*, **12***q*, **12***r*, **12***s* and **12***t* which are disposed at right angles to the strands **12***a* and **12***b*. Although not mandatory for successful practice of the present invention, it is preferable to have the strands **12***m*–**12***t* inclusive lie on the outside of the strands **12***a* and **12***b* as will hereinafter be explained.

Wall member **14** is constructed in a similar manner by having strands **14***a* and **14***b* in parallel arrangement with the strands **12***a* and **12***b* of the wall member **12**, and a plurality of strands **14***m*, **14***n*, **14***o*, **14***p*, **14***q*, **14***r*, **14***s*, and **14***t* in parallel arrangement to the corresponding strands of wall member **12**. The strands **14***m*–**14***t* inclusive, as shown in FIGURES 1, 2 and 3, should overlay the strands **14***a* and **14***b* so as to be on the outside of the wall member **14** as will hereinafter be explained in greater detail.

Such construction of the wall members **12** and **14** provides a pair of reticulated wall members each of which is provided with a plurality of square apertures as indicated at **16a**, **18a**, **20a**, **22a**, **24a**, **26a** and **28a** with respect to wall member **12**, and at **16b**, **18b**, **20b**, **22b**, **24b**, **26b** and **28b** with respect to wall member **14**. Such apertures may have substantially any desired shape. However, it has been found preferable to have the wall members **12** and **14** formed of equally spaced strands which cause such apertures to be square. Such apertures, however, may be rectangular in shape merely by having increased spacing of the strands lying in one direction with respect to the spacing of the strands lying in the other direction.

One essential feature of the present invention is that the apertures of the wall members **12** and **14** be substantially identical in size and shape. Further, such wall members should be so disposed as to provide a plurality of pairs of opposed apertures such as shown at **16a** and **16b**, **18a** and **18b**, etc. in FIGURE 1.

With the wall members **12** and **14** disposed in opposed relation as above explained, a plurality of elongated flexible strands are interwoven between such wall members in a predetermined pattern. Although the specific pattern to be hereinafter described is not mandatory for successful practice of the present invention, such pattern has been found desirable to facilitate automatic weaving of the elongated strands by apparatus constructed for that purpose.

Such interwoven strands are connected to and between the wall members **12** and **14** to provide one or more diagonals for the opposed square apertures. That is, referring to FIGURE 1 of the drawings, there is shown therein a strand **30** which extends from the juncture of the strands **12a** and **12m** of wall member **12** to the strands **14b** and **14n** of wall member **14**. This provides a diagonal between the opposed apertures **16a** and **16b**. In like fashion, there is provided an elongated flexible strand **32** which extends from the juncture of strands **12b** and **12m** of wall member **12** to the juncture of strands **14a** and **14n** of wall member **14**. Thus, strand **32** provides a second diagonal for the opposed square apertures **12a** and **16b**.

Each of the strands **30** and **32** is then weaved back and forth between the wall members **12** and **14** in a continuous pattern to provide a supporting plane which is disposed at a predetermined angle to the wall members **12** and **14**. That is, as shown in FIGURE 1, elongated strand **30** is extended over strand **14n** behind the strand **14b**. Such strand is then brought downwardly toward the juncture of strands **12a** and **12o** of wall member **12** to provide a diagonal for the opposed apertures **18a** and **18b**. Strand **30** is then wound under the strand **12o** in front of strand **12a** as viewed in FIGURE 1, and is then directed upwardly toward the juncture of strands **14b** and **14p**. Thus, the strand **30** provides a diagonal for the opposed apertures **20a** and **20b**. Strand **30** is continued the entire width of the structural member **10** to provide a multiplicity of coplaner strands between the wall members **12** and **14**.

In a manner similar to that described above with respect to strand **30**, the strand **32** is also weaved between the members **12** and **14**, to provide a supporting plane at a predetermined angle with respect to said wall members. That is, the strand **32** is looped over the strand **14n** and is then directed to the juncture of strands **12b** and **12o** where it is looped around the strand **12o**. It then extends to the juncture of strand **14a** and **14p** where it is looped over the strand **14p**. Thus, the strand **32** is caused to constitute a diagonal for the opposed apertures **18a** and **18b**, and for the opposed apertures **20a** and **20b**. Said strand **32** also continues for the entire width of the structural member **10**.

In addition to the elongated flexible strands **30** and **32**, the embodiment shown in FIGURE 1 may also include the strands **34** and **36** shown therein. The strand **34** extends from the juncture of strands **12a** and **12n** to the juncture of strands **14b** and **14o**. Here the strand **34** is looped over the strand **14o** and is then directed to the juncture of strands **12a** and **12p**.

In like manner, the strand **36** extends from the juncture of strand **12b** and **12n** to the juncture of strand **14a** and **14c**. It is then looped over the strand **14o** and is directed toward the juncture of strands **12b** and **12p**.

Thus, the above explained arrangement of flexible strands provides each pair of opposed square apertures with four diagonally arranged strands. That is, with the wall members **12** and **14** positioned so as to provide a plurality of pairs of opposed apertures, the above explained weaving of the strands **30**, **32**, **34** and **36** provides four diagonally arranged strands for each pair of opposed apertures. This is perhaps most clearly shown in FIGURE 3 of the drawings.

In view of the above interweaving of the strands **30**, **32**, **34** and **36**, it is preferable to have the strands which support such interconnecting members on the outside of the respective wall member. That is, since the strands **14m**, **14n**, **14o**, **14p**, **14q**, **14r**, **14s** and **14t** of wall member **14** support the corresponding ones of the strands **30**, **32**, **34** and **36**, they should be disposed on the outside of strands **14a** and **14b**. In like manner, the strands **12m**, **12n**, **12o**, **12p**, **12q**, **12r**, **12s** and **12t** of wall member **12** should be disposed on the outside of strands **12a** and **12b**.

The above described arrangement causes each diagonally arranged strand to form an acute angle with both of the wall members **12** and **14**. Further, since the said wall members are in parallel spaced relation, each diagonally arranged strand therebetween provides a pair of oppositely disposed acute angles and a pair of oppositely disposed obtuse angles with said wall members.

Additionally, it will be seen that the four diagonals of each pair of opposed apertures provide, with the wall members **12** and **14**, supporting planes which are quadrangularly disposed.

In like manner, it will be seen that each of the elongated continuous strands **30**, **32**, **34** and **36** provides a continuous coplanar supporting structure from one end of the structural member **10** to the other end thereof. However, each such place is disposed at an angle to the wall members **12** and **14** with two such planes being in one direction while the other planes are disposed in the opposite direction. Thus, there is provided oppositely disposed supporting planes.

After the structural member **10** is formed as above explained, all of the strands are impregnated with any appropriate material for providing rigidity and strength thereto. That is, the entire structural member **10** can then be dipped into any appropriate resin which will adhere to the various strands and, upon solidification, will cause said strands to become extremely rigid and firm. In this regard, it should be noted that the four diagonal strands of each pair of opposed apertures intersect at substantially the same given point. That is shown most clearly in FIGURES 2 and 3 where point **40** is the intersection of the diagonal strands of opposed apertures **18a** and **18b**. When the structural member **10** is coated with the resin material, the intersection of the various strands are virtually welded together as at the above mentioned point **40**. This provides a pair of opposed pyramids which are extremely strong. As will be readily understood by those persons skilled in the art, the resin can be applied to structural member **10** in substantially any manner as by painting, spraying or the like in addition to the aforementioned dipping of the entire structure in liquid resin.

It has also been found desirable for certain applications to impregnate the strands prior to the aforementioned weaving operation. Various types of resin materials are suitable for this purpose. However, such strands after being impregnated or wetted with the resin must remain flexible and pliable in order to be weaved as above explained. Thereafter, in accordance with the characteristics of the particular resin used, it may be solidified by the application thereto of heat or the addition of a catalyst. In any event, it is necessary that the impregnated strands initially be flexible, and then, after the weaving operation has been completed, that they become firm and strong.

After the resin solidifies the structural member **10** is a firm unitary structure which, due to the multiplicity of resin coated strands disposed at predetermined angles to the wall members **12** and **14**, can withstand exceptionally large forces.

As shown in FIGURE 4 of the drawings, the structural member **10** of FIGURE 1 can be further modified by having an appropriate filler **50** disposed between the wall members **12** and **14** about the multiplicity of strands therebetween. Such filler may take the form of synthetic resinous foam such as polyurethane or the like. Additionally, a pair of substantially smooth coverings or skins **52** and **54** may be applied to the external surfaces of the wall members **12** and **14** to provide substantially smooth opposite surfaces for the entire structural member. As will be readily understood by those persons skilled in the art, a given structural member can be provided with either or both of the filler **50** and the pair of skins **52** and **54** as desired.

The skins **52** and **54** may be formed of substantially any material and may be bonded to the respective wall members by any one of various resins or resin foam systems. In this regard, it has been found that by using a resin foam to bond the skins to the wall members a pair of spaced sections of solidified foam are provided. Such sections of solid foam together with the "dead" air space therebetween provide a structural member having exceptional insulation properties with respect to both temperature and sound, and unusually good acoustical properties.

FIGURE 5 shows a further embodiment of the present invention wherein there is provided a pair of structural members **60** and **62** each of which is constructed in accordance with the above explained structural member **10** of FIGURE 1. However, both of the members **60** and **62** are connected to a common reticulated wall member **64** therebetween. This embodiment provides a structural member which is thicker without causing the interconnecting strands to be so long as to effectively weaken the resulting structure. That is, the strength of the structural member **10** of FIGURE 1 is due in part to the relative angular disposition of the four diagonal strands of each pair of opposed apertures. As the wall members are separated a greater distance, such angular disposition is decreased to a point where an appreciable amount of strength of the configuration is lost. To avoid this, the structural members **60** and **62** are arranged back-to-back to provide a structural member having a considerably deeper cross section.

The embodiment shown in FIGURES 6 and 7 also comprises a pair of substantially parallel spaced reticulated wall members **70** and **72**. Each such wall member is comprised of a plurality of cross strands to provide a multiplicity of substantially square apertures as above explained with reference to the first embodiment. The wall members **70** and **72** are arranged such that there is provided a plurality of pairs of opposed square apertures.

Diagonal strands are then weaved back and forth between the spaced wall members **70** and **72**. Each strand is caused to follow along a series of opposed square apertures which are diagonally arranged in the said wall members. That is, as shown most clearly in FIGURES 6 and 7 of the drawings, the strand **74** is caused to be woven as a diagonal for the opposed apertures identified generally as **76** and **78**. The strand **74** is above the wall member **72** at point **80** and thereafter extends downwardly to pass beneath the wall member **70** at point **82**. Thereafter, it extends upwardly so as to pass over the wall member **72** at point **84**. Thus, the strand **74** constitutes diagonals of the opposed apertures identified generally as **76** and **78**.

In like fashion, the strand **86** immediately behind strand **74** as viewed in the sectional drawing of FIGURE 7, is positioned over the wall member **72** at points **88** and **90** while being beneath the wall member **70** at points **92** and **94**. Immediately behind strand **86** are strands **100** and **102** which are arranged in similar manner with respect to the wall members **70** and **72**.

In addition, there are diagonal members such as shown at **104**, **106**, **108** and **110** which extend generally at right angles to the diagonal members **74**, **86**, **100** and **102**. The strand **104**, for instance, is positioned above the wall member **72** at point **112** while being beneath the wall member **70** at points **114** and **116**. To avoid needlessly confusing FIGURE 7 of the drawings, the strands **104**, **106**, **108** and **110** have been omitted.

It is thus seen that the embodiment of FIGURES 6 and 7 comprises a plurality of opposed square apertures in each of which there is provided a pair of diagonal strands. Further, it is seen that each adjacent pair of opposed apertures are provided with diagonal members which extend in opposite angular relation. Thus, there is provided angularly disposed diagonal members which provide quadrangularly arranged supporting planes. That is, one quarter of the diagonally arranged supporting strands of this embodiment provides a supporting plane which extends in a given direction with respect to the spaced wall members **70** and **72**. Each remaining quarter of the supporting strands provides a supporting plane in a direction separate and apart from the supporting planes afforded by the other strands. Thus, the supporting strands in the embodiment of FIGURES 6 and 7 provide four quadrangularly arranged supporting planes.

It is contemplated that the embodiment of FIGURES 6 and 7 be provided with a resinous coating as above explained with respect to the first embodiment. Such coating can be applied by dipping, spraying, painting or the like, or by impregnating the strands as explained above with respect to the first embodiment.

It is contemplated within the purview of this invention that the strands used in any of the embodiments may be formed of substantially any type of flexible material. For instance, such strands may be formed of cotton fiber, or they may be formed of glass, metal, Orlon, nylon, hemp or any appropriate synthetic material. Also, the coating for the fibers can be substantially any hardening material such as ordinary glue, shellac or any of the synthetic resins.

Regarding the use of metallic strands to form the subject structural members, it is contemplated that after the flexible metallic strands have been weaved as hereinbefore described, the various junctures may be welded, brazed, soldered, or fastened together in any other appropriate manner. In fact, it is thought that the entire structure can be dip-soldered or dip-brazed, or that such junctures may be welded by either gas or arc welding operations. Also, the metallic structure may be rigidized by coating the strands with appropriate hardeners, or such metallic members may be heat-treated to remove the flexible nature and to render the same strong and rigid.

It is thus seen that the present invention provides structural members which are extremely light in weight but which provide relatively high tensile and compressive strength. The strength to weight ratio of the structural members of the present invention is extremely high. Thus, such structural members find particular use in the manufacture of airframes which require light weight members which are extremely strong.

Although I have shown and described certain specific embodiments of my invention, I am fully aware that many modifications thereof are possible. My invention, therefore, is not to be restricted except insofar as necessitated by the prior art and by the spirit of the appended claims.

I claim:

1. A structural member comprising in combination, a pair of spaced substantially parallel reticulated wall members each formed of a plurality of parallel and crossed elongated flexible glass fiber strands joined together at each juncture providing corners of apertures, said pair of wall members providing a plurality of pairs of aligned substantially identical spaced apertures each aperture having at least two pairs of opposed corners, the sole support for said wall members comprising a flexible elongated glass fiber support member extended from each corner of each aperture of one wall to the diagonally opposite corner of its aligned aperture of the other wall, said glass fiber strands and support members being impregnated and stiffened with a hardener to provide increased compressive strength for said fibers and to provide a strong juncture of said strands at the corners of said apertures.

2. A structural member comprising in combination, a pair of spaced substantially parallel recticulated wall members each wall member formed of a plurality of parallel strands and an equal number of spaced strands at right angles thereto said pair of wall members providing a plurality of pairs of aligned substantially identical spaced opposed squares each square having four substantially equally spaced corners, the sole support for said wall members comprising a support member extending from each corner of each square of one wall to the diagonally opposite corner of its aligned square of the other wall, said strands and support members each being

formed of a flexible elongated strand of glass fiber impregnated and stiffened with a hardener to provide increased compressive strength thereto, whereby a strong structural member is thereby provided.

3. A structural member according to claim **2** wherein said hardener also surrounds and stiffens the junctures of all adjacent glass fibers to strengthen said junctures and provide increased strength for the resulting structural member.

4. A structural member according to claim **3**, wherein said sole support comprises said four diagonal support members for each pair of opposed squares, said support members for each pair of opposed squares crossing each other and being adjacent each other intermediate the respective opposed squares, said hardener surrounding and stiffening said support members to provide a strong juncture thereof intermediate the respective squares.

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