

- [54] **EXPANDABLE TRUSS STRUCTURE**
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[73] Assignee: **General Dynamics Corporation**, San Diego, Calif.
[22] Filed: **Dec. 7, 1972**
[21] Appl. No.: **313,039**

- [52] U.S. Cl. **52/646**, 14/14, 182/152
[51] Int. Cl. **E04h 12/18**
[58] Field of Search 52/109, 645, 646, 52/648; 182/152

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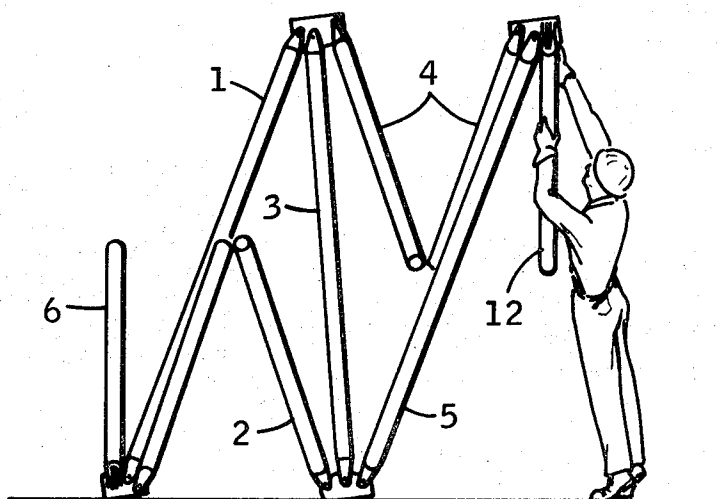
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Primary Examiner—Henry C. Sutherland
Attorney—John R. Duncan and Hugo F. Mohrlock

[57] **ABSTRACT**
A standard structural building module which is a three-dimension triangulated truss, capable of being retracted into a compact package for storage and shipment and then expanded on site for erection and connection to similar modules. Modules may be joined side-by-side or end-to-end to construct many structural forms such as, for example, a bridge in the horizontal orientation or a tower in the vertical orientation. A structure may be sized to support any magnitude or mode of loading by adding modules until adequate strength is attained.

16 Claims, 31 Drawing Figures



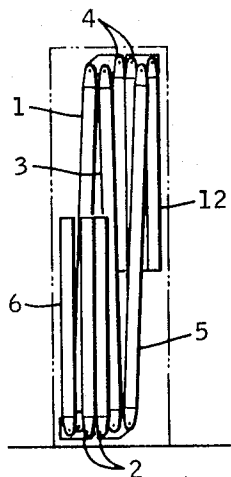


FIG. 1

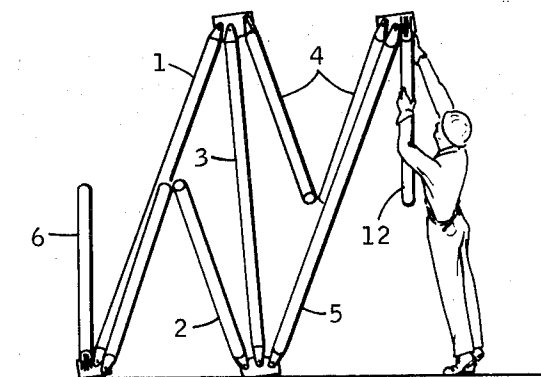


FIG. 2

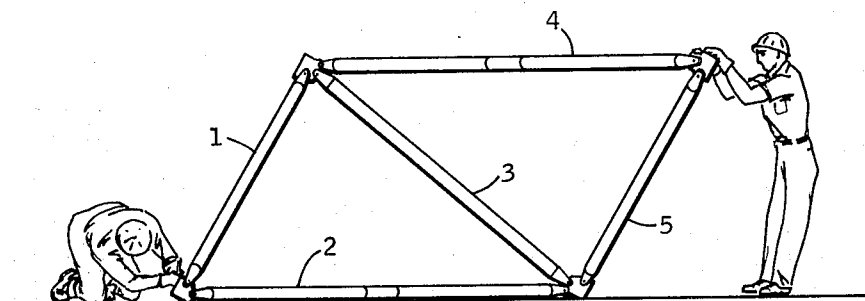


FIG. 3

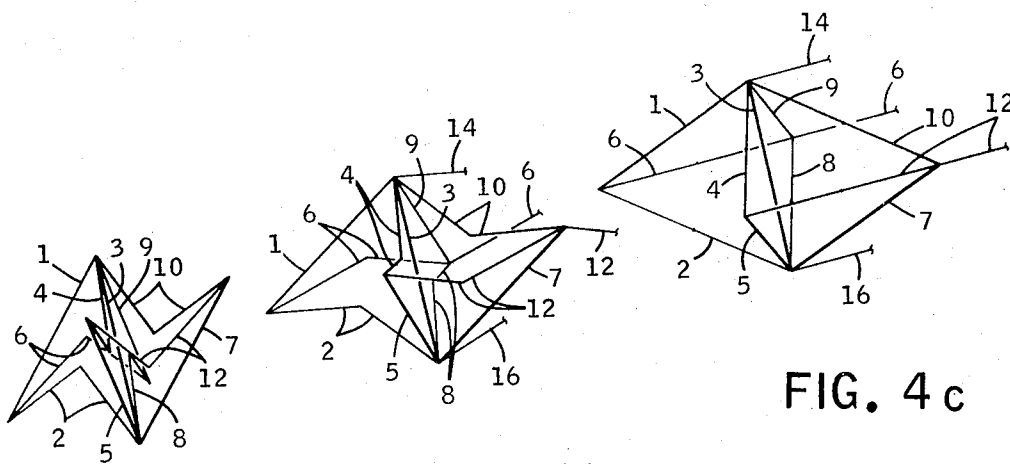


FIG. 4a

FIG. 4b

FIG. 4c

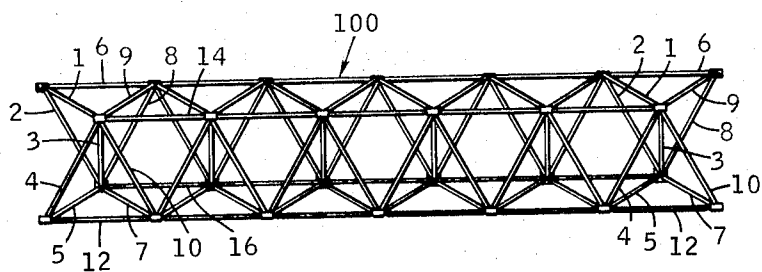


FIG. 5

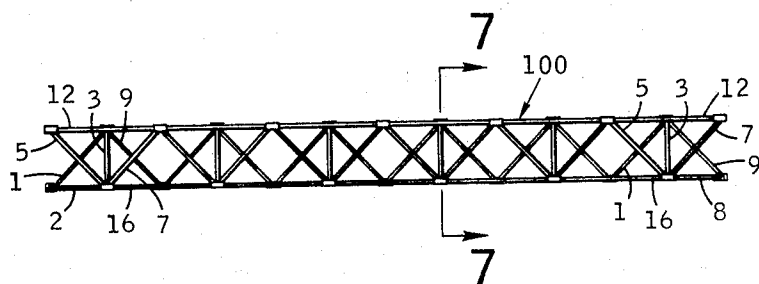


FIG. 6

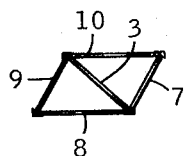


FIG. 7

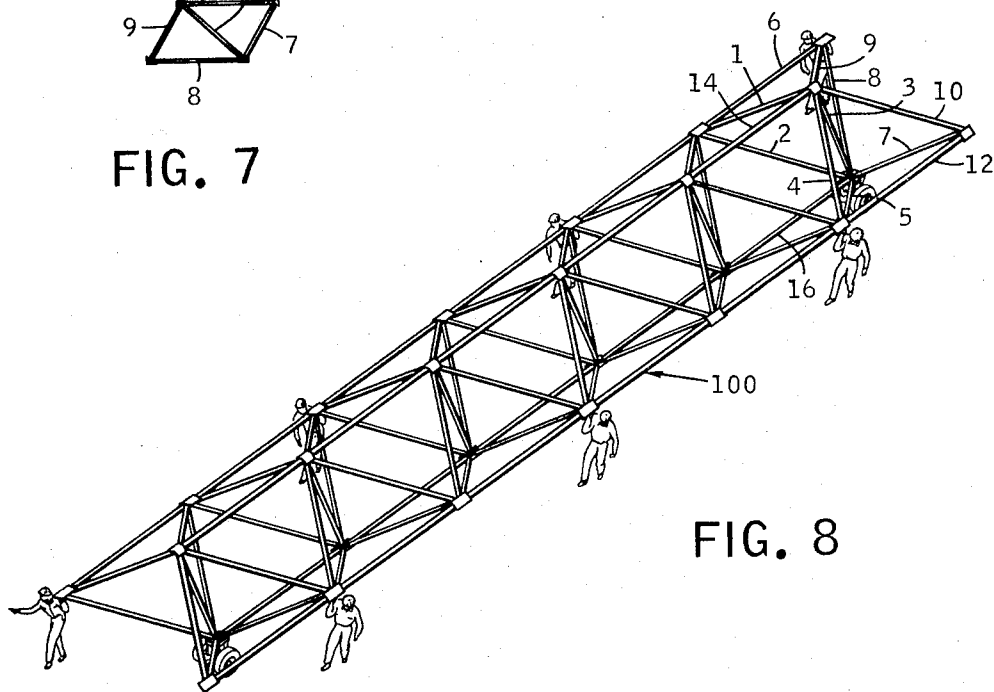


FIG. 8

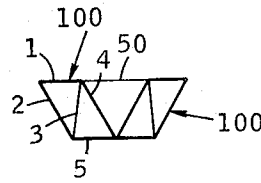


FIG. 9

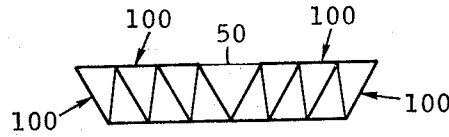


FIG. 10

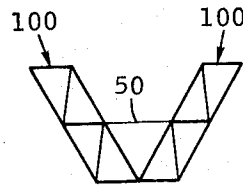


FIG. 11

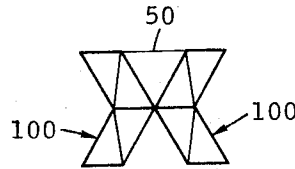


FIG. 12

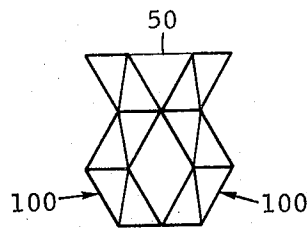


FIG. 13

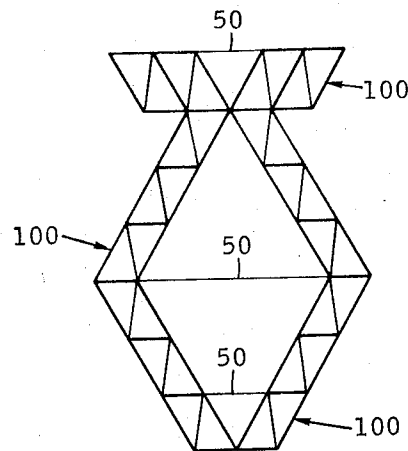


FIG. 14

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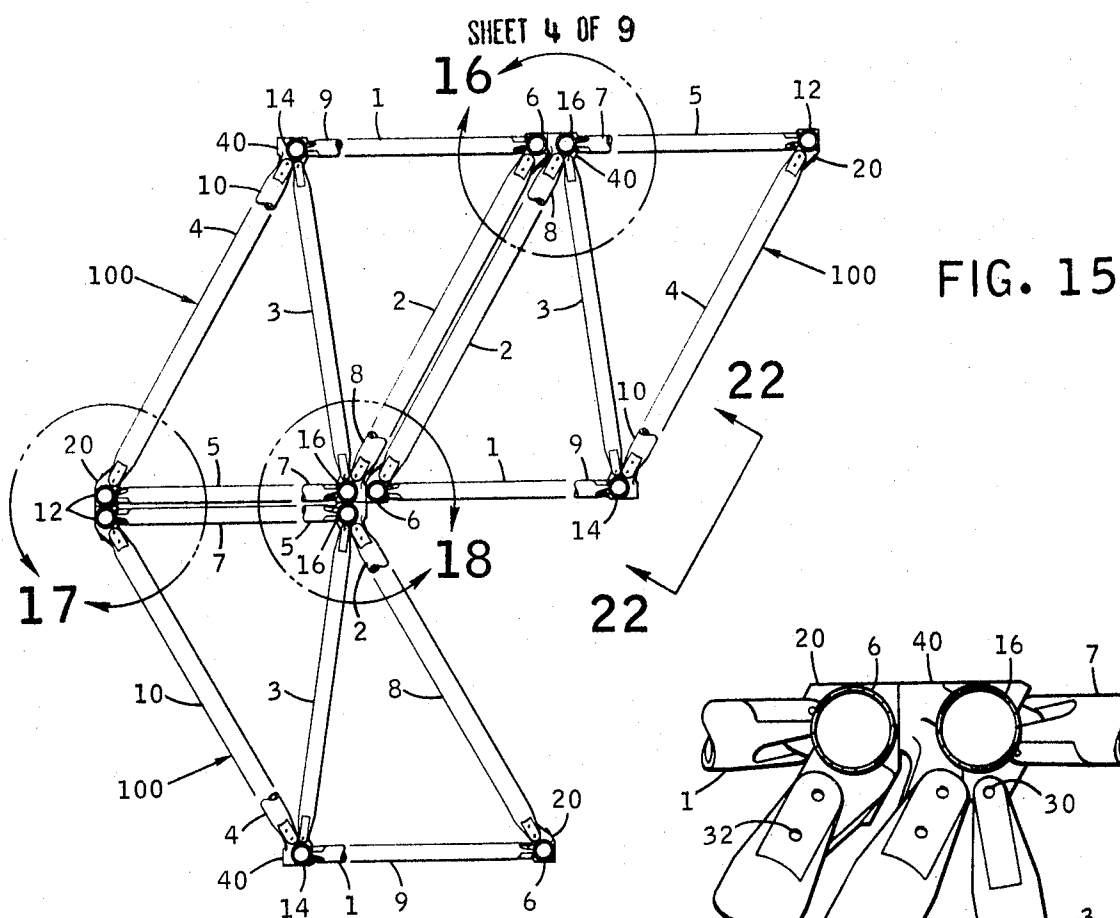


FIG. 15

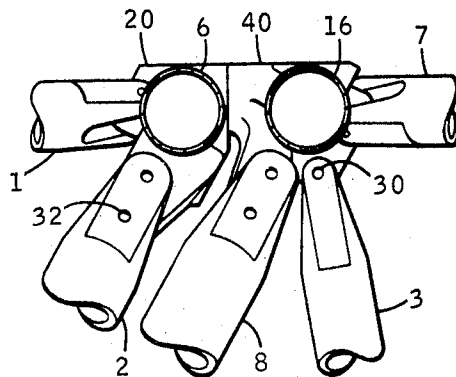


FIG. 16

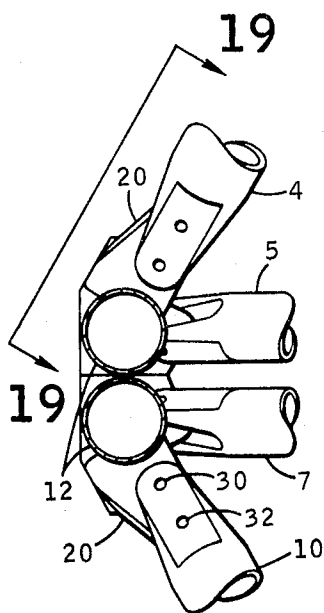


FIG. 17

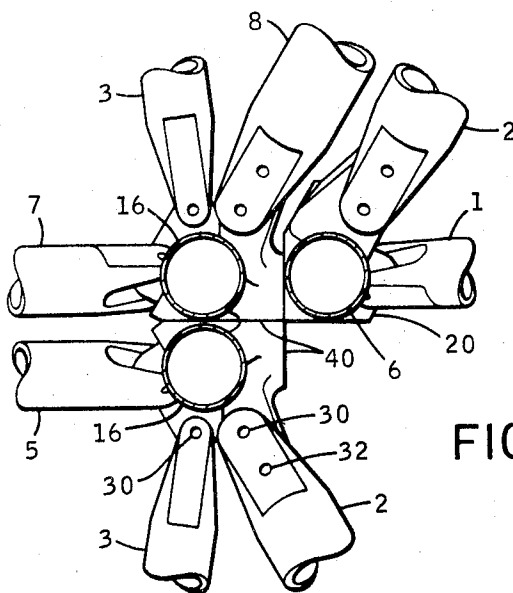
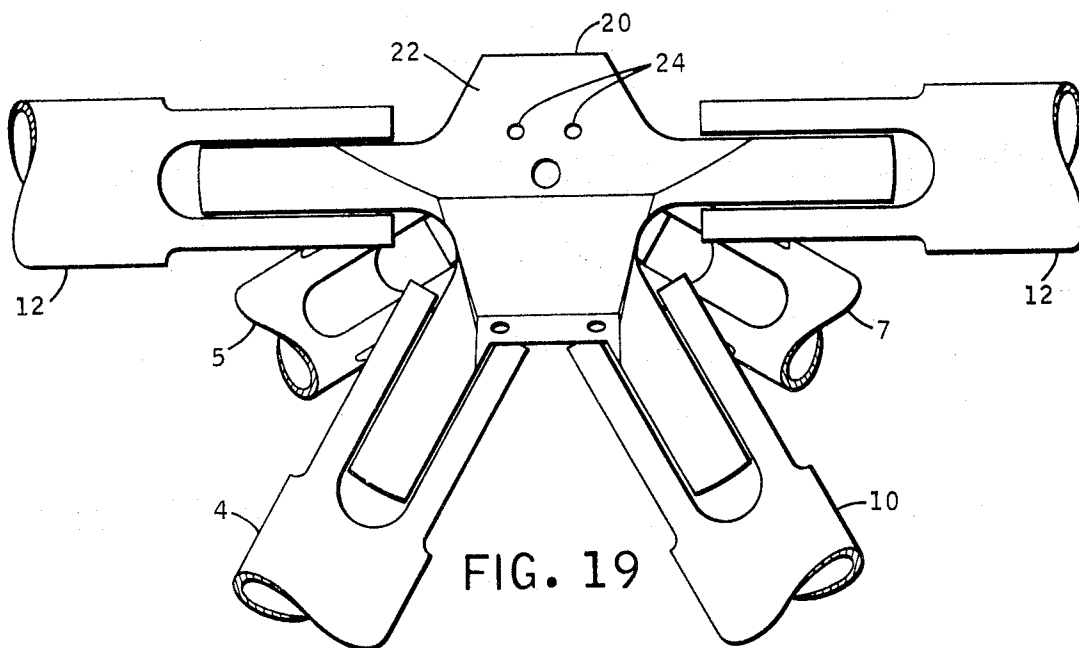
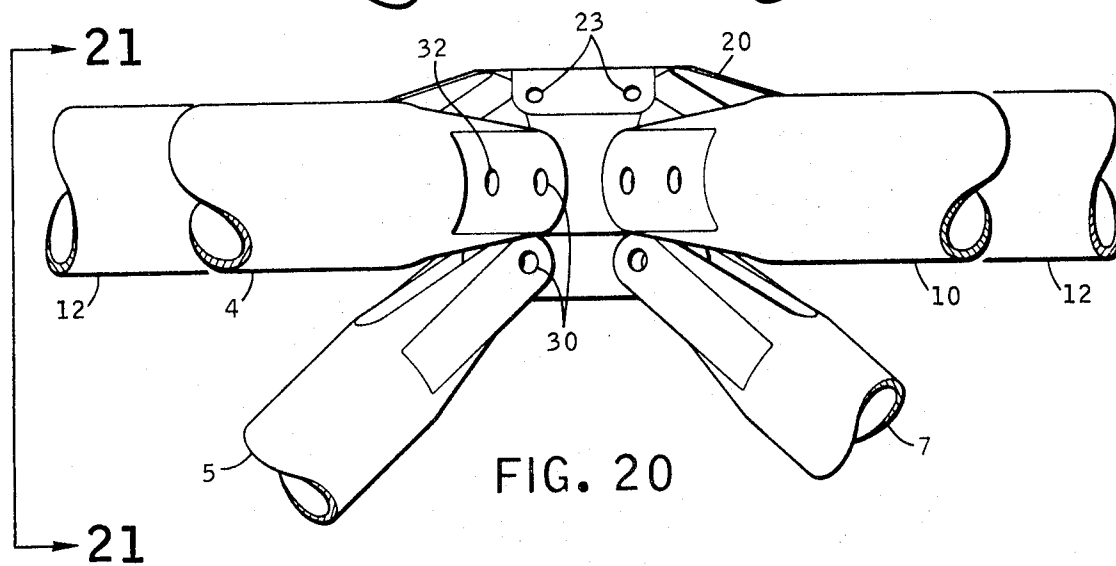
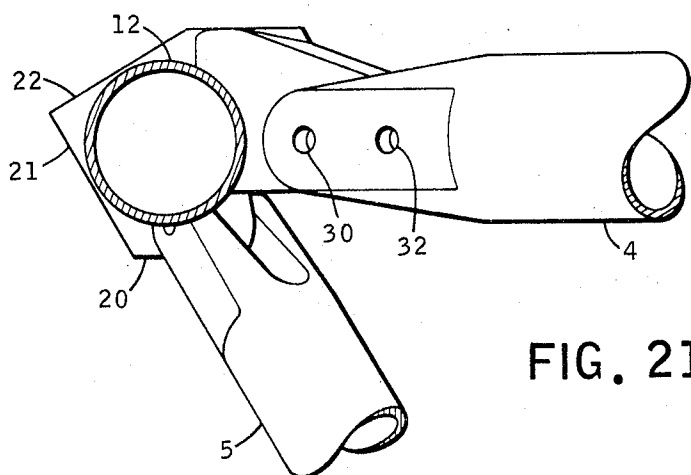


FIG. 18

SHEET 5 OF 9



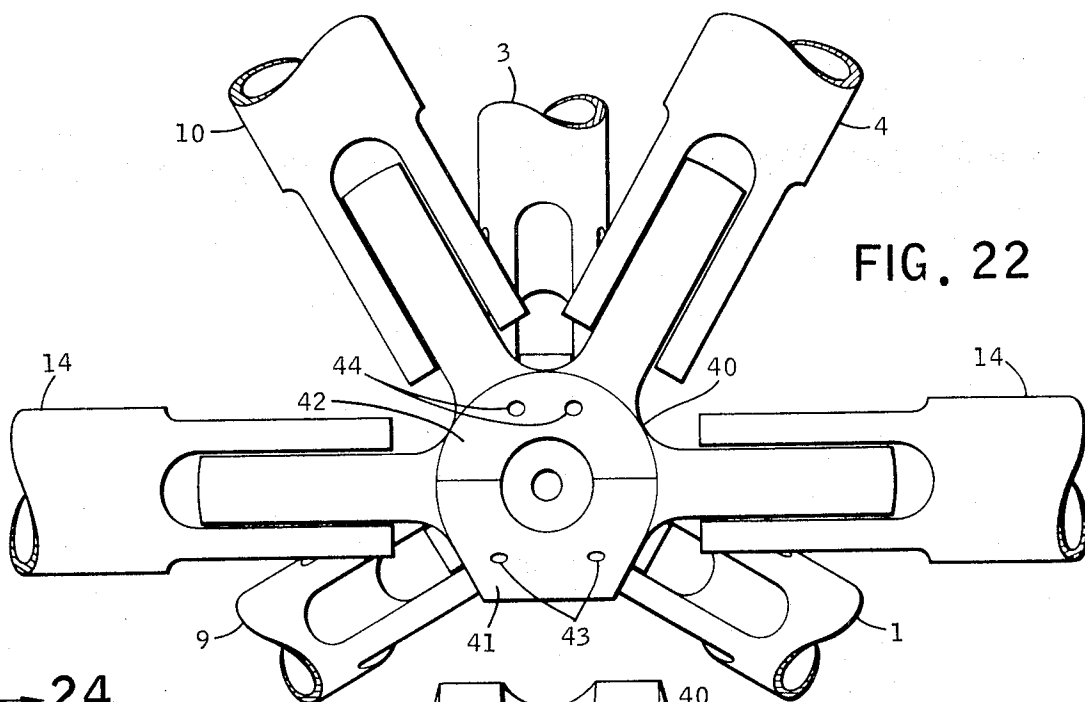


FIG. 22

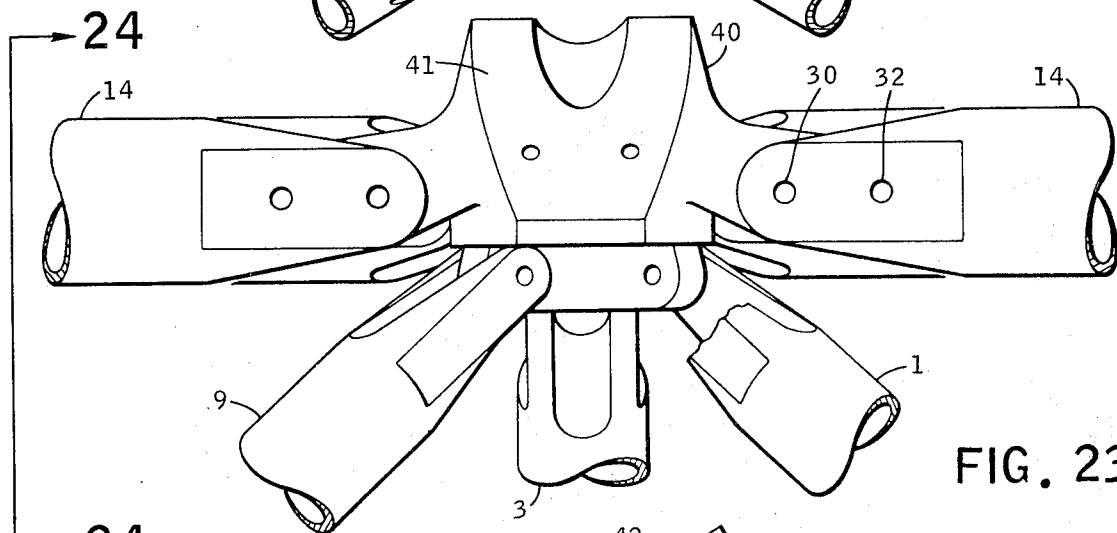


FIG. 23

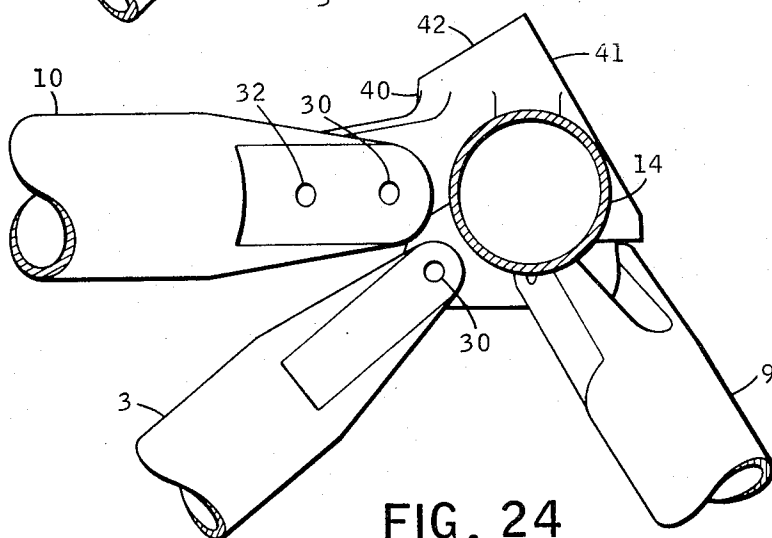


FIG. 24

FIG. 25

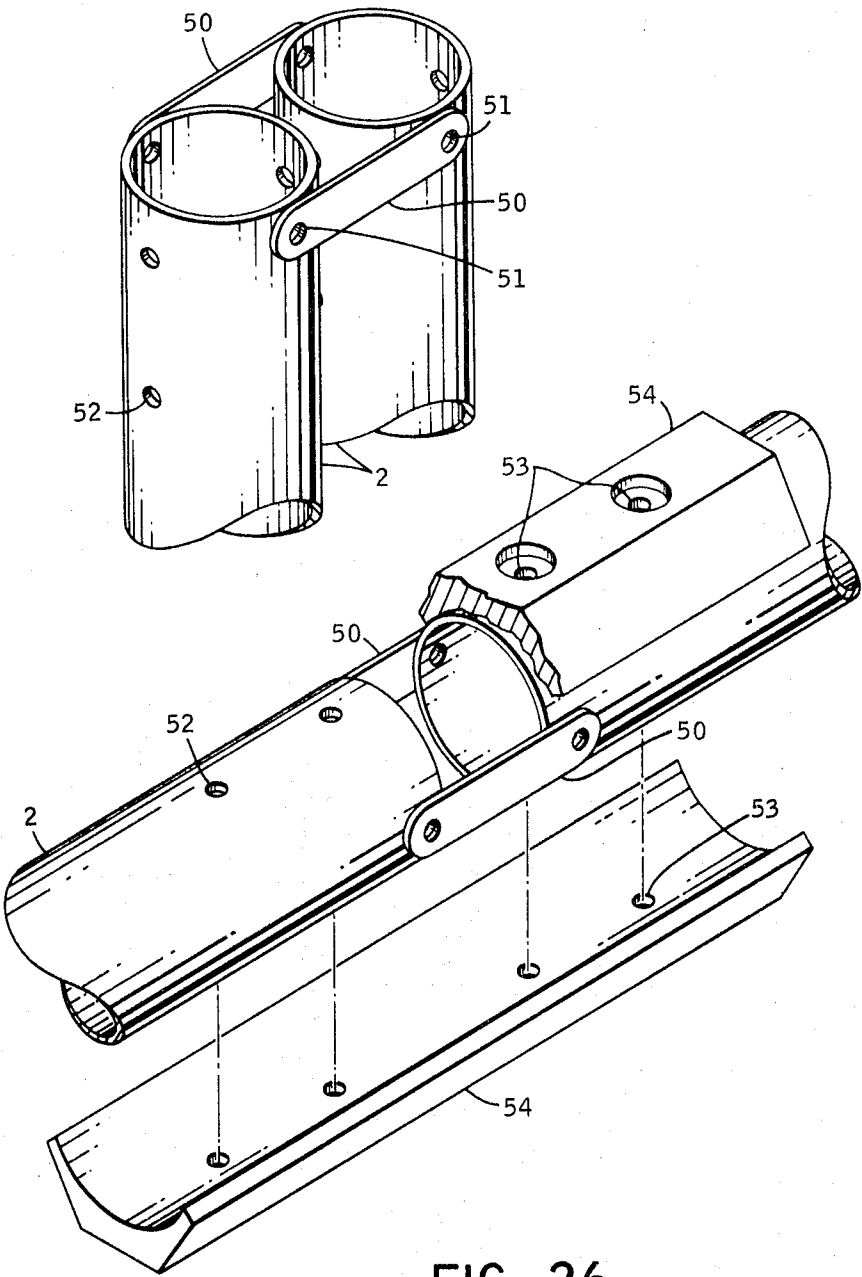
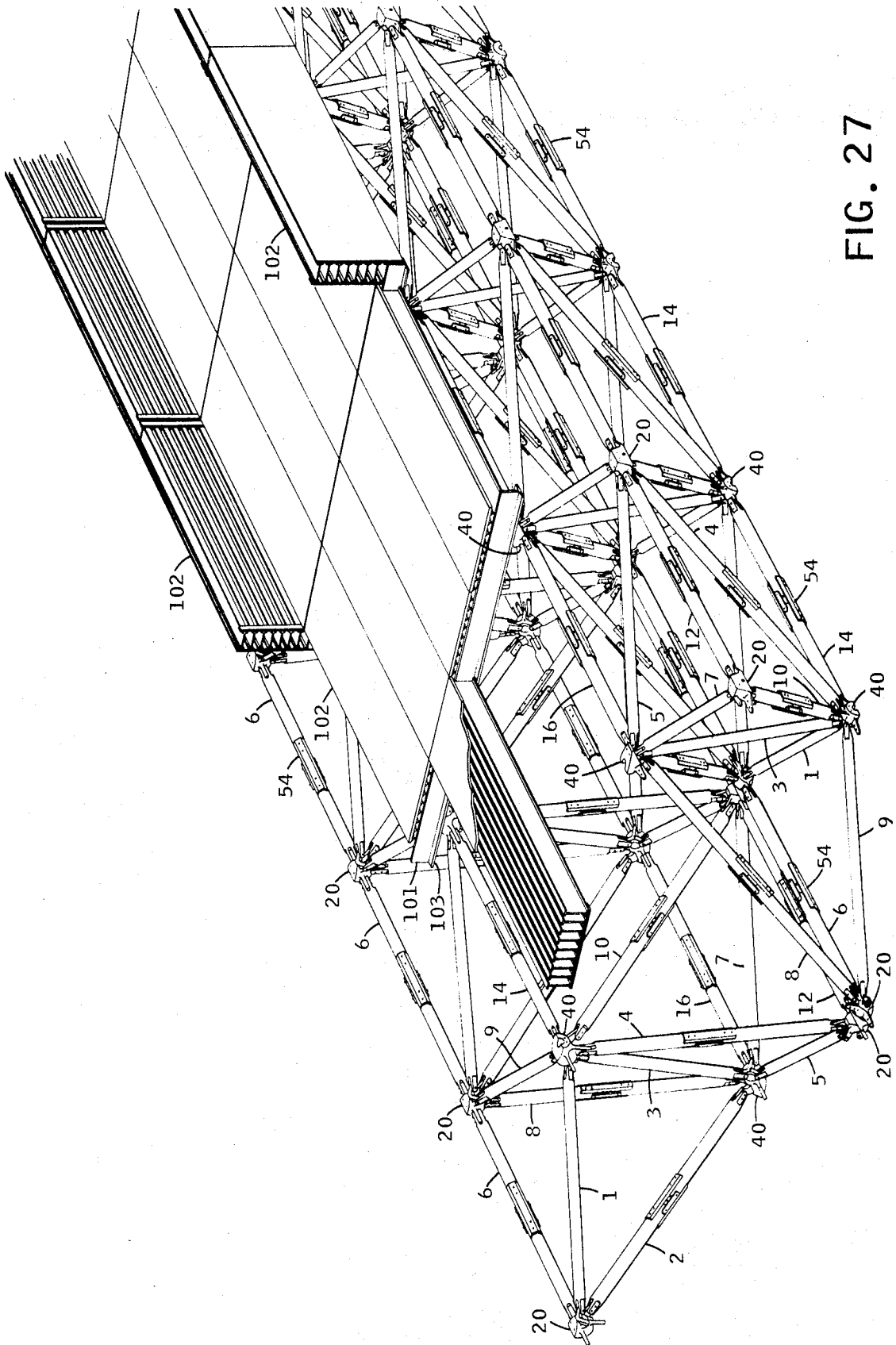


FIG. 26



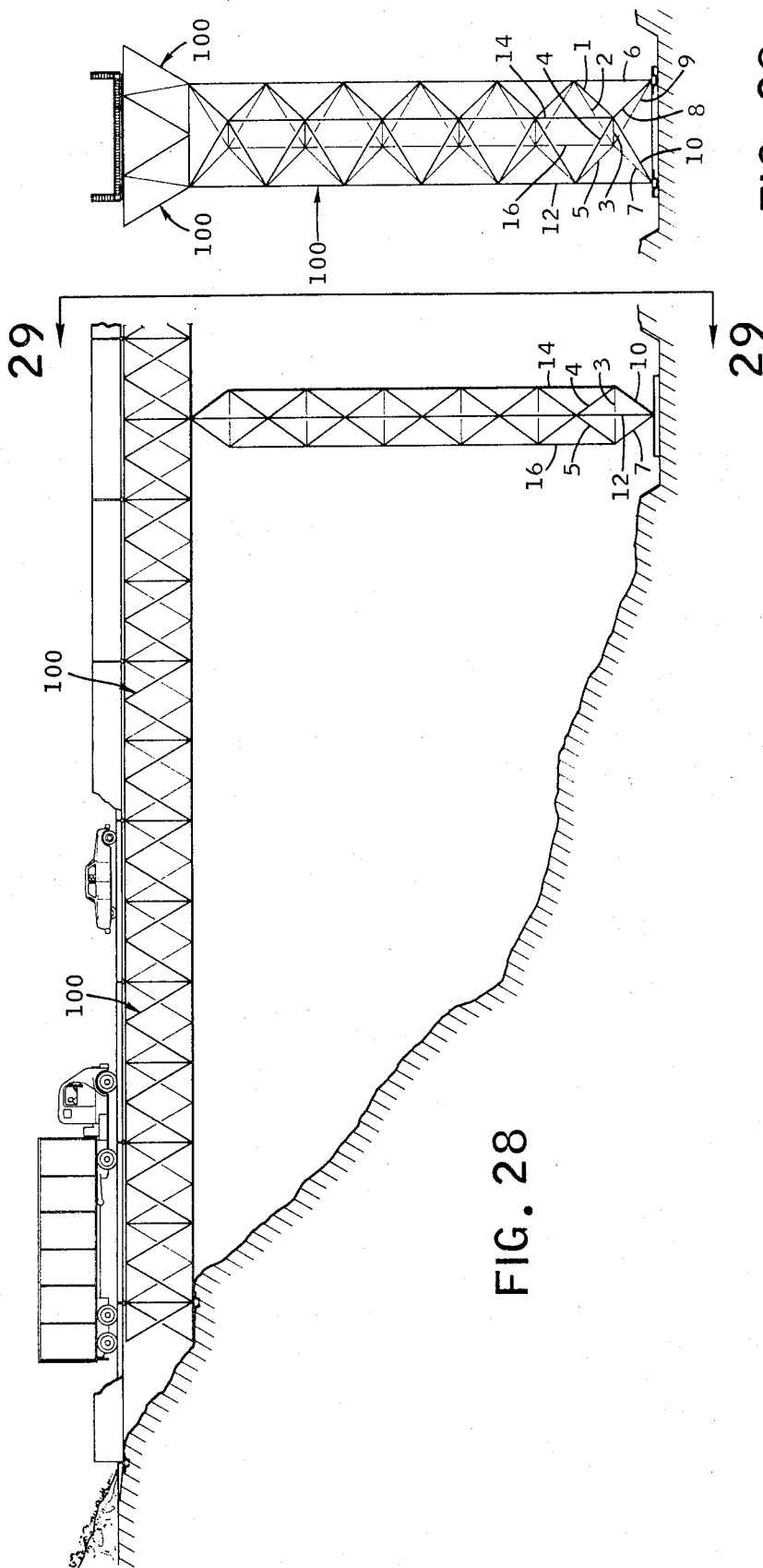


FIG. 28

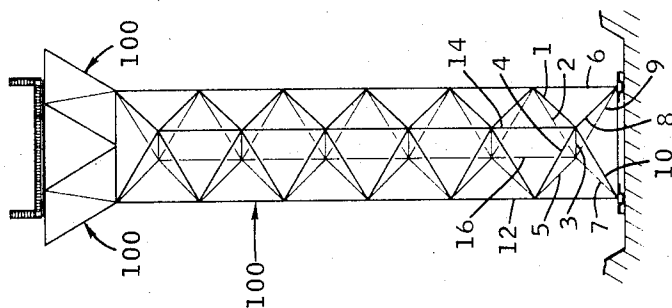


FIG. 29

EXPANDABLE TRUSS STRUCTURE

BACKGROUND OF THE INVENTION

The invention relates to a truss structure applicable to a wide variety of structures including but not necessarily limited to bridges, towers, booms, scaffolds, and open truss structural beams.

A need has long existed for structures which may be quickly erected with a minimum of on-site personnel and which have a high degree of portability in terms of compactness and light weight. When civil disaster strikes, it is usually required to quickly erect structures, such as communication towers or temporary bridges as examples, which possess the characteristic of portability. The structure must be capable of being moved into an area and set up for operation as quickly as possible. Further, it must be capable of being quickly collapsed or compressed into a compact package for rapid movement into other areas as directed by the flow or character of the disaster.

Heretofore, such features have been difficult to achieve, and structures were erected by assembling the structure in-place utilizing elements having quick attachment features. Hinged rigid panels, and prefabricated standard structural elements all have the disadvantage of being bulky and cumbersome, since for reasons of interchangeability the elements are sized to carry the peak load that may occur anywhere in the structure, but only occurs in a minority of the actual assembled structure. Secondly, most such structures require that assembly must be completed by workers at the site making numerous connections of the structural elements, requiring many manhours, and presenting a continuing possibility that errors in assembly will be made, such as utilizing the wrong length or gauge element. The most efficient compromise has been to prefabricate structures capable of carrying the predicted loads with the minimum structural weight, and limit the size of the prefabricated structures to the maximum allowable shipping dimensions. This results in shipped packages having high volume and low structural density, which raises the net shipping costs.

SUMMARY OF THE INVENTION

The invention is directed to a concept for constructing bridges, towers, scaffolds, outriggers, or the like utilizing expandable truss modules which are adapted to be collapsed for shipment and then expanded on-site for erection and connection to similarly configured modules. A plurality of modules joined side-by-side and end-to-end may be utilized as a bridge in the horizontal orientation or as a tower in the vertical orientation.

The concept of the present invention employs three-dimension triangulated truss structure to provide the required strength in lightweight folding modules. The folding modules compress into compact packages of less than one-tenth the volume of the expanded structure, thereby permitting ease of handling and shipping.

It has therefore been an object of this invention to provide an expandable and retractable structure which overcomes previous difficulties with portable structures.

Another object of the invention is to provide a fully fabricated expandable-retractable load supporting structural module that is foldable into a compact unit for storage or portage purposes.

Another object of the invention is to provide a lightweight structure which is capable of being erected in a short time with a minimum of manpower, erection tools, or other facilities and structures.

A further object of the invention is to provide a fully fabricated expandable structural module which is easily portable and which when erected provides a strong and sturdy load-carrying structure which, after accomplishing the required purpose, may be easily disassembled and each module retracted into a compact portable package for subsequent use in the erection of another structure.

The above objects and others are accomplished by the present invention utilizing a novel combination of articulated and rigid link structural elements interconnected to provide a compactly stored package which will expand into a rigid lightweight supporting structure. The shape of a structural module when expanded is dependent upon the individual lengths of the link elements, and since the entire module is preassembled, there is no danger of assembling an incorrect length element in the structure at the erection site, as is possible with unassembled structural elements currently in use.

BRIEF DESCRIPTION OF THE DRAWING

The advantages of the present invention reside in the construction and cooperation of elements as hereinafter described, reference being made to the accompanying drawings forming a part of this disclosure, wherein:

FIG. 1 is an end view of the structure in the folded position, utilized for storage or shipping.

FIG. 2 depicts the structure of FIG. 1 in a partially expanded position.

FIG. 3 is an end view of the structure of FIG. 1 in the fully-expanded position.

FIG. 4 is a perspective view of the structure of FIG. 2, in stages (a through c) of expanding.

FIG. 5 is a top view of a completely expanded structure, which exemplifies a standardized module useable in a variety of structures.

FIG. 6 is a side view of the expanded module of FIG. 5.

FIG. 7 is a section view taken along line 7-7 of FIG. 6.

FIG. 8 depicts an expanded module being moved to the construction site.

FIGS. 9-14 are schematic illustrations of various typical structural combinations utilizing a plurality of the standardized modules of FIG. 5.

FIG. 15 is an end view of three modules assembled together.

FIG. 16 is a detailed view of the spider fittings taken at line 16 of FIG. 15.

FIGS. 17 and 18 are views of other sets of spider fittings taken at lines 17 and 18 of FIG. 15.

FIG. 19 is a view of a spider fitting taken along line 19-19 of FIG. 17.

FIG. 20 is an elevation view of the fitting of FIG. 19.

FIG. 21 is a cross-section view taken at line 21-21 of FIG. 20.

FIG. 22 is a view of a spider fitting taken at line 22-22 of FIG. 15.

FIG. 23 is an elevation view of the fitting of FIG. 22.

FIG. 24 is a cross-section view taken at line 24-24 of FIG. 23.

FIGS. 25 and 26 are views of an articulated member joint in the folded and extended positions.

FIG. 27 is a broken-away view of a bridge structure utilizing the standardized structural modules.

FIGS. 28 and 29 depict a bridge structure comprising a plurality of the standardized expanded structural modules described in the prior figures.

DETAILED DESCRIPTION OF THE INVENTION

Referring now to the drawings in detail, like numerals will designate like parts, and for purposes of illustration, and not of limitation, the invention will be described in connection with a bridge structure which is an embodiment particularly illustrative of a type of use where a high degree of strength is required, and where portability and adaptability with secondary structure, such as planking, may be illustrated. It should be appreciated that while such a bridge structure is a preferred embodiment, various changes and modifications may be made in the structure to adapt it to a particular use without departing from the invention.

FIGS. 1, 2, and 3 are end views of the structure in the compressed, partially expanded, and fully expanded positions, respectively. It will be observed that the structure comprises a plurality of rigid link elements and foldable jackknife or articulating link elements. For convenience all rigid links will be designated by odd numbers (1, 3, 5, etc.) and articulated links will be even numbered (2, 4, 6, etc.).

FIG. 4 is a perspective view of the structure of FIG. 2 in stages (a) through (c) of expansion, wherein it will be observed that the structure is expanded simultaneously in length and width, such that articulated links 6, 14, 12 and 16 are parallel when fully unfolded and are the corner members of the module. This unfolding is more clearly understood when FIG. 4 is viewed in conjunction with FIGS. 5, 6 and 7.

FIGS. 5, 6, and 7 clearly show all link elements of the structure in the fully expanded position and by comparing the position of each link member in these figures with their partially expanded positions in FIGS. 2 and 4, the novel arrangement and sizing of the links may be clearly understood. It will be observed that the structure comprises a plurality of tripods, a first tripod comprising legs 1, 3, and 9, and a second tripod in inverted relationship to the first tripod, the second tripod comprising legs 3, 5, and 7. These two tripods have a common leg 3 which forms the diagonal bracing of the structure as may be seen in FIG. 3. Additionally it will be noted that each tripod leg is joined together at its feet by base struts, the first tripod's base struts being links 2, 6, and 8, and the second tripod's base struts being links 4, 10, and 12. These base struts are articulating links that limit angular rotation of their respective tripod's legs.

FIG. 5 most clearly illustrates the expanded structural arrangement and its load carrying capability. The previously described tripods and base struts when fully expanded define a plurality of pyramids, the first pyramid defined by rigid links 1, 3, and 9 are articulating links 2, 6, and 8, and the second pyramid bounded by links 3, 5, 7, 4, 10, and 12. These two pyramid structures are repeated or duplicated again and again in the structure, each pair of pyramids being joined to the next pair of pyramids by articulating links 14 and 16. Thus, the structure may be visualized as comprising a plurality of structural bays, each bay comprising two pyramids formed by links 1-10, and 12, plus interconnecting links 14 and 16, a total of five rigid links and

eight articulating links. All of these links may be of any suitable cross-section, such as square, rectangular, channel, T, I, or round, and may be constructed from any suitable material such as wood, metal, or reinforced plastic. It has been found advantageous to construct these links from round steel alloy pipe or tubing for highly loaded structures, and where lighter loads are anticipated and there is a premium on weight, the use of round aluminum alloy tubing has proved advantageous.

Thus it may be seen that the structure of FIGS. 5, 6, and 7 is comprised of six structural bays of the configuration previously described. The cross-section of the structure as seen in FIG. 7 is a parallelogram with a plurality of diagonal braces, links 3, the parallelogram being wider than it is high.

It will further be observed that all articulating links define the top and bottom planes of the structure when fully expanded, that is articulating links 4, 10, 12, and 16 fold out to form the top plane and links 2, 6, 8, and 14 fold out to form the bottom plane. The particular structural module illustrated in FIGS. 5, 6, and 7 is 60 feet long, five feet high, and has an over-all width of 12 feet, and folds into a shipping package which is 8 feet high, two feet wide, and 16 feet long, thereby occupying less than one-tenth of the expanded volume. Dimensions of such a structural module may of course be varied as a function of the individual link lengths and the number of structural bays interconnected together. For simplicity of illustration, however, all structures are shown in the dimensional ratio previously given, thereby assisting in identifying like parts in the various figures and identifying a basic "structural module" 100 which may be joined with like structural modules 100 to construct the various total structures herein illustrated.

FIG. 8 depicts one of the structural modules 100 being moved to the construction site. The structure is more easily balanced when rotated such that the cross-section major axis is horizontal, that is the workmen hold the structure at the two farthest corners, as illustrated in FIG. 2 where the workmen are preparing to rotate the structure and are holding the farthest corners. The corner nearest the ground is supported by wheeled bogies.

FIGS. 9 through 14 inclusive schematically illustrate end views of bridge roadbed support structures as example embodiments which utilize varying numbers and orientations of the structural modules 100. In FIG. 9 two modules 100 are joined side-by-side to form a support structure for roadbed surface 50. Where a wider roadbed is required four additional modules 100 are combined side-by-side as shown in FIG. 10. Where supported loads are higher or spans are longer, the bending strength of the structure of FIG. 9 may be increased by adding two structural modules on top of the existing structure as shown in FIG. 11, or below the FIG. 9 structure as shown in FIG. 12. Additional strength may be given to the structure of FIG. 12 by adding two more modules 100 below the structure to close in the bottom as shown in FIG. 13. A plurality of roadbeds 50 may be supported by the structure illustrated in FIG. 14.

Thus, it may be seen that a great variety of structural shapes may be constructed by combining standard structural modules 100, and that with a plurality of different sized standard modules available, the number and type of combinations which may be constructed

are numerous. Having described the basic concept of the invention and its inherent structural versatility, a detailed description of the structural joints will be given prior to a more detailed description of a bridge structure embodying the invention.

Referring now to FIG. 15, there is shown an enlarged and more detailed end view of three modules joined together in a manner such as the three upper right hand structural modules of FIG. 14. Because of the parallelogram shape of the structure in the end view illustrated by FIG. 15, there are two obtuse angles and two acute angles of intersection of the links, that is, for example, links 1 and 4 intersect to form an obtuse angle and links 1 and 2 intersect to form an acute intersection angle. At each acute intersection a spider fitting 20 serves to join intersecting links together, and at the obtuse intersections spider fitting 40 joints all intersecting links together. It will be noted by referring to FIGS. 5 and 15 that six links are joined together by each spider fitting 20, as for example links 2, 8, 1, 9, and two links 6, and each spider fitting 40 joins seven links together, as for example links 5, 7, 2, 8, two links 16, and link 3. Link 3, the diagonal brace and common leg of each pair of previously described tripods, is common to all brace-corner spider fitting 40 joints. It should be realized that the structure shown is for example only, and that while opposite sides of the parallelogram are equal in length, the ratio of one pair of sides with the other pair of sides may be varied to suit any particular application.

Referring to FIGS. 16 through 21, the details of brace-corner spider 40 and spider 20 may be clearly seen. It will be observed that spider 20 is shaped such that there are two orthogonal mounting surfaces 21 and 22, best seen in FIG. 21, wherein surface 21 is parallel to the planes formed by links 5 and 7, or 1 and 9. Perpendicular to mounting surfaces 21 and 22 are two pairs of mounting bolt bores 23 and 24 respectively. In a like manner brace-corner spider 40 has orthogonal mounting surfaces 41 and 42, best seen in FIG. 24, where surface 41 is parallel to the planes formed by links 1 and 9 and 5 and 7. Again two pairs of mounting bolt bores 43 and 44 are visible, bores 43 being perpendicular to surface 42. Thus, as may be seen in FIGS. 15 through 18, whenever structural modules 100 are to be joined together side-by-side, the appropriate mounting surfaces 21, 22, 41, and 42 are brought together and any suitable fastening means, as for example bolts, are inserted in the appropriate bores 23, 24, 43, and 44.

All links are provided at both ends with a bore 30 for receiving a clevis pin, bolt, rivet, or other suitable fastening means, to thereby pivotally attach the links to spiders 20 or 40. Additionally, all articulated links (even numbers 2-16) are provided with a second bore 32. Bore 32 is utilized with the structure in the expanded position by inserting a pin, bolt, or other suitable means therein, thereby preventing the articulated link from pivoting about bore 30. This facilitates the assembly of the structure by giving rigidity to the articulated links until the links are locked, as will hereinafter be described, whereafter the pins or bolts may be removed or may remain in bores 32 as desired.

FIGS. 25 and 26 illustrate the hinged joint located substantially at the mid point of each articulated link, even numbers 2-16, link 2 having been chosen for illustration in the two figures. The hinged joint comprises a pair of hinge links 50, each provided with two holes 51 for pivotally attaching the hinge links to the articu-

lated link 2, such as by shouldered rivets. Articulated link 2 is shown in the "jackknifed" position in FIG. 25, which position all articulated links assume when the structure is fully retracted. In FIG. 26 the articulated link is in the full open position which occurs when the structure is fully expanded. In this open position the joint is locked by aligning two lock plates 54 on opposite sides of the articulated link 2, such that the bores 53 in the lock plates 54 are aligned with the holes 52 in articulated link 2, and thereafter inserting bolts or other suitable fastening means through the aligned bores.

FIG. 27 shows a structural embodiment of the invention in which a plurality of structural modules are fastened together side-by-side to provide a bridge support structure of the type schematically shown in FIG. 9. In this particular embodiment the modules are joined together by spider fittings 20 back-to-back so that surfaces 22 are in mutual contact and inserting fastening means through bores 24. Roadbed beams 101 are placed across the support structure on surfaces 41 of brace-corner spiders 40 and fastened thereto by inserting fastener means through bores 43. A wider roadbed may be made by using longer beams 101 that extend beyond spider fittings 40, the extension being cantilevered from spiders 40, or, of course, the roadbed beams 101 may be of sufficient length to be supported on either end by the outside row of spider surfaces 21 of spiders 20 and attached thereto by means of bores 23. However, the more efficient loading of the support structure is obtained by supporting the roadbed on the inner row of spiders 40. Lightweight roadbed panels 102 are inserted between the roadbed beams 101 so that the panels 102 bear on the lower cap surface 103 of beam 101 and are fastened in place such as by bolting, welding, or riveting. Additional roadbed panels 102 may be mounted on edge between the beams 101 to provide a curb for the roadbed.

Elevation views of the bridge are shown by FIGS. 28 and 29, wherein the structure shown in FIG. 27 is supported along its span by a tower or pier fabricated from similar structural modules 100. By adding structural modules 100 to the towers to extend them above the roadbed, locating the towers alongside the roadbed, interconnecting the towers with catenary cables, and connecting suspension cables from the catenary cables to the roadbed, a suspension bridge may be fabricated. Another type of suspension bridge, wherein the roadbed itself forms a catenary curve, may be fabricated from a plurality of modules 100, wherein some of the articulating links are cables, such as for example interconnecting links 14 and 16 and the base struts 6 and 12. It should also be clear that modules 100 may be curved rather than straight by having some links longer than others, as for example links 12 and 16 longer than links 6 and 14, to construct an arch bridge.

Thus, as may be seen from the above, there is disclosed a new and novel combination of articulated or jackknife links, cables, and rigid links interconnected by spider fittings to provide a compactly stored package which may be expanded into an efficient load supporting open truss structural module. Modules may be connected together end-to-end or side-by-side in a variety of combinations of size and structure for supporting various modes and magnitudes of loads. The basic structural bay is simple to fabricate, comprising a plurality of only four parts; spider 20, cornerbrace spider

40, articulated link 2, and rigid link 1. Contiguous bays are connected one to another by two articulated links, designated numbers 14 and 16 herein and usually dimensionally and structurally the same as articulated link 2, as usually are all articulated links 4, 6, 8, 10, and 12, to form a structural module 100 of the desired length. The module 100 is expandable and retractable by means of the expansion and retraction capability of each individual structural bay in the manner previously described herein.

It is to be understood that the foregoing disclosure of my invention is merely illustrative and that many other arrangements may be devised to tailor the structure to specific requirements, and that the specification and drawings disclosed herein are not to be taken as a limitation, the spirit and scope of the invention being limited only by the claims.

I claim:

1. An open truss structural module capable of being expanded and retracted, wherein an individual structural bay comprises:

a first tripod comprising three legs, one end of each of said legs pivotally attached together to form a first tripod apex and the opposite end of each leg being a foot of said first tripod;

a second tripod comprising one leg of said first tripod and two additional legs pivotally attached together at the foot end of said first tripod leg, the opposite end of each leg being a foot of said second tripod;

a first set of three base struts, hinge-jointed substantially at mid-length, and each pivotally attached at opposite ends to adjacent feet of said first tripod;

a second set of three base struts, hinge-jointed substantially at mid-length, and each pivotally attached at opposite ends to adjacent feet of said second tripod; and

means for locking said base struts hinge joints.

2. The structural module of claim 1, wherein adjacent structural bays are joined together by a pair of interconnecting links, each link hinge-jointed substantially at mid-length, one of said links pivotally attached at opposite ends to said apex of adjacent first tripods, and the other interconnecting link pivotally attached at opposite ends to said apex of adjacent second tripods.

3. The structural module of claim 2, further comprising:

a plurality of first spider fittings, each shaped and adapted for pivotally attaching to one end each of two of said tripod legs and four of said base struts; and

a plurality of second spider fittings, each shaped and adapted for pivotally attaching to one end each of three of said tripod legs at said apex, two of said base struts, and two of said interconnecting links.

4. The structural module of claim 3, wherein each of said first and second spider fittings is provided with orthogonal mounting surfaces, at least one of said mounting surface being parallel to one side of said structural bay.

5. The module of claim 3, wherein said base strut hinge joint comprises a pair of hinge links located on opposite sides of and parallel to said base strut, said hinge links adapted for pivotal attachment at opposite ends to respective halves of said base strut.

6. The module of claim 5, wherein said means for locking said base strut hinge joint comprises a pair of locking plates located on opposite sides of said base

strut in close proximity to and substantially 90° from said hinge links, and attached to both halves of said base strut to prevent pivoting of said strut on said hinge links.

7. A truss structure module capable of being expanded and retracted comprising:

a plurality of first tripods each comprising three legs, each leg having a foot end and apex end, said three legs pivotally attached together at their apex ends to form a first tripod apex;

a plurality of second tripods each comprising one leg of one of said first tripods, and two additional legs each having a foot end and apex end, said two additional legs pivotally attached together at their apex ends and to the foot end of said first tripod leg to form a second tripod apex;

a plurality of first and second base struts each hinge-jointed substantially at mid-length, each of said first struts being pivotally attached at opposite ends to respective adjacent foot ends of said first tripod legs, and each of said second struts being pivotally attached at opposite ends to respective adjacent foot ends of said second tripod legs; and

a plurality of first and second interconnecting links each hinge-jointed substantially at mid-length, each of said first links being pivotally attached at opposite ends to adjacent first tripod apexes, and each of said second links being pivotally attached at opposite ends to adjacent second tripod apexes.

8. The truss structure module of claim 7, further comprising locking means for said mid-length hinge joints of said first and second base struts and said first and second interconnecting links.

9. The truss structure module of claim 8, further comprising secondary locking means at said pivotal attachments of said first and second base struts and said first and second interconnecting links.

10. The truss structure module of claim 7, further comprising a plurality of spider fittings, one spider fitting located at each pivotal attachment comprising any of said first and second tripod legs, said first and second base struts, and said first and second interconnecting links.

11. A truss structure capable of being expanded and retracted comprising a plurality of structural modules, wherein each module comprises:

a plurality of spider fittings, each fitting adapted to provide a plurality of pivotal attachments and shaped to provide at least two orthogonal mounting surfaces, at least one of said mounting surfaces located parallel to one side of said module;

a plurality of first tripods each comprising three legs, each leg having a foot end and apex end, said three legs pivotally attached together at said apex ends by means of one of said spider fittings to form a first tripod apex;

a plurality of second tripods each comprising one leg of one of said first tripods, and two additional legs each having a foot end and apex end, said two additional legs pivotally attached together at their apex ends and to the foot end of said first tripod leg by means of one of said spider fittings to form a second tripod apex;

a plurality of first and second base struts each having a hinge joint located substantially at mid-length and capable of being locked in the expanded position, each of said first struts pivotally attached at

opposite ends by means of said spider fittings to respective adjacent foot ends of said first tripod legs, and each of said second struts pivotally attached at opposite ends by means of said spider fittings to respective adjacent foot ends of said second tripod legs; and

a plurality of first and second interconnecting links each having a hinge joint located substantially at mid-length and capable of being locked in the expanded position, each of said first links being pivotally attached at opposite ends by means of said spider fittings to adjacent first tripod apexes, and each of said second links being pivotally attached at opposite ends by means of said spider fittings to adjacent second tripod apexes.

12. The truss structure of claim 11, wherein at least some of said structural modules are joined together side-by-side by means of said spider fittings.

13. The truss structure of claim 11, wherein at least some of said structural modules are joined together above and below by means of said spider fittings.

14. The truss structure of claim 11, wherein adjacent structural modules are joined by attachment means through abutting mounting surfaces of said spider fittings.

15. The truss structure of claim 11, wherein:

a first plurality of structural modules are joined end-to-end by means of said spider fitting pivotal attachments;

a second plurality of structural modules are located adjacent to said first structural modules by means of mounting surfaces of at least some of said first module spider fittings bearing on mounting surfaces of at least some of said second module spider fittings; and

a plurality of attachment means are located through said bearing mounting surfaces to join said second modules to said first modules.

16. A truss structure capable of being expanded and

retracted comprising a plurality of structural modules, wherein each module comprises:

a plurality of spider fittings, each fitting adapted to provide a plurality of pivotal attachments and shaped to provide at least two orthogonal mounting surfaces, at least one of said mounting surfaces located parallel to one side of said module;

a plurality of first tripods each comprising three legs, each leg having a foot end and apex end, said three legs pivotally attached together at said apex ends by means of one of said spider fittings to form a first tripod apex;

a plurality of second tripods each comprising one leg of one of said first tripods, and two additional legs each having a foot end and apex end, said two additional legs pivotally attached together at their apex ends and to the foot end of said first tripod leg by means of one of said spider fittings to form a second tripod apex;

a plurality of first and second base struts at least some being flexible and the remainder being rigid, each of said rigid struts having a hinge joint located substantially at mid-length and capable of being locked in the expanded position, each of said first struts pivotally attached at opposite ends by means of said spider fittings to respective adjacent foot ends of said first tripod legs, and each of said second struts pivotally attached at opposite ends by means of said spider fittings to respective adjacent foot ends of said second tripod legs; and

a plurality of first and second flexible interconnecting links, each of said first links being pivotally attached at opposite ends by means of said spider fittings to adjacent first tripod apexes, and each of said second links being pivotally attached at opposite ends by means of said spider fittings to adjacent second tripod apexes.

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