The invention relates to a tetrahedral beam that can be compactly stowed, sequentially deployed, and widely manipulated to provide a structurally sound yet highly maneuverable truss structure. The present beam is comprised of a plurality of repeating units comprised of tandem tetrahedra sharing common sides. Tetrahedra are comprised of fixed length battens joined by joint into equilateral triangles called batten frames. Apexes of adjacent triangles are interconnected by longerons having mid-point folding hinges. Joints permit two independent degrees of rotational freedom between joined adjacent batten frames, and provide a stable structure throughout all stages of beam deployment, from packaged configuration to complete deployment. The longerons and joints can be actuated in any sequence, independently of one another. The present beam is well suited to remote actuation. Longerons may be provided with powered mid-point hinges enabling beam erection and packaging under remote control. Providing one or more longerons with powered telescoping segments permits the shape of the beam central axis to be remotely manipulated so that the beam may function as a remote manipulate arm.
FIG. 1
A further object is to provide a stable beam comprised of fewer structural members per unit length than prior art truss beams.

BRIEF SUMMARY OF THE INVENTION

According to the present invention, the foregoing and other objects are attained by forming a tetrahedral truss beam comprised of a series of interconnected tetrahedra. Two tandem tetrahedra sharing common sides comprise the repeating unit of the present beam; a plurality of repeating units can be interconnected by the novel joint disclosed herein to form a beam of desired length.

The present beam compactly packages into a generally triangular solid about one-fourteenth as long as the extended beam. Longeron structural members can be remotely actuated by appropriate state of the art means to sequentially deploy the beam from the packaged geometry, as well as to operate the beam as a remote manipulator arm. The present joint design constitutes a stable linkage system throughout the entire range of deployment, from packaged configuration to complete deployment.

BRIEF DESCRIPTION OF THE DRAWINGS

A more complete appreciation of the invention and many of the attendant advantages thereof will be more clearly understood by reference to the following detailed description when considered in connection with the accompanying drawings, wherein:

FIG. 1 is a view of an exemplary tetrahedral beam of the present invention;
FIG. 2 is a view of one repeating unit of the present beam;
FIG. 3 is a view of the folded configuration of the present invention;
FIG. 4 is an exploded view of the novel joint of the present invention;
FIG. 5 is a view of the novel joint of the present beam in a folded configuration;
FIG. 6 is a partial view of the novel joint of the present beam;
FIG. 7 is a view of the novel joint of the present invention in a partially deployed configuration;
FIG. 8 is a view of the novel joint of the present invention in a fully deployed configuration; and
FIG. 9 is a schematic view of the powered activating members of the present beam.

DETAILED DESCRIPTION OF THE INVENTION

Referring now to the drawings wherein like reference numerals designate identical parts throughout the several views, and more particularly to FIG. 1, there is shown a tetrahedral beam constructed in accordance with the present invention and designated by reference numeral 10. Tetrahedral beam 10 is constructed of a plurality of identical, fixed length battens 12. Battens 12 may be fabricated of tubular aluminum, composite, or other strong yet lightweight material. Joints 14 as described in detail later join battens 12 and longeron members 16. Longeron 16 include folding hinges 20 at longeron mid-points. As can be seen in FIG. 1, the beam is comprised of repeating units comprised of tandem tetrahedra. Adjacent tetrahedra share common sides as a beam of desired length is assembled of an appropriate number of repeating tandem tetrahedral units joined by joints 14. In the interest of clarity, joints 14 have not
been drawn in detail in FIG. 1. but are fully described below and in subsequent FIGS.

By referring to FIG. 2 (which depicts one repeating unit of tandem tetrahedra as well as partial views of several members of adjoining repeating units), the basic construction of the present beam may be more readily appreciated. Battens 12a, 12b, 12c, joined by joints 14a, 14b, 14c form an equilateral triangle herein referred to as a batten frame. A second batten frame is formed of battens 12c, 12d, 12e joined by joints 14a, 14b, 14d. The apexes of these two batten frames, at joints 14d, 14c, are held apart and interconnected by hinged longeron 16 thus, it is readily apparent that the two batten frames have a "common base batten" 12c. Longeron 16 is hinged at its mid-point by hinge 20 to enable compact packaging of the beam, as will be hereinafter described.

In the interest of clarity, joints 14 have not been illustrated in fine detail in FIGS. 1-3, but will be hereafter completely disclosed by further reference to this specification and the accompanying drawings.

Referring now to FIG. 3, tetrahedral beam 10 of the present invention is depicted in folded configuration. Batten frames now lie on parallel planes in a stacked configuration with battens 12 stacked on top of other battens and joints 14 stacked on joints. Longerons 16 have completely folded about their mid-point hinges 20 and are stacked in the interior of the triangular solid formed by the stacked batten frames. When completely folded as in FIG. 3 the present beam continues to provide a stable structure, and does not require a canister or other external packaging. The present packaging geometry is extremely efficient, as the folded length of the beam is only one-fourteenth as long as the fully deployed beam (FIG. 1).

To provide a tetrahedral beam with the ability to be maneuvered and compactly packaged, a novel joint designated generally by reference numeral 14, and shown in FIGS. 4-7, was constructed. Joint 14 is comprised essentially of gusset 24 connected to gusset 34 by link 25. Link 25 permits gusset 34 to swivel about gusset 24 with two degrees of freedom as follows. First from a folded position in which gussets 34, 24 lie on parallel planes (FIG. 4), gusset 34 swivels counterclockwise about batten 12/ to any desired angle, while link 25 and gusset 24 remain fixed. Secondly, link 25 swivels about the end of batten 12/ which protrudes from gusset 24. In this latter swivelling, gusset 34 rotates along with link 25 to any other desired angle. These two rotational degrees of freedom thus permit each corner to deploy to any desired angle, independently of other corners. The beam axis may be straight or crooked when deployed, depending on whether all joints are deployed equally or unequally, respectively.

Referring now to FIG. 4, an exploded view of joint 14, the structure of joint 14 can be readily appreciated. Battens 12/ and 12g are joined by gusset 34. Batten 12g is fixed within gusset 34 by keeper pin 18, but batten 12/ is free to rotate (swivel) within gusset 34. Collar 32 with a keeper pin 18 retains batten 12/ within gusset 34 from one direction. Link 25 and keeper pin 18 retains batten 12/ within gusset 34 from the other direction. A longeron 16 is pivotally mounted in slot 26 by hinge pin 19.

A second gusset 24 joins battens 12h, 12i. Batten 12h is fixed within gusset 24 by keeper pin 18. Batten 12i is also fixed within gusset 24 with a keeper pin 18. Link 25 swivels about batten 12i and is retained from slipping off batten 12i by gusset 24, retaining collar 42, and a keeper pin 18. A longeron 16 is pivotally mounted by a hinge pin 19 in a slot (not shown) in gusset 24.

Link 25 serves to pivotally join gussets 24, 34. Batten 12/ of gusset 24 passes through an aperture of link 25 and is secured by retaining collar 42 with a keeper pin 18. attaching system 90 to provide power to and suitable control over powered hinges 20a and telescoping longeron
segments 16a is also schematically depicted in FIG. 8. Although both longeron halves could be equipped with telescoping segments 16a, the depicted embodiment retains much maneuverability. Although all longerons 16 of the present beam could be equipped with powered telescoping segments 16a, one-half of the longerons 16, or fewer, could be so equipped and still render a highly maneuverable beam.

OPERATION

Operation of the present beam should now be apparent. From a fully packaged configuration (FIG. 3) the present beam 10 is erected by unfolding longerons 16. In the powered embodiment this is accomplished by operating the actuating system 90 (FIG. 9) which provides electrical power to powered hinges 20a. Each powered hinge 20a is provided with a separate control switch, thus the beam may be sequentially deployed by powering successive powered hinges 20a. Once erected, the beam may be maneuvered as desired by selectively powering individually powered telescoping segments 16a to lengthen or shorten longerons 16, with the actuating system 90 (FIG. 9). To collapse the beam, powered telescoping segments 16a are returned to their neutral position with the actuating system 90, after which powered hinges are operated to sequentially collapse the beam in reverse order of erection.

Although the invention has been described relative to specific embodiments it is not so limited and many modifications and variations thereof will be readily apparent to those skilled in the art in light of the above teachings. For example, a combination folding hinge and telescoping members in place of respective hinge 20a and telescoping members 16a, with appropriate power and control means, could be employed.

What is claimed as new and desired to be secured by Letters Patent is:

1. A highly maneuverable and fully collapsible tetrahedral beam comprised of a plurality of interconnected tetrahedral, each tetrahedron including:

(a) five fixed length battens;
(b) joint means joining said battens into batten frames to form two equilateral triangles and providing two rotational degrees of freedom at each joint;
(c) two batten frames sharing a common base batten; and
(d) a longeron connecting each of the apexes of said batten frames, said longeron including a foldable hinge at its mid-point and being pivotally hinged at its ends to said joint means.

2. A fully collapsible tetrahedral beam as in claim 1 including means for independently inducing movement of said joint means relative to other joints in said tetrahedral beam.

3. A fully collapsible tetrahedral beam as in claim 1 wherein said joint means includes:

(a) a first gusset maintaining two battens in a fixed 60° relationship and pivotably hinging a longeron located as to bisect said 60° angle;
(b) a second gusset maintaining two battens in a fixed 60° relationship and pivotably hinging a longeron located as to bisect said 60° angle; and
(c) a link pivotably connecting said first gusset and said second gusset to form a joint assembly such that said upper gusset and said lower gusset pivot to provide two degrees of rotational freedom at each joint assembly whereby, said joint assembly can be folded or actuated independently of and in any sequence relative to other joints of the tetrahedral beam permitting the tetrahedral beam to deploy to any desired position.

4. A fully collapsible tetrahedral beam as in claim 1 wherein said foldable hinge is electrically powered.

5. A fully collapsible tetrahedral beam as in claim 1 wherein said longeron contains telescoping segments.

6. A fully collapsible tetrahedral beam as in claim 4 including power means for inducing telescoping movement of said telescoping segments, said power means being selected from hydraulic, pneumatic and electrical power means.