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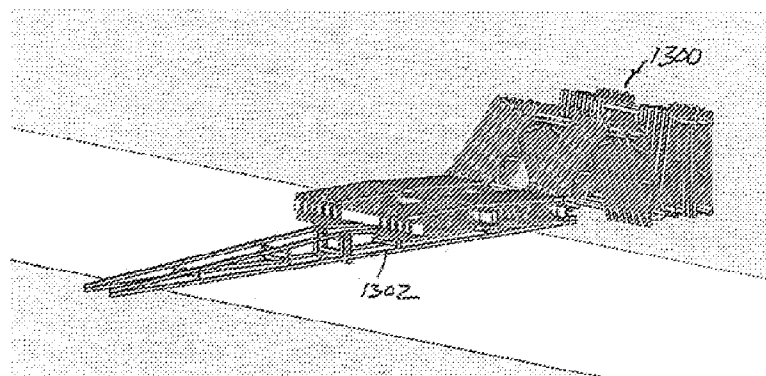
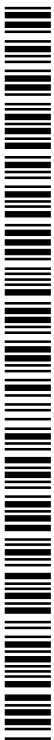


FIG. 13C

(57) Abstract: A modular crossing system generally includes a set of modules and a set of segments (e.g., bridge segments). Each segment includes a subset of the set of modules, and at least a portion of the set of segments are configured to be rotateably interlocked with a subsequent segment such that the set of segments form a crossing assembly having a deployed state and a collapsed state. Each module of the set of modules may include a hinge pin opening configured to removeably accept one of the set of hinge pins. The set of segments may be rotateably interlocked via the set of hinge pins.



A MODULAR FOLDING BRIDGE SYSTEM AND ITS METHOD OF EXECUTION

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims priority to U.S. Prov. Pat. Appl. No. 61/445,412, filed Feb. 22, 2011, which is hereby incorporated by reference in its entirety.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[0002] This invention was made with U.S. Government support under Contract No. W56HZV-09-C-0059 awarded by the U.S. Army. The U.S. Government has certain rights in this invention.

TECHNICAL FIELD

[0003] Embodiments of the subject matter described herein relate generally to bridges and other forms of crossing systems, and more particularly, to methods and systems for configuring and deploying such crossing systems.

BACKGROUND

[0004] It is often desirable to employ bridges and other such structures to safely cross over rivers, roads, chasms, and other geographical features. In a military context, there is a particular need to quickly erect crossing structures that can support a wide variety of military vehicles, sometimes under assault conditions. While armored-vehicle-launched bridges have been successfully used in some contexts, such systems generally lack versatility since the required span length, maximum load, crossing width, and required deployment method can vary widely from situation to situation.

[0005] It is therefore desirable to provide improved methods and systems for bridges and other such crossing systems. Other desirable features and characteristics of the present invention will become apparent from the subsequent detailed description and the appended claims, taken in conjunction with the accompanying drawings and the foregoing technical field and background.

BRIEF SUMMARY

[0006] A modular crossing system in accordance with one embodiment of the invention includes a set of modules and a set of segments, each segment comprising a subset of the set of modules. At least a portion of the set of segments are configured to be rotateably interlocked with a subsequent segment such that the set of segments form a crossing assembly having a deployed state and a packed state.

[0007] In accordance with another embodiment of the invention, an automated method of providing a crossing assembly includes: providing a set of modules and a set of segments, each segment comprising a subset of the set of modules; determining a required span length; determining a required deployment method; selecting, using a processor, a subset of the set of segments based on the required span length and the required deployment method; and rotateably interlocking at least a portion of the selected subset of segments to form a crossing assembly having a deployed state and a packed state. The crossing assembly is configured to transition from the packed state to the deployed state in accordance with the required deployment method, and is configured to achieve the required span length in the deployed state.

[0008] In accordance with another embodiment of the invention, a modular bridge system includes a plurality of bridge segments, each bridge segment comprising a plurality of modules, a plurality of hinge pins. At least a portion of the plurality of segments are configured to removeably accept one or more of the hinge pins such that the plurality of segments are rotateably interlocked to form a bridge assembly having a deployed state and a packed state. The plurality of segments are selected such that the bridge assembly, in the deployed state, fulfills predetermined criteria including at least one of span length, load category, deployment method, and shipping constraints.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] A more complete understanding of the subject matter may be derived by referring to the detailed description and claims when considered in conjunction with the following figures, wherein like reference numbers refer to similar elements throughout the figures.

[0010] FIG. 1 is a conceptual block diagram of an exemplary crossing system in accordance with various embodiments of the invention;

- [0011] FIG. 2 is an isometric view of a module in accordance with one embodiment of the invention;
- [0012] FIG. 3 is an isometric view of a segment in accordance with one embodiment of the invention;
- [0013] FIG. 4 is an isometric view of a crossing assembly suitable for shipping in accordance with one embodiment of the invention;
- [0014] FIG. 5 is an isometric view of a crossing assembly just prior to deployment in accordance with one embodiment of the invention;
- [0015] FIG. 6 is an isometric view of a crossing assembly packed in a container in accordance with one embodiment of the invention;
- [0016] FIG. 7 is a close-up isometric view of an exemplary module in accordance with one embodiment of the invention;
- [0017] FIG. 8 is a side-view of an exemplary crossing assembly in an as-deployed state;
- [0018] FIG. 9 is a close-up of the joint and cable configuration depicted in FIG. 8;
- [0019] FIG. 10 depicts a captured hinge pin in accordance with one embodiment of the invention;
- [0020] FIG. 11 is an isometric view of a deployed crossing assembly in accordance with one embodiment of the invention;
- [0021] FIGS. 12A-12D depict the deployment of a crossing assembly in accordance with one embodiment of the invention;
- [0022] FIGS. 13A-13D depict the deployment of a crossing assembly in accordance with another embodiment of the invention; and
- [0023] FIG. 14 is a flowchart depicting a method in accordance with one embodiment of the invention.

DETAILED DESCRIPTION

[0024] The subject matter described herein generally relates to a versatile, modular crossing system that allows crossing assemblies to be quickly configured and deployed in contexts involving a wide range of span lengths, deployment methods, span widths, and load conditions. In this regard, the following detailed description is merely illustrative in nature and is not intended to limit the invention or the application and uses of the invention. Furthermore, there is no intention to be bound by any expressed or implied

theory presented in the preceding technical field, background, brief summary or the following detailed description. For the purposes of conciseness, many conventional techniques and principles related to structural mechanics, bridge design and the like are not described in detail herein.

[0025] Referring now to the conceptual block diagram shown in FIG. 1, an exemplary crossing system 100 in accordance with the present invention generally includes a plurality of crossing modules ("bridge modules," or simply "modules") 102, a plurality of crossing segments ("bridge segments," or simply "segments") 104, a plurality of additional components 106 (e.g., hinge pins, cable support systems, bridge guides, and the like), and a processing system 108 (e.g., a general purpose computer system of the type known in the art). Each of the segments 104 is composed in part by one or more modules 102. As described in further detail below, a set of segments 104 and/or a set of modules 102 are selected to achieve certain predetermined criteria regarding deployment method, span length, load capacity, etc., to form a bridge assembly 110 that has a packed state and a deployed state (i.e., deployed to allow vehicles to safely cross a river, road, chasm, or other geographical feature). As used herein, the term "packed state" is used without loss of generality to refer to a crossing assembly that is ready for deployment or a crossing assembly that is compacted and ready for storage or shipping.

[0026] FIG. 2 illustrates an exemplary module 200 in accordance with one embodiment of the present invention. As shown, module 200 is generally rectangular and has a length (along the x-axis, extending from end 220 to end 221) that is substantially greater than its width (along the z-axis) and height (along the y-axis). Longitudinal members 202 and 204 are generally parallel and are interconnected by various support structures 206 to achieve a desired level of structural strength. Module 200 may include one or more hinge pin openings (210-213) configured to removeably accept respective hinge pins (not shown). The components of module 200 may be fabricated using any number of materials, including various metals such as aluminum and steel, as well as various light, strong composite materials known in the art, and timber.

[0027] The length, width, and height of module 200 may be selected to achieve a desired range of strengths and versatility. In one embodiment, for example, module 200 measures approximately 0.5m x 2.0m x 0.1m. The particular structure illustrated in FIG. 2 is not intended to be limiting, however. Module 200 may be configured as a plate, a truss, a girder, or any other form suitable for use in a crossing assembly as described herein.

Furthermore, while it is desirable for modules 102 (FIG. 1), or any given set of modules 102, to have a similar structure, it is not necessary for the modules to be identical in every respect. As will be described below, for example, the placement of hinge pin openings 210-213 may vary from module to module.

[0028] FIG. 3 illustrates an exemplary segment 300 in accordance with one embodiment of the present invention. As shown, segment 300 includes a plurality of generally parallel modules 200 distributed along structural members 310 and 312. Modules 210 are distributed, in this embodiment, to form bearing regions 302 and 306 (i.e., regions configured to support a vehicle), and optional open region 304 (i.e., regions left open to help reduce overall weight.) Structural members 310 and 312 may each comprise a beam, such as an I-beam, a C-beam, or the like, or have any other suitable structure. Modules 200 are mechanically fastened (either permanently or impermanently) to members 310 and 312. As shown, modules 200 are distributed such that their hinge pin openings are aligned, allowing a hinge pin (not shown) to be removeably inserted therethrough.

[0029] In the illustrated embodiment, modules 200 composing each segment 300 are equispaced (along the z-axis) such that modules 200 may be interdigitated with those of a subsequent segment. That is, as described in further detail below, multiple modules of the type shown in FIG. 3 may be placed end-to-end such that the modules 200 of one segment can be positioned to fit within the spaces between modules 200 of a subsequent segment and such that their hinge pin openings are aligned. In this way, hinge pins may be removeably inserted (and secured in any suitable manner) to allow a chain of segments 300 to be rotateably interlocked for rapid deployment, and then removed for placing the crossing assembly in a packed state for transportation and storage. Furthermore, in the field, extra modules and segments may be added to accommodate changing conditions, such as damage to one or more modules or segments.

[0030] In accordance with one embodiment, the position of the hinge pin openings is configured such that the crossing assembly, in its deployed state, has a predetermined curvature along all or part of its span. More particularly, referring briefly to FIG. 7, hinge pin opening 213 (the "bottom" opening) may be a first distance (d_1) from end 221 of the module, while hinge pin opening 212 (the "top" opening) may be a second distance (d_2) from end 221. If multiple modules of the type shown in FIG. 7 are secured end-to-end via hinge pins within their respective hinge pin openings, then it can be seen that the resulting

structure will have an arc shape determined by the difference between d_1 and d_2 . In some embodiments, a combination of linear and curved sections (groups of segments) may be employed to optimize the crossing assembly geometry for a particular application.

[0031] Referring again to FIG. 3, bearing region 302 may be configured to include one fewer number of modules 200 than bearing region 306. For example, as illustrated, bearing region 302 includes five modules, while region 306 includes six modules. Accordingly, a subsequent module configured in the same way as module 300 (not shown) may be "flipped over" relative to that shown in FIG. 3 (that is, rotated 180 degrees around the x-axis) and interdigitated with segment 300 such that the six modules of segment 300 accept the set of five modules of the subsequent segment, and vice versa. In this way, the resulting bearing regions (302 and 306), when deployed, will have substantially the same bearing area (i.e., supported by a width of approximately eleven modules).

[0032] The spacing between modules 200 may be selected to achieve the desired structural characteristics. In general, modules 200 are preferably positioned close enough to allow a vehicle to pass over without the inter-module gap becoming problematic.

[0033] FIGS. 4, 5, and 6 illustrate how the same general crossing assembly (i.e., six segments having the same span length) can be configured in different packed states to accommodate differences in container constraints and deployment method. FIG. 4, for example, is an isometric view of a crossing assembly 400 in which multiple segments 300 (in this case, six segments) are stacked to form a compact, rectangular structure. Depending upon deployment method and other factors, hinge pins may or may not be inserted within the respective hinge pin openings in the packed state. In one embodiment, described in detail below, hinge pins are inserted in all or some of the hinge pin openings to facilitate a collapsing-type deployment or a scissor-type deployment.

[0034] FIG. 5 is an isometric view of a deployment-ready crossing assembly 500 in accordance with another embodiment in which segments 300 are secured together in sets of three, and then stacked as shown. In one embodiment, described in detail below, hinge pins are inserted in all hinge pin openings to facilitate a scissor-type deployment, discussed in further detail below.

[0035] FIG. 6 is an isometric view of a crossing assembly 600 in accordance with another embodiment of the invention in which segments 300 are secured together in collapsed sets of three, but are packed end-to-end as shown. Such a configuration may be

desirable in cases where the container constraints require that crossing assembly 600 fit within a predetermined rectangular container 610.

[0036] FIG. 8 depicts an exemplary six-segment crossing assembly 800 in its deployed state. In its packed state, crossing assembly 800 may be stored and transported as in FIG. 4, and depending upon the deployment method, may include hinge pins one or more hinge pin openings.

[0037] In one embodiment, nearly all of the top and bottom pins (802, 803, 820) of crossing assembly 800 are installed and captive in the deployed state. At the center top joint, the pin is normally captive on one side of the joint, but retained compressively by a slotted receiver feature in a subset of modules (shown in FIG. 10) on the other side to facilitate deployment and recovery. A cable 810 may be suitably secured to the underside of crossing assembly 800 to provide tensioning for further stability.

[0038] In an alternate embodiment, the six segments 300 are rotateably interlocked via hinge pins only at joints 820. Since, in this embodiment, each segment 300 is connected to its neighbor segments via both a hinge pin fully captive on each side of the joint and another hinge pin compressively captive by a slotted receiver feature in a subset of modules (shown in FIG. 10) on one side of the joint, alternating between the top of the assembly and the bottom of the assembly, some joints (i.e., bottom joints 803) will tend to open under load, while other joints (i.e., top joints 802) will remain closed under load. In such an embodiment, referring now to FIG. 9, cable assembly 810 may be configured to secure at least a portion of the set of segments in the deployed state by providing a closing force at downward-facing joints 803. More particularly, cable assembly 810 may be wound (e.g., via multiple windings) between a hinge pin 903 and an additional pin 905 to assist in securing joint 803. Cable assembly 810 can then be routed across the entire span, as shown in FIG. 8, and be similarly secured at a second joint 803. In this way, a tensioning force assists in keeping joints 803 closed under load.

[0039] With respect to the top joints 802, hinge pins may be used to transfer the top (compressive) chord forces to add stability. More particularly, FIG. 10 depicts a captured hinge pin 1004 in accordance with one embodiment of the invention. In this image, only one segment is depicted. However, it can be seen that the inner surfaces 1002 of modules 200 bear on hinge pin 1004. Hinge pin 1004 is held captive by the neighboring segment (not shown) with its modules interdigitated with modules 200.

[0040] FIG. 11 is an isometric view of a deployed crossing assembly 1100 in accordance with one embodiment of the invention, and illustrates the degree to which the modularity of the present invention can be exploited. As shown, crossing assembly 1100 is an arch suspension bridge suitable for large (e.g., around 50.0m) spans subject to high load conditions. Crossing assembly includes a deck assembly 1110 comprising deck segments 1102, and arch assembly 1112 comprising arch segments 1104 and 1105, all of which are composed of the same general module type. Suspension cables are provided between deck segments 1110 and arch segments 1104, 1105. As shown, segments 1104 and 1105 may be interdigitated in a manner similar to that used for deck segments 1110. Platforms 1106 may be placed on deck segments 1102 to facilitate traversal by motorcycles, humans, and the like.

[0041] FIGS. 12A-12D (which may correspond to the embodiment depicted in FIG. 5) depict the deployment of a crossing assembly in accordance with one embodiment of the invention, and corresponds to what is referred to herein as a "scissor-type" deployment. In FIG. 12A, crossing assembly 1200 is provided at one end of the region to be spanned, and is in an upright configuration hinged at its center, with three rigidly connected segments on each side. That is, in this embodiment, hinge pins have been inserted into all hinge pin openings except for at the center top of the span (joint 1204) where a slotted receiver (FIG. 10) feature in a subset of modules provides only compressive capture of the hinge pin on one side of the joint while a normal hinge pin opening retains the pin on the other side. As deployment progresses, in FIGS. 12B and 12C, crossing assembly 1200 undergoes a scissor action, opening downward at joint 1204. A guide 1202 may be provided to assist in deployment, and then removed after deployment. Finally, as shown in FIG. 12D, crossing assembly 1200 is deployed across the entire span.

[0042] FIGS. 13A-13D (which may correspond to the embodiment depicted in FIG. 8) depict the deployment of a crossing assembly in accordance with another embodiment of the invention, and corresponds to what is referred to herein as a "collapsing-type" deployment. In FIG. 13A, crossing assembly 1300 is provided at one end of the region to be spanned, and is in an collapsed configuration of six segments rotateably interconnected (e.g., as described above in connection with FIG. 8). As deployment progresses, in FIGS. 13B and 13C, crossing assembly 1300 undergoes an unfolding action, wherein the leading segments deploy and extend across the span (via guide 1302) as subsequent segments

unfold. Finally, as shown in FIG. 13D, crossing assembly 1300 is deployed across the entire span, and guide 1302 is removed.

[0043] As mentioned above, the set of segments, modules, and additional components are selected such that the crossing assembly, in the deployed state, fulfills predetermined criteria. In this regard, FIG. 14 is a flow chart depicting a method in accordance with one embodiment of the invention. As a preliminary matter, it is presumed that a set of modules and a set of segments have been provided and are available as depicted in FIG. 1 (e.g., stored within a dedicated warehouse or other site, or distributed over multiple sites). The method depicted in FIG. 14 may be performed by processing system 108 of FIG. 1, which may include any number of hardware, software, and/or firmware components configured to perform the functions described herein. In one embodiment, processing system 108 includes a general purpose computer, suitable storage media, network interface devices (local area network, Internet, etc.), input/output devices, display devices, and software configured to carry out the steps outlined herein. Other components, such as laptops, tablet computers, mobile devices, RFID readers, and the like, may also be used in connection with processing system 108.

[0044] During steps 1402-1408, various requirements and/or parameters relating to the crossing assembly are determined. In the illustrated embodiment, the system determines the required span length (step 1402), the load category (step 1404), the deployment method (step 1406), and the shipping constraints (step 1408). In other embodiments, additional constraints and requirements are determined.

[0045] The span length relates to the required length of the deployed crossing assembly (i.e., total length of the bridge). In general, the span length is directly related to the number of installed segments and the lengths of those segments. In one embodiment, for example, spans in increments of 2.0m may be specified, ranging from about 8.0m to 40.0m. The invention, however, is not so limited.

[0046] Load category relates to the width, weight, and type of vehicles and other objects expected to traverse the crossing assembly in its deployed state. The load category may specify, for example, that tracked and wheeled vehicles from military load classification (MLC) 30 to 50 must be able to traverse the crossing assembly. In general, the ability to accommodate a particular load category is related to the number of modules within each segment. Stated another way, a segment's load capacity is directly related to the number of modules in that segment.

[0047] Deployment method relates to how the crossing assembly is to be transitioned from the packed mode to the deployed mode. Example deployment methods include, for example, the scissor-like and collapsing-type deployment methods. Other deployment methods may also be specified.

[0048] Shipping constraints relates to the geometry (e.g., shape and volume) of the shipping enclosure in which the crossing assembly is to be placed while in packed mode. Example shipping constraints include the standard ISO 40-foot container used for road, sea, and rail transportation, the C-130 cargo bay enclosure used for air transportation.

[0049] Information specified by steps 1402-1408 may be determined manually and then provided, via a suitable user interface, to processing system 108 for storage and subsequent processing. For example, an operator may manually enter the requirements into processing system 108. In other embodiments, one or more of these requirements are determined based on details relating to a particular mission.

[0050] Next, the system specifies the required modules, segments, and any additional components (hinge pins, guides, other components) that are required for the crossing system. These components may be generally determined by the geometry of particular modules, the number of modules required to provide a particular width of segment, the required curvature, and other information specified in steps 1402-1408. For example, the system may determine that a 20.0 meter MLC50 bridge for a particular application may require 150 modules, while a 12.0 m MLC30 bridge may require 66 modules. Segments with the desired hinge pin offsets (to achieve a required curvature) are specified. As mentioned above, the load capacity of the crossing assembly is generally determined by the number of modules installed per segment, and the span of the crossing assembly is generally determined by the number and length of installed segments.

[0051] Subsequently, the various modules, segments, and other components are, in part, rotateably interlocked and placed in a packed state and stored along with any additional components (such as deployment guides, extra hinge pins, cable assemblies, and the like).

[0052] While at least one example embodiment has been presented in the foregoing detailed description, it should be appreciated that a vast number of variations exist. It should also be appreciated that the example embodiment or embodiments described herein are not intended to limit the scope, applicability, or configuration of the claimed subject matter in any way. Rather, the foregoing detailed description will provide those

skilled in the art with a convenient road map for implementing the described embodiment or embodiments. It should be understood that various changes can be made in the function and arrangement of elements without departing from the scope defined by the claims, which includes known equivalents and foreseeable equivalents at the time of filing this patent application.

CLAIMS

What is claimed is:

1. A modular crossing system comprising:
a set of modules; and
a set of segments, each segment comprising a subset of the set of modules;
wherein at least a portion of the set of segments are configured to be rotateably interlocked with a subsequent segment such that the set of segments form a crossing assembly having a deployed state and a packed state.
2. The modular crossing system of claim 1, further comprising a set of hinge pins, wherein each module of the set of modules includes a hinge pin opening configured to removeably accept one of the set of hinge pins, and wherein the set of segments are configured to be rotateably interlocked via the set of hinge pins.
3. The modular crossing system of claim 2, wherein the position of the hinge pin openings are configured such that the crossing assembly has a predetermined curvature in the deployed state.
4. The modular crossing system of claim 2, further including a cable assembly configured to secure at least a portion of the set of segments in the deployed state.
5. The modular crossing system of claim 2, wherein the set of segments and the hinge pins are configured such that the crossing assembly transitions from the packed state to the deployed state using a scissor-type movement.
6. The modular crossing system of claim 2, wherein the set of segments and the hinge pins are configured such that the crossing assembly transitions from the deployed state to the packed state using a collapsing-type movement.

7. The modular crossing system of claim 1, wherein the set of segments is selected such that the crossing assembly, in the deployed state, fulfills predetermined criteria including at least one of span length, load category, deployment method, and shipping constraints.

8. The modular crossing system of claim 1, wherein each module of the set of modules is a generally rectangular structure, and wherein the subset of modules composing each segment are equispaced and configured to be interdigitated with the subsequent segment.

9. An automated method of providing a crossing assembly, comprising:
providing a set of modules and a set of segments, each segment comprising a subset of the set of modules;
determining a required span length;
determining a required deployment method;
selecting, using a processor, a subset of the set of segments based on the required span length and the required deployment method; and
rotateably interlocking at least a portion of the selected subset of segments to form a crossing assembly having a deployed state and a packed state;
wherein the crossing assembly is configured to transition from the packed state to the deployed state in accordance with the required deployment method; and
wherein the crossing assembly is configured to achieve the required span length in the deployed state.

10. The method of claim 9, further including determining a required load category, wherein the crossing assembly is configured to achieve the required load category in the deployed state.

11. The method of claim 9, further including determining required shipping constraints, wherein the crossing assembly is configured to achieve the required shipping constraints in the packed state.

12. The method of claim 9, wherein rotateably interlocking the portion of the selected subset of segments includes inserting set of hinge pins into corresponding hinge pin openings in the selected subset of segments.

13. The method of claim 9, further including selecting the subset of the set of segments such that the crossing assembly has a predetermined curvature in the deployed state.

14. The method of claim 9, wherein the required deployment method is a scissor-type movement.

15. The method of claim 9, wherein the set of segments and the hinge pins are configured such that the crossing assembly transitions from the deployed state to the collapsed state using a collapsing-type movement.

16. The method of claim 9, wherein each module of the set of modules is a generally rectangular structure, and wherein the subset of modules composing each segment are equispaced and configured to be interdigitated with the subsequent segment.

17. A modular bridge system comprising:
a plurality of bridge segments, each bridge segment comprising a plurality of segments; and
a plurality of hinge pins;
wherein at least a portion of the plurality of segments are configured to removeably accept one or more of the hinge pins such that the plurality of segments are rotateably interlocked to form a bridge assembly having a deployed state and a packed state; and
wherein the plurality of segments are selected such that the bridge assembly, in the deployed state, fulfills predetermined criteria including at least one of span length, load category, deployment method, and shipping constraints.

18. The modular bridge system of claim 17, wherein the respective positions of the hinge pins within the plurality of segments are configured such that the bridge assembly has a predetermined curvature in the deployed state.

19. The modular bridge system of claim 17, wherein each module of the plurality of modules is a generally rectangular structure, and wherein each of the plurality of segments comprises a set of generally parallel modules.

20. The modular bridge system of claim 17, wherein the deployment method is selected from the group consisting of scissor-type and collapsing-type.

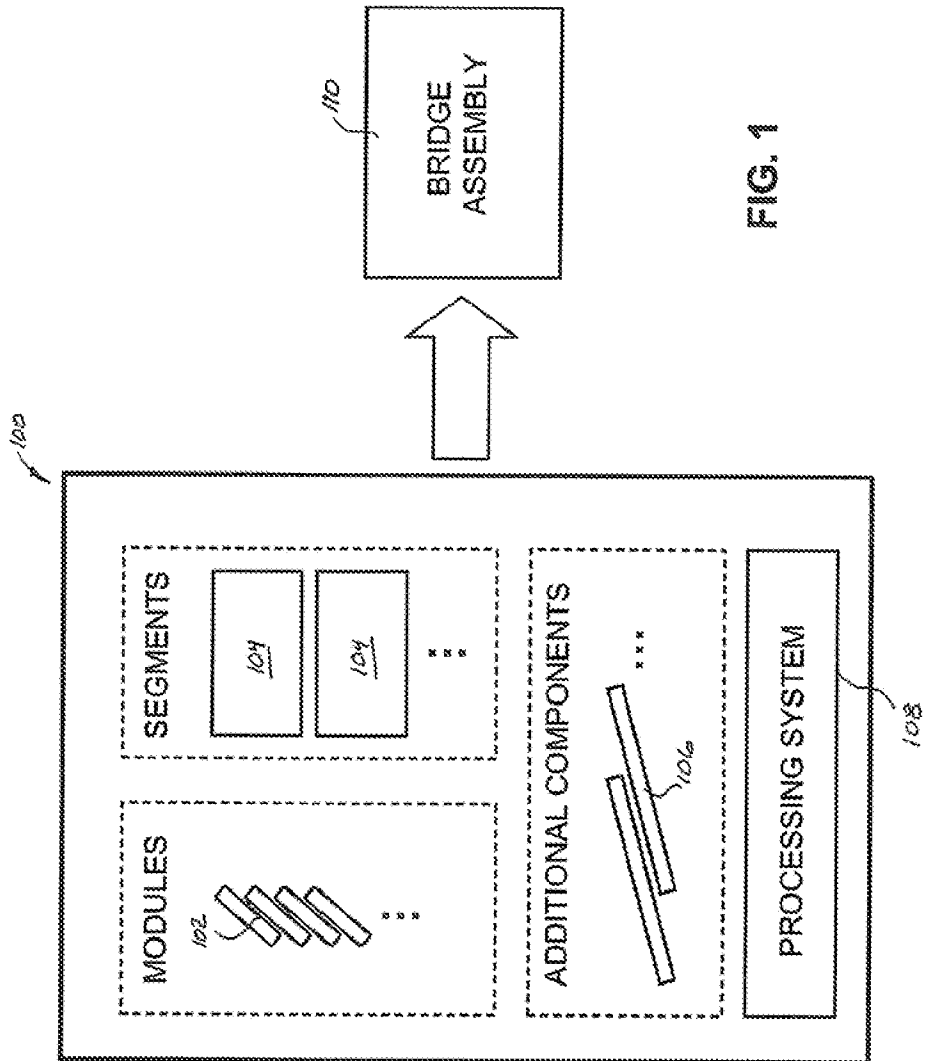


FIG. 1

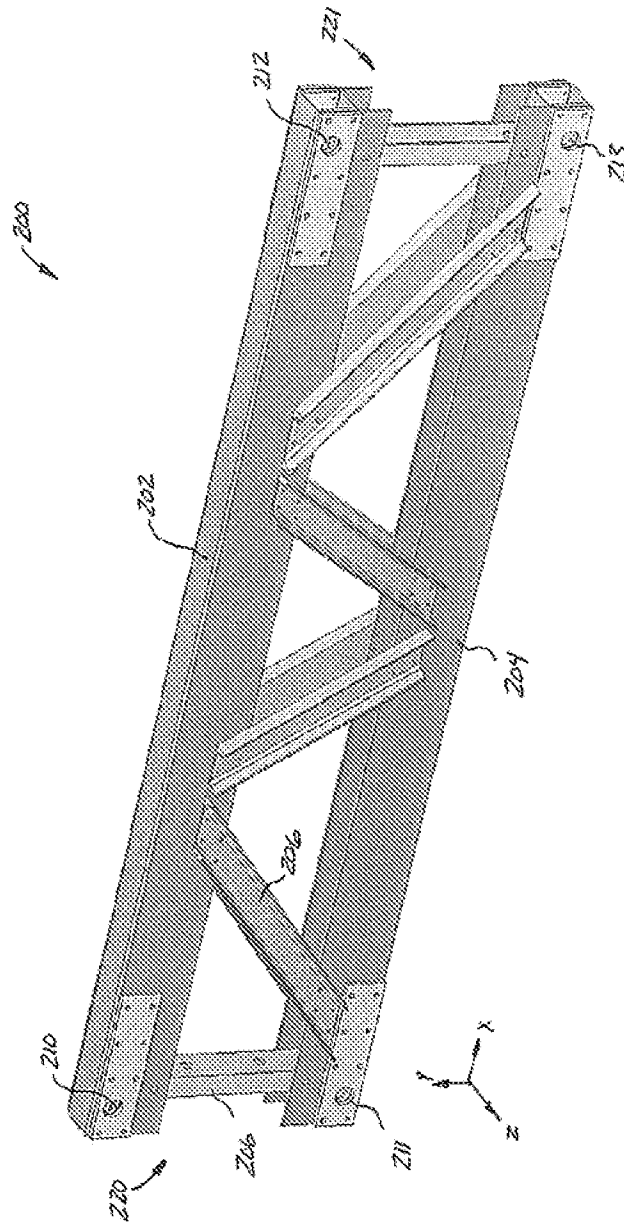


FIG. 2

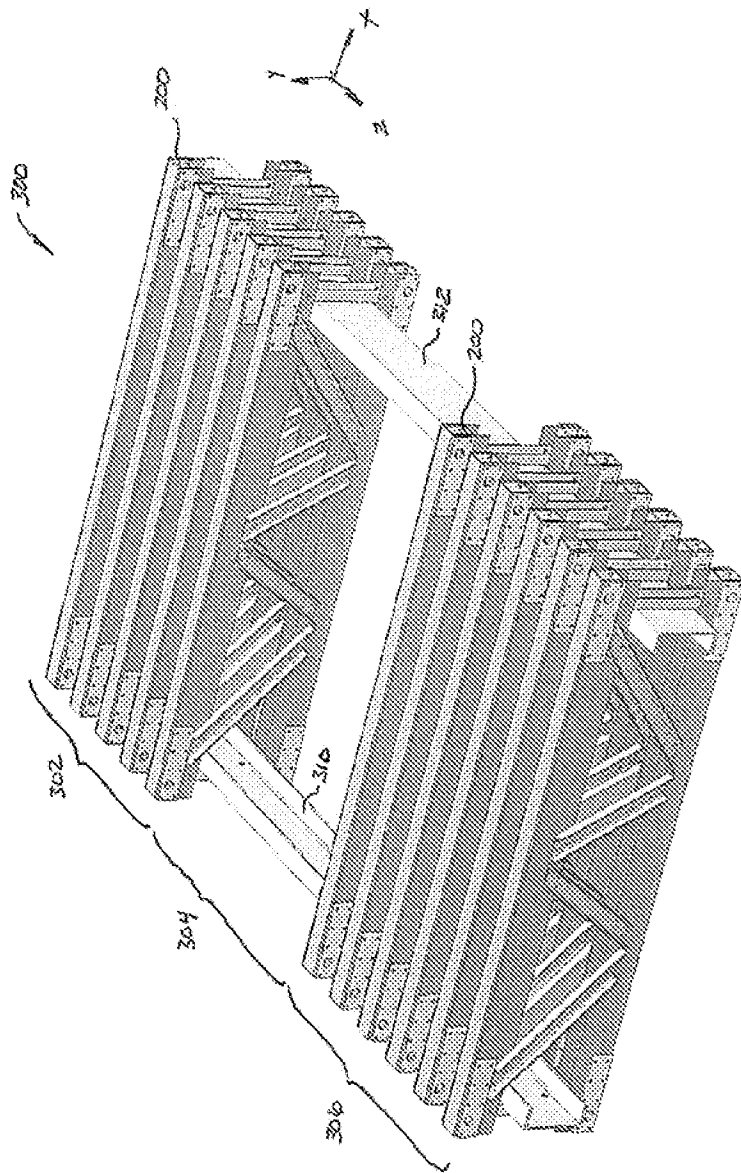


FIG. 3

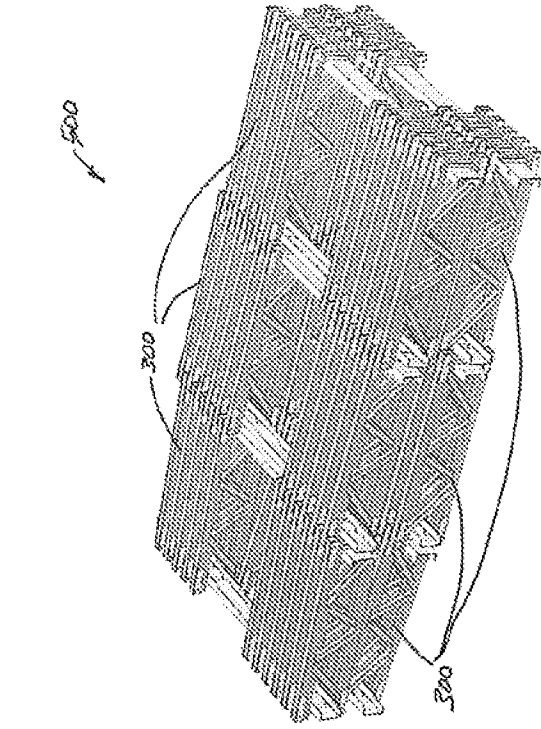


FIG. 4

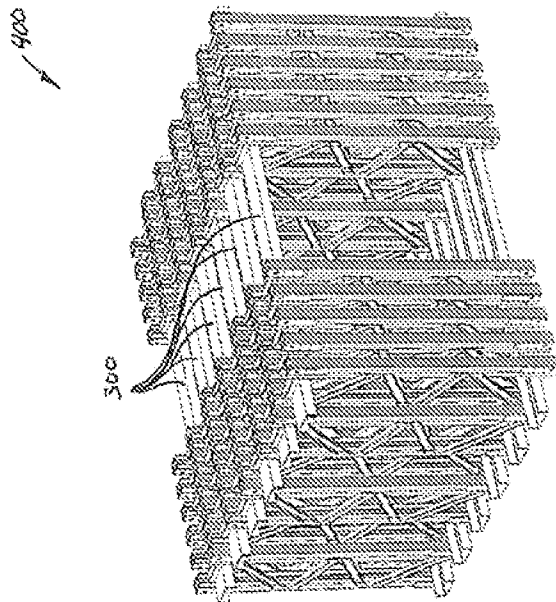


FIG. 5

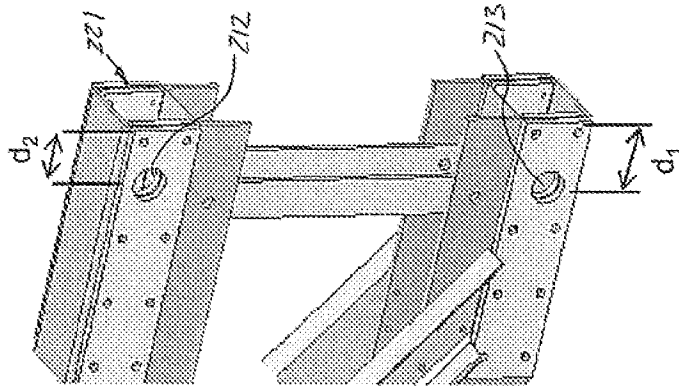


FIG. 7

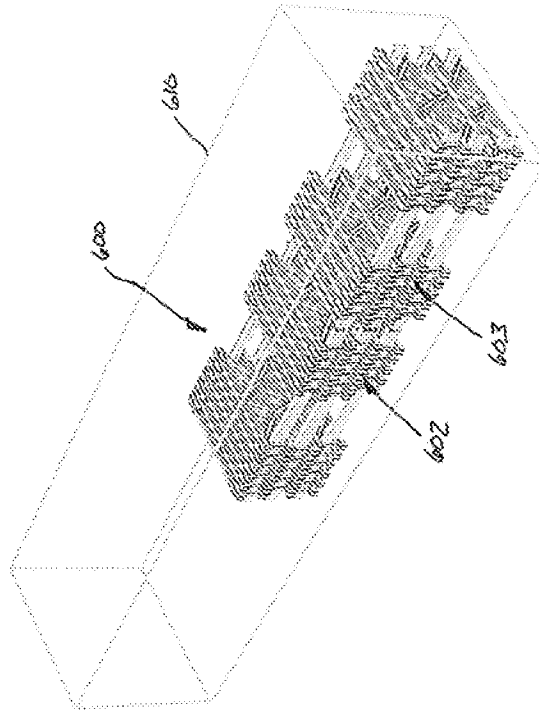


FIG. 6

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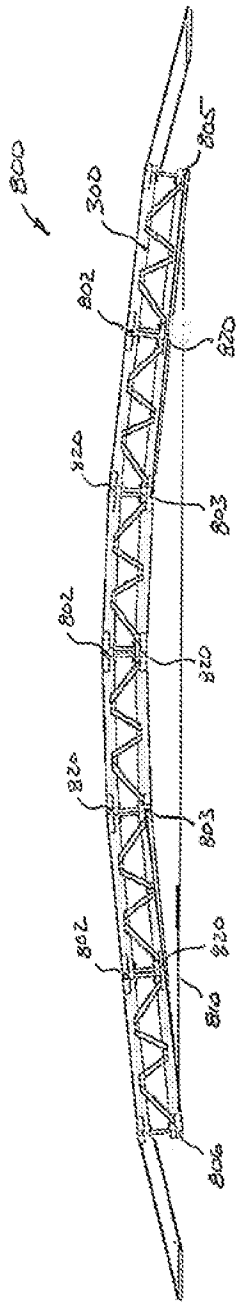


FIG. 8

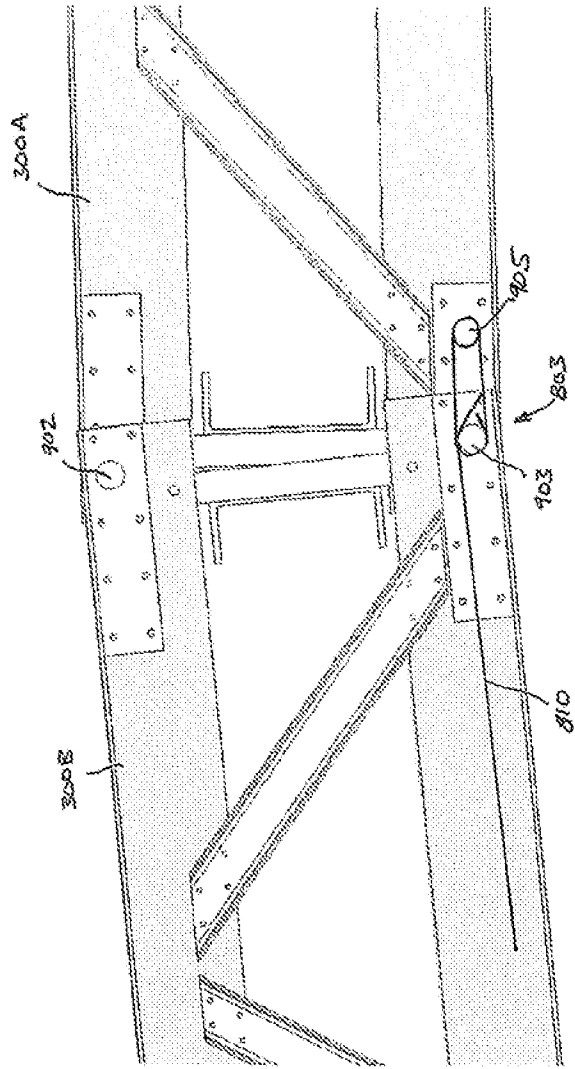


FIG. 9

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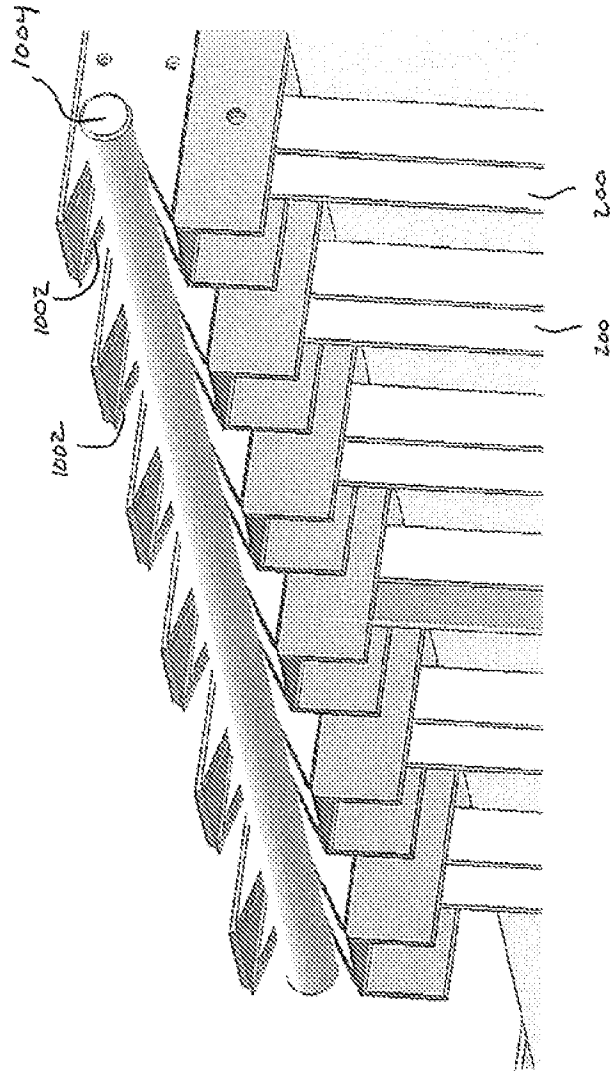


FIG. 10

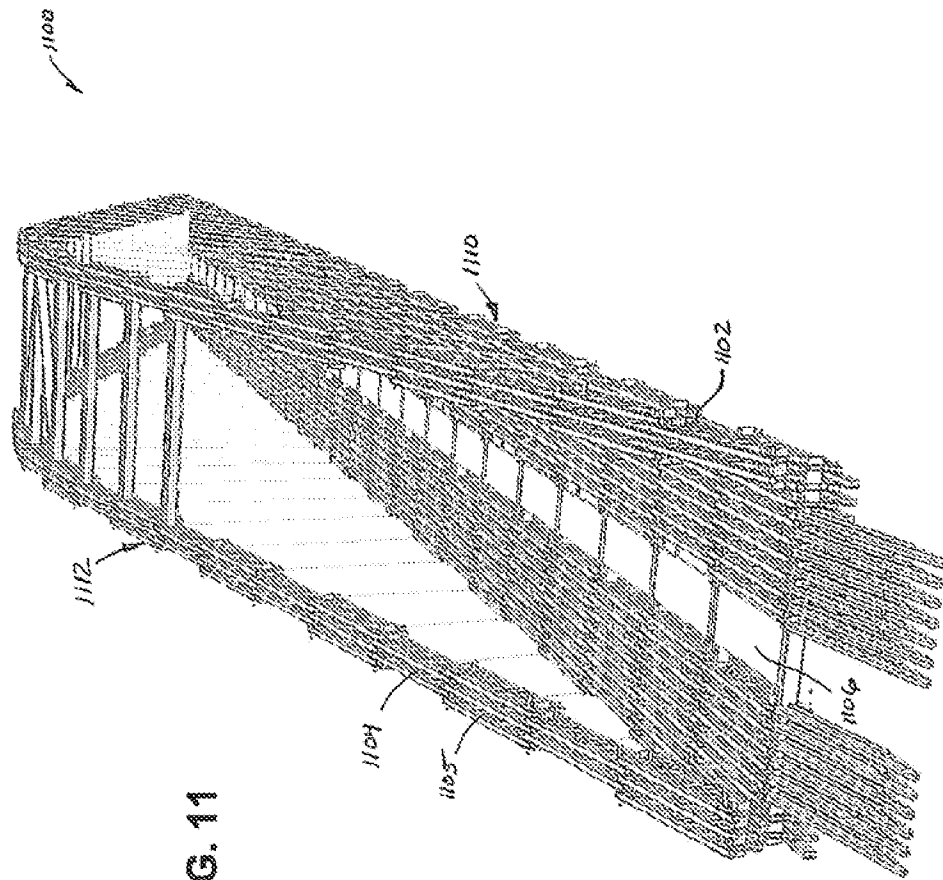


FIG. 11

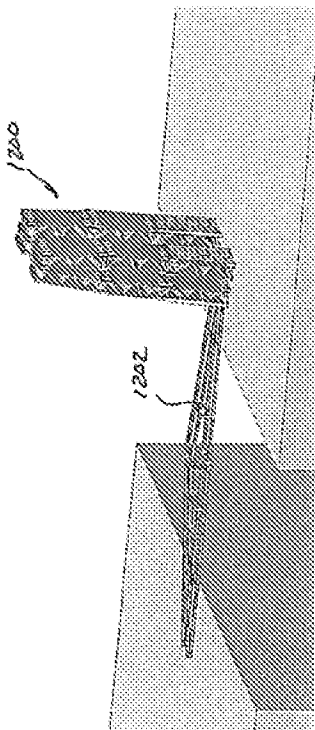


FIG. 12A

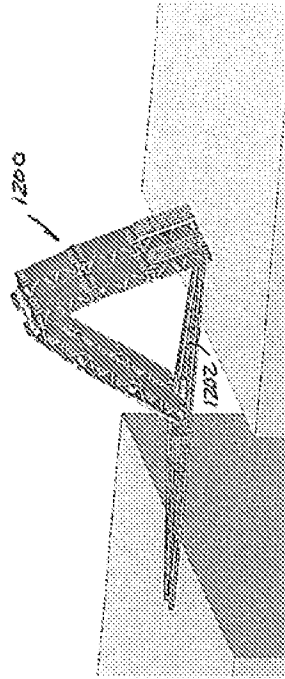


FIG. 12B

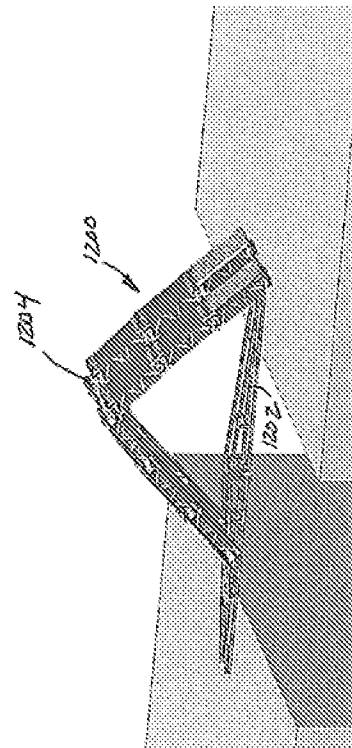


FIG. 12C

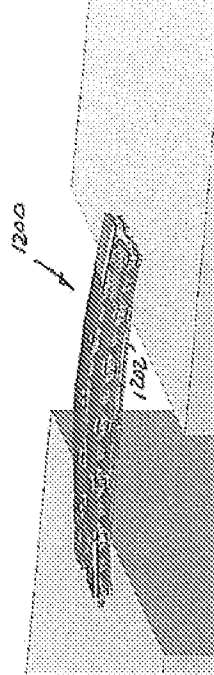


FIG. 12D

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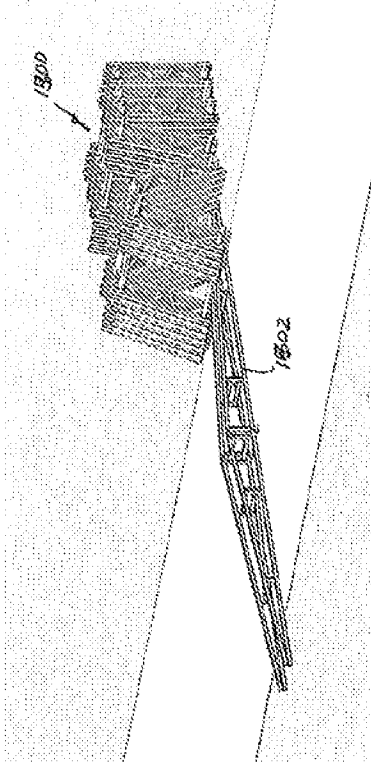


FIG. 13B

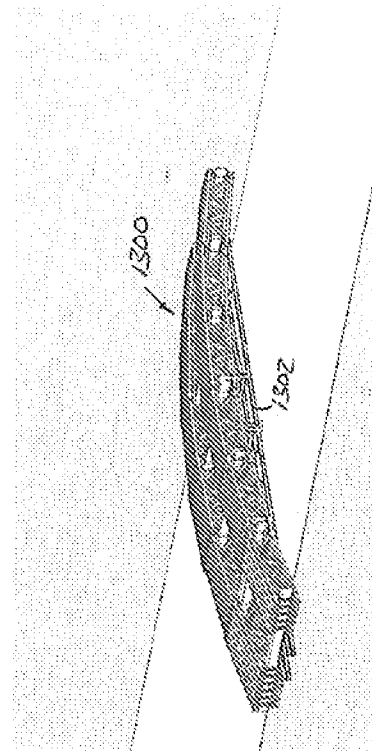


FIG. 13D

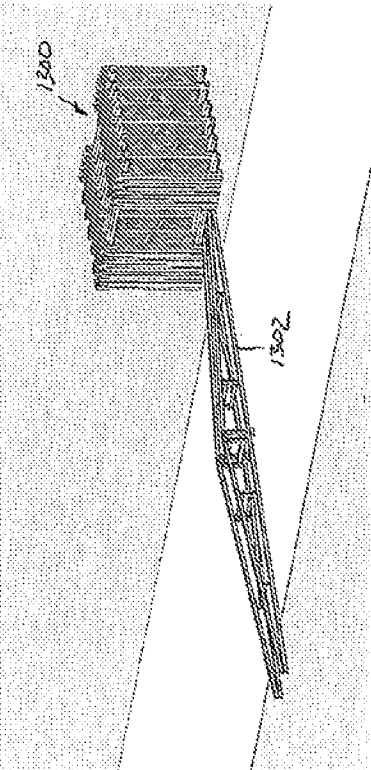


FIG. 13A

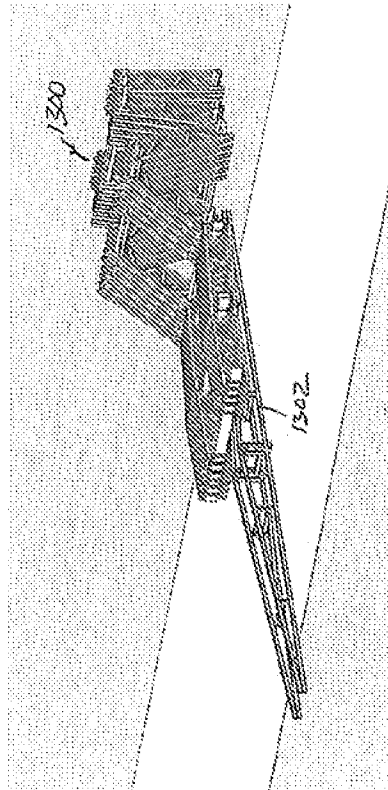


FIG. 13C

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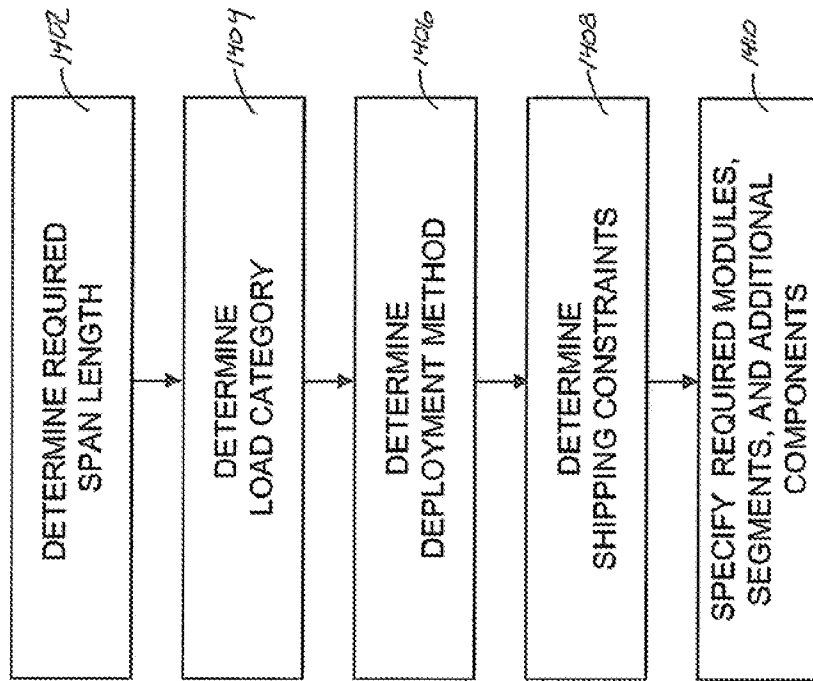


FIG. 14

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2012/023372

A. CLASSIFICATION OF SUBJECT MATTER
 INV. E01D15/12 B63B27/14 E04B1/343 E04B1/344
 ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED
 Minimum documentation searched (classification system followed by classification symbols)
 E01D B63B E04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
 EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2007/044415 A1 (MERRIFIELD DONALD [US] ET AL) 1 March 2007 (2007-03-01) figures 1-9 paragraphs [0008] - [0010], [0012], [0040], [0054] - [0056], [0061], [0063], [0067]	1-20
Y	US 4 200 946 A (LAWRENCE DEREK I [GB]) 6 May 1980 (1980-05-06) figures 1-10 column 2, line 52 - column 3, line 14 column 3, lines 65-68 column 4, line 45 - column 5, line 11	1-20
Y	US 5 784 738 A (UPDIKE GREGORY J [US]) 28 July 1998 (1998-07-28) figures 1-4 column 2, lines 19-43	1-20
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Further documents are listed in the continuation of Box C.

See patent family annex.

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- "&" document member of the same patent family

Date of the actual completion of the international search 24 May 2012	Date of mailing of the international search report 06/06/2012
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Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer Schnedler, Marlon
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INTERNATIONAL SEARCH REPORT

International application No

PCT/US2012/023372

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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INTERNATIONAL SEARCH REPORT

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			EP 0435741 A1 03-07-1991
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			FR 2656353 A1 28-06-1991
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