ROD-REINFORCED CUSHION BEAM

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ABSTRACT
A reinforced cushion beam includes a rigid frame having a plurality of interconnected elements; a plastic body encapsulating and substantially solidly filling the frame, and one or more panel members connected to the plastic body with a plurality of recessed fasteners that extend through the panel(s) and into the plastic body to form a scuff-resistant load-bearing surface. Also disclosed is a method for forming the cushion beam.
ROD-REINFORCED CUSHION BEAM

RELATED APPLICATIONS

This application is a continuation-in-part of application Ser. No. 10,927,569 filed Aug. 25, 2004, which is a continuation-in-part of application Ser. No. 10,346,204, now U.S. Pat. No. ______, which is a continuation-in-part of application Ser. No. 10/278,754, filed on Oct. 22, 2002, now U.S. Pat. No. ______, each of these applications being incorporated herein by the respective references.

BACKGROUND

The present invention relates to elongated structural members such as pilings, columns, beams, piers, and beams, particularly for use in marine environments, and methods for making such members. Concrete, steel, and wood are conventionally used for pilings, telephone poles, beams, and the like. However, each of these materials has disadvantages. Concrete and steel pilings are heavy and awkward to maneuver. Neither concrete nor steel pilings make good fender pilings because neither is "forgiving" when impacted. Under impact, steel bends and buckles and concrete shatters. Both concrete and steel pilings are expensive to repair. Moreover, steel, either standing alone or as a reinforcement in porous concrete, is subject to corrosion.

Wood pilings, planks, and beams are plagued by wear, tear, and particularly in marine environments such as in piers and ship moorings, are attacked by wood-boring marine organisms. Wood pilings, poles, and planks are typically treated with creosote, but even this material can be ineffective against modern marine borers. These marine borers can only be stopped by wrapping the wood pilings in plastic coverings. However, these plastic coverings cannot withstand much wear and tear, especially abrasion from normal vessel contact. So in addition to a thin plastic wrap, wooden fender pilings and planks often require thick plastic wrappings, which are expensive to put in place and are subject to separation.

Composite pilings are also known, being disclosed for example in U.S. Pat. No. 5,180,531 to Borzakian, that document being incorporated herein by this reference. The '531 patent discloses a plastic pipe having an inner pipe core or mandrel being 6 inches or less in diameter, and a substantially homogeneous coating being at least two inches thick. The thick plastic coating provides the bulk of the mechanical strength, being formulated with a desired combination of flexibility, brittleness, and impact resistance for use as pilings including fender pilings of docks, telephone poles, light standards, etc.

U.S. Pat. No. 5,766,711 to Barmakian, which is incorporated herein by this reference, discloses a composite camel structure including a pipe mandrel and a thermally bonded plastic cushion surrounding the mandrel. A mold having the mandrel centered therein is filled with molten plastic, the plastic being cooled and solidified by feeding water into the mandrel for progressively solidifying the cushion member along mandrel for producing a thermal bond without excessive tensile strain in the plastic material, thereby to achieve a substantially unbroken outside surface.

U.S. Pat. No. 6,244,014 to Barmakian, which is incorporated herein by this reference, discloses a composite piling having a welded cage including a circular array of parallel spaced main rod members that are welded about a helically formed secondary rod member, the cage being encapsulated in a plastic body.

U.S. Pat. No. 6,412,431 to Barmakian et al., which is also incorporated herein by this reference, discloses a composite fender having a cage frame encapsulated in a plastic body, the cage frame having an attachment structure connected to plural spaced apart locations of the frame.

Notwithstanding the above, it is believed that there is a need for further improvements in structural components to be used as beams in moorings, piers, and the like that are contemplated to be used in marine environments, that such components have high bending strength and high resistance to impact loading, and that they have long life, are easily installed, environmentally sound, and durable in use.

SUMMARY

The present invention meets this need by providing a reinforced cushion beam of high bending strength, being particularly suitable for a variety of marine applications. In one aspect of the invention, a composite beam having cross-sectional area of at least 50 square inches includes a frame having a plurality of interconnected members; a resilient plastic body member substantially encapsulating the frame; a panel member spaced from the frame, a portion of the resilient body filling space between the panel member and the frame, the panel member forming a load-bearing outside surface portion of the beam; and a spaced plurality of fasteners extending through the panel member in recessed relation thereto, through portions of the plastic body, and into engagement with the frame. Preferably the panel member includes a resilient material for cushioned contact with objects coming into contact with the beam. Preferably the panel member includes ultra-high molecular weight (UHMW) polymer for providing a desired combination of cushioning, strength, and scuff resistance. More preferably the panel member substantially consists of the ultra-high molecular weight (UHMW) polymer. It is also preferred that the plastic body include a resilient material having a first rigidity, the material of the panel member having a second and greater rigidity for withstanding localized impact loading.

The composite beam can include an attachment structure defining a spaced plurality of attachment elements connected to plural spaced apart locations of the frame. Preferably the attachment structure includes a plurality of transverse members bonded at spaced locations along the frame, each of the transverse members having at least one receptacle for engagement by a corresponding one of the fasteners for facilitating spacing the threaded openings to match a predetermined spacing of the fasteners. The fasteners can be threaded fasteners such as cap screws, the receptacles being threaded openings.

The frame can include a plurality of longitudinal main rod members, at least three of the main rod members being spaced laterally in different corresponding directions relative to the longitudinal axis; and a plurality of transverse elements, each transverse element being rigidly connected between a spaced pair of the main rod members, at least three of the main rod members being connected to at least two others of the main rod members by at least some of the
transverse elements. At least some of the transverse elements can be shear panels. The composite beam of claim 10, wherein the shear panels comprise laterally spaced first and second sets of longitudinally spaced shear panels, the panels of each set being bonded between a pair of the main rod members. Preferably at least some of the shear panels have openings and/or notches formed therein, the body member having portions external to the cage frame integrally joined through the openings and/or notches with portions of the body member within the frame for enhanced structural integrity of the body member.

Alternatively (or additionally) at least one pair of the main rod members is connected by some of the transverse elements being transverse rod segments such that diverging pairs of the transverse rod segments are connected in proximal relation at spaced intervals along each main rod member of the pair, whereby the pair of main rod members and the diverging pairs of transverse rod segments form a truss.

Preferably the main rod members and the transverse elements are each spaced at least 0.5 inch within an outside contour of the plastic body for enhanced cushioning and isolation of the frame from harmful contamination. The main rod members can be selected from the group consisting of formed steel reinforcing bars, formed nickel alloy reinforcing bars, fiberglass reinforcing bars, and carbon fiber reinforcing bars. The at least some of the transverse elements can be selected from the group consisting of formed steel reinforcing bars, formed nickel alloy reinforcing bars, fiberglass reinforcing bars, carbon fiber reinforcing bars, plastic dowels, wooden dowels, steel plates, and fiberglass panels.

A plurality of the composite beams can be assembled to form a fender assembly.

In another aspect of the invention, a method for forming a scuff-resistant composite beam includes the steps of: (a) providing a frame comprising a plurality of interconnected members; (b) encapsulating the frame in a plastic body; (c) providing a one or more scuff-resistant panel members; (d) providing a plurality of headed fasteners; and (e) connecting each of the one or more panel members to the plastic body with at least two of the fasteners projecting through each panel member in recessed relation thereto, and through portions of the plastic body to provide a scuff resistant load bearing surface on the resulting composite beam. The step of connecting can further include the steps of (i) affixing a plurality of attachment members at spaced locations along the frame; and (ii) engaging the fasteners with corresponding ones of the attachment members, thereby anchoring the one or more panel members to the frame. Preferably the step of affixing includes the further step of positioning the attachment members at sufficiently greater spacing along the frame to compensate for thermal extension of the frame at ambient temperature following the step of encapsulating.

**DRAWINGS**

These and other features, aspects, and advantages of the present invention will become better understood with reference to the following description, appended claims, and accompanying drawings, where:

**FIG. 1** is a fragmentary sectional side view of a reinforced cushion beam structure according to the present invention, the section being taken on line 1-1 of **FIG. 2**;

**FIG. 2** is a fragmentary sectional top view of the beam structure of **FIG. 1** taken on line 2-2 therein;

**FIG. 3** is an oblique perspective view of a cage truss portion of the beam structure of **FIG. 1**;

**FIG. 4** is a lateral sectional view of a beam structure of **FIG. 1**;

**FIG. 5** is a flow chart for a process of forming the piling structure of **FIG. 1**;

**FIG. 6** is a fragmentary sectional side view showing the beam structure having an alternative configuration of the cage truss of **FIG. 3**;

**FIG. 7** is an oblique perspective view showing another alternative configuration of the cage truss of **FIG. 3**;

**FIG. 8** is a lateral sectional view as in **FIG. 4**, showing an alternative configuration of the beam structure of **FIG. 1**; and

**FIG. 9** is an end elevational view of a fender panel incorporating beam structures of the present invention and fastened on stationary structure;

**FIG. 10** is a front elevational view of the fender panel of **FIG. 9**; and

**FIG. 11** is an oblique perspective view showing a cage frame as another alternative configuration of the cage truss of **FIG. 3**;

**FIG. 12** is a side view as in **FIG. 6**, showing the beam structure having an alternative cage frame configuration of the cage truss of **FIG. 3**;

**FIG. 13** is a lateral phantom view of the beam structure of **FIG. 12**;

**FIG. 14** is a side view as in **FIG. 12**, showing an alternative configuration of the cage frame;

**FIG. 15** is an oblique perspective phantom view of a cushion beam structure having another alternative configuration of the cage frame of **FIG. 12**;

**FIG. 16** is a side view as in **FIG. 1** showing another alternative configuration of the beam structure;

**FIG. 17** is a plan view of the beam structure of **FIG. 16**;

**FIG. 18** is a fragmentary lateral sectional view of the beam structure of **FIG. 17**; and

**FIG. 19** is a partially exploded detail sectional view within region 19 of **FIG. 18**.

**DESCRIPTION**

The present invention provides a novel reinforced plastic cushion beam that is particularly effective as a sheathing plank, wale, or other structural element of a wharf facility. With reference to **FIGS. 1-4** of the drawings, a cushion beam 10 according to the present invention includes an elongate cage structure 11 in the form of a cage truss 12, and a resilient plastic material forming a cylindrical plastic body 14 and encapsulating the cage truss 12. As used herein,
a “resilient material” is one that can be compressed significantly in volume under load, yet will return to substantially the same volume when the load is released. The relative “rigidity” of resilient materials as used herein is proportional to the amount of compressive loading required to effect a given change in volume.

[0038] As best shown in FIGS. 1, 2, and 4, an exemplary configuration of the cushion beam 10 is generally rectangular in cross-section, having an outside width W and an outside depth D which can be the same as the width W, and an overall length L that can be from approximately 10 feet to approximately 60 feet, or even longer. In one specific exemplary configuration the width W and the depth D are each approximately 12 inches. Also, the plastic body 14 as shown in the drawings is cylindrical, having a uniform cross-section between opposite end extremities of the cushion beam 10. As used herein, the term “cylindrical” means having a surface that is generated by a straight line that moves parallel to a fixed line. Thus, although the body 14 is shown in the drawings as rectangularly cylindrical, other cross-sectional shapes such as circular, elliptical, polygonal, and rounded polygonal are also contemplated within the scope of the present invention. Moreover, it is also contemplated that the cushion beam 10 can be curved and/or have a non-uniform cross-section within the scope of the present invention.

[0039] The cage truss 12 includes a plurality of longitudinal main rod members 16 that are rigidly interconnected by transverse elements 17 that can include a multiplicity of transverse rod segments 18, opposite end portions of each segment 18 being connected between a pair of the main rod segments 16. As best shown in FIG. 4, the main rod segments 16 are spaced laterally in plural directions relative to a longitudinal axis 19 of the truss 12, with each of the main rod members having transverse rod segments projecting in plural directions having components perpendicular to the longitudinal axis 19 (the plane of FIG. 4 being generally perpendicular to the longitudinal axis 19). Preferably at least some of the transverse rod segments 18 are diagonal segments 20, as shown in FIGS. 1 and 3. In such an arrangement primarily tension and compression loads on the main rod members 16 and the transverse rod segments 18 in response to bending and shear loading of the cage truss 12 as a whole. In the exemplary configuration shown in FIGS. 2-4, the cage truss 12 is adapted for transmitting bending and shear loading primarily in the plane of FIG. 1. In particular, the cage truss 12 has at least one additional transverse rod segment 18 connected in coplanar relation proximate each end portion of the diagonal rod segments 20. As shown in FIG. 1, there are two such additional coplanar transverse rod segments 18 proximate each diagonal rod end extremity, one being another of the diagonal rod segments 20, the other being a lateral rod segment, designated column rod segment 22) except at opposite ends of the cage truss 12, where there is one such additional transverse segment (a column rod segment 22) at each connection location. Other lateral rod segments, designated tie rod segments 24, extend perpendicularly between opposite sides of the cage truss 12 as shown in FIGS. 2-4.

[0040] In another aspect, the cage truss 12 includes a spaced pair of generally planar truss units 26 that are connected in generally parallel-spaced relation by the tie rod segments 24. In one preferred form, the cage truss 12 is a weldment of steel reinforcing bars having ribbed contours as indicated in FIG. 4 for enhanced gripping and adhesion by the plastic body 14, weldable steel reinforcing bars (ASTM 706), being commercially available from a variety of sources. More particularly, a first truss unit 26A includes a first pair (16A and 16B) of the main rod members connected proximate opposite ends of one subset 18A of the transverse rod segments 18, and a second pair 16C and 16D of the main rod members connected on opposite ends of another subset 18B of the transverse rod segments 18, one subset 24A of the tie rod segments 24 being connected between the rod members 16A and 16C, another subset 24B of the tie rod segments 24 being connected between the rod members 16B and 16D as best shown in FIG. 4. Additionally, a third pair (16E and 16F) of the main rod members are connected proximate opposite ends of the first transverse rod subset 18A opposite the first pair 16A and 16B, and a fourth pair (16G and 16H) of the main rod members connected proximate opposite ends of the second transverse subset 18B. Thus each of the truss units 26A and 26B is laterally symmetrical on opposite sides of the (typically planar) surface defined by the respective transverse rod segment subsets 18A and 18B for maximum resistance to deflection from loads applied (at least locally) coplanar with that surface. It will be understood that for additional lateral stability and/or for resistance to loading in directions having components parallel to the tie rod segments 24, the cage truss 12 can include additional diagonal rod segments 20 in other orientations (not shown), such as diagonally between pairs of the tie rod segments 24 of the respective subsets 24A and 24B.

[0041] As shown in FIG. 2, the cage truss 12 also includes a plurality of fastener attachments 30 for mounting the cushion beam 10 to other structure and/or for mounting other structural elements to be supported by the cushion beam 10. As shown in FIG. 1, a plurality of the attachments, designated threaded sleeves 32, is welded to the cage frame 10 and forming a rigidly connected component thereof at spaced locations defining a first mounting surface 33. A second plurality of attachments, designated floating sleeve 34, are imbedded proximate a second mounting surface 35 the resilient body 14 so as to form a cushioned mounting for other supported structure as described below in connection with FIGS. 9 and 10. It will be understood that, particularly for connections required to transmit mainly compressive and/or shear forces, it is contemplated that fasteners such as lag screws can be threadingly engaged with the plastic body, without requiring imbedded attachments, whether or not such attachments form a part of the cage structure.

[0042] An important feature of the present invention is a formulation of polymeric material that is suitable for encapsulating the cage truss 12 and that does not form voids or cracks due to tensile thermal strains being generated during solidification. This problem is exacerbated by the absence of a tubular mandrel that can receive cooling water as disclosed in the camel structure of the above-referenced ’711 patent. It has been discovered that a particularly suitable composition for forming the plastic body 14 as an uninterrupted covering of the cage truss 12 is a main first quantity of low density polyethylene of which at least 60 percent and preferably 65 percent is linear low-density polyethylene (L.LDPE), the balance being regular low-density polyethylene (L.DPE), and a process additive second quantity including an effective amount of UV inhibitor, the composition not
having any significant volume of filler material such as calcium carbonate. Preferably, the first quantity is at least 90 percent of the total volume of the plastic body 14, approximately 5 percent of the total volume being a mixture of coloring, foaming agent, and UV inhibitor. Preferably the composition is substantially free (not more than 5 percent) of high density polyethylene.

[0043] Thus the composition of the cushion member 14 has polymeric elements being preferably exclusively polyethylene as described above (substantially all being of low-density and mainly linear low-density), together with process additives as described below. As used herein, the term “process additive” means a substance for enhancing the properties of the polymeric elements, and does not include filler material such as calcium carbonate. The composition preferably contains a process additive which can be a foaming or blowing agent in an amount of up to about 0.9% by weight to insure that when the plastic body 14 is made by extruding the plastic composition into a mold, the mold is completely filled. The foaming agent can be a chemical blowing agent such as azodicarbonamide. A suitable chemical blowing agent is available from Uniroyal of Middlebury, Conn., under the trade name Celogen AZ 130.

[0044] Other process additives of the composition can include a coupling agent, preferably a silane, for improved bonding between the plastic body 14 and the cage truss 12.

[0045] The plastic composition can also include a fungicide, typically in an amount of about 0.25% by weight, and an emulsifier, in an amount of from about 0.1% to 0.3% by weight. The use of emulsifier improves surface appearance of the product.

[0046] The composition can also contain a carbon black, generally a furnace black, as a colorant, to improve the physical properties, and as a UV stabilizer. The amount of carbon black used is generally about 2.5% by weight.

[0047] A mold apparatus (not shown) for encapsulating the cage truss 12 to form the plastic body 14 of the cushion beam 10 includes a mold assembly and a conventional extruder press, including one or more flanged tubular mold segments as further described in the above-referenced ‘014 patent, but with the cross-sectional shape of the mold segments conforming to the cross-sectional shape of the body 14, with appropriate allowances for shrinkage as further described in the ‘014 patent.

[0048] As further described in the ‘014 patent, the cage truss 12 centered within a main cavity of the mold assembly, being supported by a plurality of projections 20, and/or by fasteners temporarily engaging one or more of the fastener attachments 30, or by centering screws as disclosed in the above-referenced ‘711 patent. Alternative mold construction is also described in the above-referenced ‘431 patent.

[0049] With further reference to FIG. 5, a process 100 for forming the cushion beam 10 includes providing the main and transverse rods 16 and 18 in a provide rods step 102, a weld trusses step 104 in which the truss units 26A and 26B are assembled and welded, the truss units 26 being joined in spaced relation in a weld cage step 105. Then, in a load mold step 106, the cage truss 12 is placed within the mold assembly and anchored in registration therewith. The mold is closed in a close mold step 108 and, optionally in an incline mold step 109, the mold assembly is propped up on a suitable support for elevating an exhaust vent thereof.

[0050] Next, the material of the plastic body 14 is fed into the main cavity in an inject body step 110. Then in a cooling step 112, the mold assembly with its contents is submerged in cooling water for solidifying the material of the plastic body 14, after which the assembly 42 is removed from the water (step 114), the mold is opened (step 116), and the substantially complete cushion beam 10 is withdrawn (step 118). Further details of this process are described in the above-referenced ‘014 and ‘431 patents.

[0051] With further reference to FIG. 6, an alternative configuration of the cushion beam, designated 10’, a counterpart of the cage truss, designated 12’, has a single formed rod member, designated 20’, substituted for the diagonal rod segments of each of the truss units 26A and 26B. As shown in FIG. 6, some of the other transverse rod segments of the configuration of FIGS. 1-4 are omitted, namely all but the endmost column rod segments 22 and every other one of the tie rod segments 24. With further reference to FIG. 7, a counterpart of the cage truss 12’, designated 12”, has the members omitted from the truss 12 restored, the restored column rod segments, designated 22”, being foreshortened and abutting formed portions of the diagonal rod member 20’.

[0052] With further reference to FIG. 8, another alternative configuration of the cushion beam, designated 10”, has a non-rectangular cross-sectional configuration, and a counterpart of the cage truss, designated 12””, is non-rectangular. In particular, counterparts of the first and second truss units, respectively designated 26A’ and 26B’, are inclined laterally, counterparts of the main rod members 16A and 16D being shared by the truss units 26A’ and 26B’, the tie rod segments 24 of the first subset 24A being omitted. Thus the first truss unit 26A’ includes counterparts of the main rod members 16A, 16B, 16C, and 16F, the second truss unit 26B including counterparts of the main rod members 16A, 16C, 16D, and 16L, there being no counterparts of the main rod members 16E and 16G. Also, the alignment of locally proximate pairs of the main rod members, namely 16A and 16C, 16B and 16F, and 16D and 16L, are oriented in facing relation to the longitudinal axis 19 for simultaneous engagement at opposite sides of the transverse rod segments that project in respective acutely divergent planes, which in the example configuration shown in FIG. 8 form an equilateral triangle. Further, counterparts of the threaded sleeves 32 are located proximate a counterpart of the first mounting surface 32 and proximate opposite end extremities of the tie rod segments 24, being welded thereto and to adjacent ones of the main rod segments 16 as well as transverse rod segments 18 of the first and second truss units 26A’ and 26B’. As yet further shown in FIG. 8, one or more counterparts of the floating sleeve, designated 34’, is located proximate a second mounting surface and in spaced relation proximate the main rod members 16A and 16C. One or more formed counterparts of the anchor member, designated 36, has opposite ends welded to opposite sides of the floating sleeve 34’, the anchor members 36 together with the floating sleeve 34 enclosing the main rod members 16A and 16C in spaced relation such that the floating sleeve 34’ is resiliently supported relative to the cage truss 12””.

[0053] With further reference to FIGS. 9 and 10, a fending panel assembly 40 includes at least one cushion
beam, three vertically spaced and transversely mounted beams being shown, and at least one panel member 42, a plurality of panel members 42 being shown connected between the cushion beams 10. More particularly, the first mounting surfaces 34 of the beams 10 are oriented vertically, being fastened against a stationary structure 43 by a plurality of first fasteners 44 that engage respective ones of the fastener attachments 30. The panel member 42 is fastened against the second mounting surface 35 by a plurality of second fasteners 46 that engage the floating sleeves 34 to form a fender assembly for cushioning moored ships. A plurality of sheathing planks 48 are also shown fastened in generally coplanar relation to the panel members 42 in FIG. 9, it being understood that any combination of panel(s) and/or plank(s) (or other structural elements) can be supported by one or more of the cushion beams 10, 10′ and/or 10″. Moreover, the sheathing planks can be additional counterparts of the cushion beams, such as the cushion beams 10 and 10″.

[0054] In some military based naval applications, it is undesirable for a marine-exposed structure to be electromagnetically sensitive. In such applications the cage truss 12 can be formed with non-magnetic materials, such as nickel reinforcing bar (formed of a corrosion-resistant steel alloy), which is available from MMFX Steel Corp. of America, Charlotte, N.C. Another suitable material is carbon-reinforced plastic bar, available from Aero Space Composite Products of San Leandro, Calif. The cage truss 12 can also be developed by using fiberglass reinforcing rods, with reinforced epoxy joints at points of contact between the main rods 12 and the various transverse rod segments 18 and/or diagonal rod segments 20. Additional suitable materials include Nylkon Reinforcement, available from McMasters Co. of Los Angeles, Calif., plastic dowels, also available from McMasters, and wooden dowels, which are available from typical lumber yards.

[0055] With further reference to FIG. 11, certain of the non-metallic materials, most particularly the fiberglass reinforcing rods, are suitably joined with epoxy resin and locally applied layers or other quantities of fiberglass reinforcement to form rigidly bonded joints. When this form of construction is utilized it is often possible to dispense with the diagonal rod segments 20 in that the resulting frame, designated 12″′, imparts a desired amount or resistance to bending. As shown in FIG. 11, one or more of the column rod segments 22 and the tie rod segments 24 are rigidly bonded to the main rod members 16 by epoxy resin 52 having one or more layers of fiberglass fabric 54 therein.

[0056] With further reference to FIGS. 12-15, another alternative configuration of the cushion beam, designated 60, has an alternative configuration of the cage structure 11 that incorporates shear panels as some or all of the transverse elements 17 of the cage truss 12, in place of (or in addition to) some or all of the diagonal rods segments 20 or the diagonal rods 20 of FIG. 6 and column rod segments 22 (and/or 22′ of FIG. 7) as described herein. As shown in FIGS. 12 and 13, one such cage structure, designated cage frame 62, has a spaced plurality of rectangular shear panels 64 joined along opposite edges thereof to a spaced pair of the main rod members 16. It will be understood that although the term “cage truss” as applied to the cage structures 11 of FIGS. 1-11 does not strictly apply in that the shear panels 64 (and portions of the main rod members 16 between the shear panels) have shear loading, the deflection of the cage frame 62 that is attributable to shear loading of the main rod members is much less than would be present in the cage truss 12 of FIG. 1. If the diagonal rod segments 20 were omitted, because the portions of the main rod members 16 that are subject to shear loading (and consequent strain) make up only a small proportion of the length of the cage frame 62.

[0057] In the exemplary configuration of FIGS. 12 and 13, there are two sets of the shear panels 64, designated 64A and 64B in FIG. 13, that are sandwiched between pairs of the main rod members, the panels 64A being welded along one edge between the main rod members 16A and 16E, and along the opposite edge between the main rod members 16B and 16F. Similarly, the other panels 64B are welded along one edge between the main rod members 16C and 16G, and along the opposite edge between the main rod members 16D and 16H as shown in FIG. 13. The tie rod segments 24 (24A and 24B) are located within gaps between the shear panels 64 as shown in FIG. 12. It is not necessary that there be tie rod segments in each of the gaps, depending on the size of the panels 64, the gaps having a primary purpose of providing structural integrity of the plastic body 14 within and outside of the cage frame 62 in that the material of the body 14 extends through passages formed by the gaps. The gaps also result in a reduction in the total weight of the shear panels 64, which are preferably provided in a thickness sufficient to carry compressive loading between the main rod members (16A and 16B, for example) at opposite edges of the panels 64. Thus the shear panels 64 are substituted for both the diagonal rod segments 20 and the column rod segments 22 of FIG. 1. In a counterpart of the exemplary 12-inch by 12-inch beam 10 described above, the shear panels 64 can be provided as approximately ⅛ inch thick mild steel plates measuring 9½ inch in a direction perpendicular to the main rods 16 (for extending just beyond the midpoints of the rods to which they are welded), and from 6 to 8 inches in a direction parallel to the main rods, the spacing between the panels 64 being from approximately 1 inch to approximately 3 inches. The shear panels 64 can also be formed of non-metallic materials such as fiberglass, being suitably bonded to the main rod members 16, substituting for some or all of the transverse rod elements (the column rod segments 22 and the tie rod segments 24) in the cage truss 12″ of FIG. 11.

[0058] With particular reference to FIG. 14, an alternative configuration of the cage frame, designated 62″, has one or more counterparts of shear panels, designated 64″, in extended lengths and having notches and/or openings therein for clearing the tie rod segments 24 and/or providing passages connecting outer and inner portions of the plastic body 14. In the exemplary configuration of FIG. 14, the shear panel 64″ extends substantially the full length of the cage frame 64, having notches 66 formed along opposite edges thereof for clearing the tie rods 24, and having a spaced plurality of openings 68 that are configured for maintaining shear and transverse compression strength while robustly connecting inner and outer portions of the plastic body and reducing the overall weight of the cage frame 62″.

[0059] With particular reference to FIG. 15, another alternative configuration of the cage frame, designated 62‴, is arranged similarly to the cage truss 12″ of FIG. 8. The cage
frame 62" includes counterparts of the main rod members 16A, 16B, 16C, and 16D, the rod members 16A and 16C being closely spaced, the rod members 16B and 16D being spread apart. A sloping spaced plurality of the shear panels 64A are connected between the main rod members 16A and 16B, and an oppositely sloping spaced plurality of the shear panels 64B are connected between the main rod members 16C and 16D. Also, an additional plurality of shear panels, designated 64C, are rigidly connected between the main rod members 16B and 16D, the shear panels 64C being substituted for the tie rod segments 24 of FIG. 8. Optionally, further shear panels 64D can be vertically oriented and connected between certain ones of the shear panels 64C and the main rod members 16A and 16C as shown in FIG. 15. The shear panels 64C provide augmented resistance to compressive loading of the cushion beam in regions between the main rod members 16B and 16D. As further shown in FIG. 15, the shear panels 64D are extended longitudinally, spanning pluralities of the shear panels 64C, and having counterparts of the openings 68 formed therein for connection of opposite portions of the plastic body 14. It will be understood that the main rod members 16A and 16C are rigidly connected at suitable locations along the cage frame 62", and the connection of the upper edges of the shear panels 64D to the main rod members 16A and 16C also forms corresponding connections between those main rod members. Also, although the plastic body 14 in FIG. 15 is rectangular in cross-section, other shapes, such as that of FIG. 8, are also contemplated.

With further reference to FIGS. 16-19, a further and preferred configuration of the cushion beam, designated 60", includes a counterpart of the cage structure, designated cage frame 62" and described below, and incorporates one or more load-bearing panel members 70 that are formed of materials having higher scuff resistance than those of the plastic body 14. More particularly, the panel members 70 are preferably resilient as defined above, but having higher rigidity as defined above than that of the plastic body 14. A particularly suitable and preferred material for the panel members 70 is ultra-high molecular-weight (UHMW) polymer, whereas the plastic body 14 preferably includes high and low-density polyethylene components, the low-density component forming not less than 50 percent of the plastic body 14, thereby providing the preferred combination of the panel members 70 having relatively high rigidity and the plastic body having relatively lower rigidity. Although these materials are preferred for their combination of load-bearing capacity, cushioning, and scuff resistance, attachment of the panel members 70 presents a problem in that no suitable adhesive has been developed for joining the panel members to the plastic body. Further, it is desired that shear loads borne by the panel members 70 be coupled directly to the cage frame 62". Moreover, it is important in applications wherein fending of moving objects such as ships is contemplated that the panel members 70 present a load-bearing surface that does not have fasteners or the like projecting outwardly therefrom.

While threaded fasteners had been considered for joining the panel members 70 to the frame, an additional problem is that the molding process alters the spacing between different locations of the frame. More particularly, if threaded studs are welded to specific locations on the frame to match a hole spacing of the panel members, there will be significant initial expansion of the frame when the encapsulating plastic is introduced at approximately 450°F. As the plastic cools and hardens at about 350°F, the steel is still significantly extended, causing compressive forces within the plastic body as the combination cools to ambient. As a result, the frame remains somewhat extended, even at ambient temperatures.

It has been discovered that a particularly suitable means for affixing the panel members 70 to the plastic body 14 is a plurality of headed fasteners 72 that directly engage the cage frame 62". More particularly, and as best shown in FIGS. 18 and 19, a preferred form of the cage frame 62" includes one or more attachment members 74 that are affixed at adjustably selected locations along the frame to provide a properly spaced plurality of threaded openings 75 for engagement by respective ones of the fasteners 72. Each of the attachment members 74 has a transversely spaced pair of the threaded openings 75, the distance between those openings being relatively small (typically under eight inches) compared with the length of typical panel members 70 (about four feet). The fasteners 72 project through the panel members 70 and portions of the plastic body 14, the fasteners having head portions 73 that are recessed within respective counterbore cavities 71 of the panels 72. This configuration advantageously facilitates exclusion of corrosive contamination from the frame, the fasteners 72 being preferably formed of corrosion-resistant steel.

As further shown in FIGS. 16-18, the cage frame 62" has the attachment members 74 configured as counterparts of the tie rod segments 24, the attachment members being affixed at suitable intervals along the main rod members 16A (16E and 16G, if present) and 16C, by suitable means, such as welding. Advantageously, the attachment members 24 are located opposite the main rod members 16B and 16D, conveniently for affixing anywhere along the frame according to placement of the panel members 70 with allowances for extension of the frame as a result of the encapsulation process.

The cage frame 62" also includes counterparts of the shear panels 64A and 64B of FIGS. 12 and 13, as well as the shear panels 64C of FIG. 15, the shear panels 64C connecting the main rod members 16F and 16I. Additional shear members 64C also connect the main rod members 16E and 16G. In the exemplary configuration of FIGS. 16-19, the panel members are positioned end-to-end, forming a load-bearing surface 76 that is approximately parallel with the longitudinal axis 19 of the cushion beam 60', substantially co-extensive with one face of the cushion beam 60'. The load-bearing surface 76 has a planar central region 76C and a relatively narrow perimeter region 76F that is formed with a shallow chamfer for protection against chipping by passing objects. In a typically configured example of the cushion beam 60', the panel members can be formed in lengths of approximately four feet, having a width such as one foot to match the width W of the cushion beam, and a thickness of from about two to about four inches. It will be understood that the attachment members 74 can serve as some or all of the shear members 16C connecting the main rod members 16A (16E and 16G, if present) and 16C, particularly when configured in suitable widths. Also, the cage frame 62" can incorporate one or more of the shear panels 64' having extended lengths as described above in
connection with FIG. 14. Alternatively, the cage frame can be configured as a truss as described above in connection with FIGS. 1-3, 7, and 8.

[0065] The cushion beam (as well as the alternatively configured beams 10', 10'', 60, 60', and 60'') of the present invention is immune to marine borer attack, and thus requires no further protection, such as creosote or plastic sheathing, being practically maintenance free. The cushion beam is abrasion resistant, and thus has excellent effectiveness as a marine fender planks without any added protective covering.

[0066] The composite cushion beam is chemically inert, so it can last indefinitely. It does not react with sea water, is corrosion free, is substantially immune to the effects of light, is not bothered by most petroleum products, and is not subject to dry rot. Because it can be made with recycled plastic, it is an environmentally sound investment.

[0067] Although the present invention has been described in considerable detail with reference to certain preferred versions thereof, other versions are possible. For example, the main rods 16 can be formed having a flattened or elongate cross-section that is preferably oriented to facilitate forming the connections with the transverse rod elements 18. Also, the one or more panel members 70 can be concentrated at one end of the cushion beam 60 for use of the beam as a cushioned piling. Therefore, the spirit and scope of the appended claims should not necessarily be limited to the description of the preferred versions contained herein.

What is claimed is:

1. A composite beam having a longitudinal axis and a cross-sectional area of at least 50 square inches, comprising:
   (a) a frame comprising a plurality of interconnected members;
   (b) a resilient plastic body member substantially encapsulating the frame;
   (c) a panel member spaced from the frame, a portion of the resilient body filling space between the panel member and the frame, the panel member forming a load-bearing outside surface portion of the beam; and
   (d) a spaced plurality of fasteners extending through the panel member in recessed relation thereto, through portions of the plastic body, and into engagement with the frame.

2. The composite beam of claim 1, wherein the panel member comprises a resilient material.

3. The composite beam of claim 2, wherein the panel member comprises ultra-high molecular weight (UHMW) polymer.

4. The composite beam of claim 2, wherein the panel member substantially consists of an ultra-high molecular weight (UHMW) polymer.

5. The composite beam of claim 2, wherein the plastic body comprises a resilient material having a first rigidity, the material of the panel member having a second rigidity being greater than the first rigidity.

6. The composite beam of claim 1, further comprising an attachment structure defining a spaced plurality of attachment elements connected to plural spaced apart locations of the frame.

7. The composite beam of claim 6, wherein the attachment structure comprises a plurality of transverse members bonded at spaced locations along the frame, each of the transverse members having at least one receptacle for engagement by a corresponding one of the fasteners.

8. The composite beam of claim 7, wherein at least some of the fasteners are threaded fasteners, the receptacles being threaded openings.

9. The composite beam of claim 1, wherein the frame comprises:
   (a) a plurality of longitudinal main rod members, at least three of the main rod members being spaced laterally in different corresponding directions relative to the longitudinal axis; and
   (b) a plurality of transverse elements, each transverse element being rigidly connected between a spaced pair of the main rod members, at least three of the main rod members being connected to at least two others of the main rod members by at least some of the transverse elements.

10. The composite beam of claim 9, wherein at least some of the transverse elements are shear panels.

11. The composite beam of claim 10, wherein the shear panels comprise laterally spaced first and second sets of longitudinally spaced shear panels, the panels of each set being bonded between a pair of the main rod members.

12. The composite beam of claim 10, wherein at least some of the shear panels have openings and/or notches formed therein, the body member having portions external to the cage frame integrally joined through the openings and/or notches with portions of the body member within the frame for enhanced structural integrity of the body member.

13. The composite beam of claim 9, wherein at least one pair of the main rod members is connected by some of the transverse elements being transverse rod segments such that diverging pairs of the transverse rod segments are connected in proximal relation at spaced intervals along each main rod member of the pair, whereby the pair of main rod members and the diverging pairs of transverse rod segments form a truss.

14. The composite beam of claim 9, wherein the main rod members and the transverse elements are each spaced at least 0.5 inch within an outside contour of the plastic body.

15. The composite beam of claim 9, wherein the main rod members are selected from the group consisting of formed steel reinforcing bars, formed nickel alloy reinforcing bars, fiberglass reinforcing bars, and carbon fiber reinforcing bars.

16. The composite beam of claim 15, wherein at least some of the transverse elements are selected from the group consisting of formed steel reinforcing bars, formed nickel alloy reinforcing bars, fiberglass reinforcing bars, carbon fiber reinforcing bars, plastic dowels, wooden dowels, steel plates, and fiberglass panels.

17. An installed fender assembly comprising a plurality of composite beams according to claim 1.

18. A method for forming a scuff-resistant composite beam, comprising the steps of:
   (a) providing a frame comprising a plurality of interconnected members;
   (b) encapsulating the frame in a plastic body;
(c) providing a one or more scuff-resistant panel members;
(d) providing a plurality of headed fasteners; and
(e) connecting each of the one or more panel members to
the plastic body with at least two of the fasteners
projecting through each panel member in recessed
relation thereto, and through portions of the plastic
body to provide a scuff resistant load bearing surface on
the resulting composite beam.

19. The method of claim 18, wherein the step of connect-
ing further comprises the steps of:
(i) affixing a plurality of attachment members at spaced
locations along the frame; and
(ii) engaging the fasteners with corresponding ones of the
attachment members, thereby anchoring the one or
more panel members to the frame.

20. The method of claim 19, wherein the step of affixing
further comprises the step of positioning the attachment
members at sufficiently greater spacing along the frame to
compensate for thermal extension of the frame at ambient
temperature following the step of encapsulating.