A LIGHTWEIGHT, HIGH-STRENGTH, AND MULTI-PURPOSE LAMINATED BAMBOO LUMBER (LBL) FREIGHT CONTAINER AND MANUFACTURING METHOD THEREOF

TECHNICAL FIELD

[0001] The present invention relates to a lightweight, high-strength, multi-purpose laminated bamboo lumber (LBL) freight container and a manufacturing method thereof, belonging to the field of cargo transportation.

TECHNICAL BACKGROUND

[0002] Steel freight containers possess substantial tare weight. Taking a common 20-foot standard steel freight container as an example, its tare weight reaches approximately 2.3 metric tons. Such tare weight reduces effective payload capacity and increased fuel consumption.

[0003] Steel is susceptible to corrosion and requires periodic maintenance. The steel production process necessitates the consumption of substantial quantities of iron ore, coal, and other resources, while simultaneously generating significant amounts of carbon dioxide, slag, and other pollutants.

[0004] Should lightweight materials such as aluminum alloys be adopted, the costs are relatively high, and certain limitations exist regarding strength and impact resistance, making it difficult to fully satisfy the requirements of the complex operating environments encountered by freight containers.

SUMMARY OF THE INVENTION

[0005] To solve the above-mentioned problems, an object of the present invention is to provide a lightweight, high-strength, multi-purpose laminated bamboo lumber (LBL) freight container

having light dead weight, excellent mechanical properties, a stable structural system, low cost, and suitability for prefabricated production and use.

[0006] Another object of the present invention is to provide a manufacturing method for the lightweight, high-strength, multi-purpose LBL freight container.

[0007] The lightweight, high-strength, multi-purpose LBL freight container and manufacturing method thereof disclosed by the present invention comprises LBL corner posts, LBL side posts, LBL longitudinal side beams, LBL or glass fiber reinforced plastics (GFRP)-steel transverse short beams, LBL or GFRP-steel longitudinal middle beams, corner fitting-GFRP-steel plate-steel sleeve-bolt integrated connections, LBL diagonal braces, GFRP-steel composite square cylinders for forklifts, GFRP-steel sleeve bolt connections, GFRP-steel bolt connections, diagonal T-shaped GFRP-steel filling plate bolt connections, doors, a "K"-shaped structural system, and peripheral plates. A "Mu"-shaped (rectangular grid with two horizontal dividing bars) bottom GFRP-steel-LBL frame structure is formed by two GFRP-steel composite square cylinders for forklifts, two first longitudinal side beams, two second longitudinal side beams, two third longitudinal side beams, and two GFRP-steel transverse short beams. The LBL or GFRP-steel longitudinal middle beams are mounted on the inner side of the bottom GFRP-steel-LBL frame structure by means of GFRP-steel bolt connections. The LBL corner posts are mounted at four corners of the bottom GFRP-steel-LBL frame structure by means of corner fitting-GFRP-steel plate-steel sleeve-bolt integrated connections and GFRP-steel sleeve bolt connections. The LBL side posts are mounted on the outer frame of the bottom GFRP-steel-LBL frame structure by means of GFRP-steel bolt connections.

[0008] Further, the two first longitudinal side beams are symmetrically arranged, the two second longitudinal side beams are symmetrically arranged, and the two third longitudinal side beams are symmetrically arranged. The first longitudinal side beams, the second longitudinal side beams, and the third longitudinal side beams are sequentially arranged to form a broken line. The two GFRP-

steel composite square cylinders for forklifts are placed in parallel and vertically disposed between the two broken lines. The spacing between the two GFRP-steel composite square cylinders for forklifts enables forklift tines to be freely inserted therebetween. The first longitudinal side beams, the second longitudinal side beams, the third longitudinal side beams, and the two GFRP-steel composite square cylinders for forklifts are collinear and lie in a common plane. An end portion of one GFRP-steel composite square cylinder for forklifts is located between the first longitudinal side beam and the second longitudinal side beam, and an end portion of the other GFRP-steel composite square cylinder for forklifts is located between the second longitudinal side beam and the third longitudinal side beam. The first longitudinal side beam, the second longitudinal side beam, and the third longitudinal side beam are connected to the end portions of the GFRP-steel composite square cylinders for forklifts by means of fifth GFRP-steel bolt connections. Notches are formed at both ends of the GFRP-steel transverse short beams to constitute a "Men"-shaped (portal-shaped with two vertical supports and one horizontal top beam) structure. One GFRP-steel transverse short beam is vertically disposed between the two first longitudinal side beams and connected thereto by means of second corner fitting-GFRP-steel plate-steel sleeve-bolt integrated connections. The other GFRP-steel transverse short beam is vertically disposed between the two third longitudinal side beams and connected thereto by means of second corner fitting-GFRP-steel plate-steel sleeve-bolt integrated connections.

[0009] Further, fifth LBL transverse short beams are mounted on the inner side of the outer frame of the bottom GFRP-steel-LBL frame structure in a transverse direction at intervals not exceeding 1.5 meters.

[0010] Further, the LBL or GFRP-steel longitudinal middle beams are equally spaced in a longitudinal direction on the inner side of the outer frame of the bottom GFRP-steel-LBL frame structure, and are connected to the fifth LBL transverse short beams and the GFRP-steel composite square cylinders for forklifts.

[0011] Further, the LBL corner posts comprise two first LBL corner posts at door frame spans and two second LBL corner posts at non-door frame spans. The two first LBL corner posts and the two second LBL corner posts are mounted at four corners of the outer frame of the bottom GFRP-steel-LBL frame structure by means of second corner fitting-GFRP-steel plate-steel sleeve-bolt integrated connections. The centroids of the first LBL corner posts and the second LBL corner posts and the corresponding corner fitting centroids are collinear, or the horizontal projection distance between the two centroids is less than one-fifth of the short side length of the LBL corner posts.

[0012] Further, the LBL side posts comprise a first LBL side post, a second LBL side post, a third LBL side post, a fourth LBL side post, and a fifth LBL side post. The first LBL side post, the second LBL side post, the third LBL side post, the fourth LBL side post, and the fifth LBL side post are mounted on the outer frame edges of the bottom GFRP-steel-LBL frame structure by means of second GFRP-steel bolt connections.

[0013] Further, LBL diagonal braces are mounted between the first longitudinal side beam and the first LBL corner post, and between the first LBL side posts, respectively. The two LBL diagonal braces constitute an inverted "V"-shaped configuration. LBL diagonal braces are mounted between the third longitudinal side beam and the second LBL corner post, and between the fourth LBL side posts, respectively. The two LBL diagonal braces constitute an inverted "V"-shaped configuration. LBL diagonal braces are mounted between the second longitudinal side beam and the second LBL side post, and between the third LBL side posts, respectively. The two LBL diagonal braces constitute an inverted "V"-shaped configuration. If a cargo access door is installed on this side surface, no LBL diagonal brace is installed at this location.

[0014] Further, the "K"-shaped structural system comprises a fifth longitudinal side beam and two LBL diagonal braces disposed on the fifth longitudinal side beam. The fifth longitudinal side beam is disposed directly above the end portions of the GFRP-steel composite square cylinders

for forklifts. Both ends of the fifth longitudinal side beam are supported on the corresponding second longitudinal side beam and first longitudinal side beam, or the first longitudinal side beam is disposed above and connected thereto by means of "T"-shaped or "Gong"-shaped (I-shaped with upper and lower horizontal segments) fourth GFRP-steel bolt connections. Both ends of the two LBL diagonal braces are connected to the corresponding fifth longitudinal side beam and the first LBL side post or the second LBL side post by means of diagonal T-shaped GFRP-steel filling plate bolt connections.

[0015] Further, a second LBL transverse short beam of the LBL or GFRP-steel transverse short beams is connected to tops of the two first LBL corner posts by means of first corner fitting-GFRP-steel plate-steel sleeve-bolt integrated connections. A third LBL transverse short beam of the LBL or GFRP-steel transverse short beams is connected to tops of the two second LBL corner posts by means of first corner fitting-GFRP-steel plate-steel sleeve-bolt integrated connections. The centroids of the first LBL corner posts and the second LBL corner posts and the corresponding corner fitting centroids are collinear, or the horizontal projection distance between the two centroids is less than one-fifth of the short side length of the LBL corner posts. A fourth longitudinal side beam of the LBL longitudinal side beams is connected to tops of the first LBL corner post and the second LBL corner post on the same side by means of first corner fitting-GFRP-steel plate-steel sleeve-bolt integrated connections. A fourth LBL transverse short beam of the LBL or GFRP-steel transverse short beams is connected between the two fourth longitudinal side beams by means of first GFRP-steel bolt connections.

[0016] Further, LBL diagonal braces are connected between the fourth longitudinal side beam and the first LBL corner post, between the fourth longitudinal side beam and the second LBL corner post, and between the fourth longitudinal side beam and the second LBL transverse short beam, respectively, by means of diagonal T-shaped GFRP-steel filling plate bolt connections. LBL diagonal braces are connected between both ends of the third LBL transverse short beam and the

second LBL corner posts by means of diagonal T-shaped GFRP-steel filling plate bolt connections.

[0017] Further, the peripheral plates comprise LBL plates mounted on the bottom GFRP-steel-LBL frame structure, a top LBL plate, a first side LBL plate, and a second side LBL plate mounted on the periphery of the LBL frame structure to form an enclosure structure.

[0018] Further, the doors comprise end doors, side doors, and top doors. The end doors are mounted between the first LBL corner posts. The upper side doors are mounted between the second LBL side posts and the third LBL side posts. The top doors are mounted on the top LBL plate.

[0019] Further, the LBL may be formed from one of bamboo scrimber, bamboo woven plywood, bamboo-plastic composite, bamboo particle composite, bamboo chip profile, engineered wood, ordinary wood, and straw, or may be replaced by a composite of multiple materials selected from LBL, bamboo scrimber, bamboo woven plywood, bamboo-plastic composite, bamboo particle composite, bamboo chip profile, engineered wood, ordinary wood, and straw.

[0020] Further, the GFRP may be formed from one of basalt fiber, carbon fiber, and aramid fiber, or may be replaced by a composite of multiple materials selected from GFRP, basalt fiber, carbon fiber, and aramid fiber. Alternatively, GFRP may be omitted depending on service life requirements.

[0021] Further, the doors are made of a metallic material, or are made of one or more composite materials selected from LBL, bamboo scrimber, bamboo woven plywood, wood, FRP, and straw.

[0022] Further, the LBL longitudinal side beams are made of LBL, or steel, or FRP profiles, or wood, or a composite of two or more materials selected from bamboo, steel, FRP profiles, and wood.

[0023] Further, the two LBL diagonal braces and the fifth longitudinal side beam constitute the "K"-shaped structural system, which may be arranged or omitted depending on the material characteristics of the bottom longitudinal side beams.

[0024] Further, the cargo access doors may be provided at one, two, or three positions selected

from the top, the side, and the end.

[0025] Further, the lightweight, high-strength, multi-purpose LBL freight container may be used as a dwelling.

[0026] Based on the same inventive concept, the present invention further discloses a manufacturing method for the lightweight, high-strength, multi-purpose LBL freight container, comprising the following steps:

[0027] Step 1: Preparing integrated corner fitting-GFRP-steel plate-steel sleeve-bolt integrated connections having end holes, side holes, top holes, or bottom holes. The corner fitting-GFRP-steel plate-steel sleeve-bolt integrated connections are capable of being used for connecting beam structural members, column structural members, and hoisting the LBL freight container. The steel sleeve portions and bolt assemblies of the corner fitting-GFRP-steel plate-steel sleeve-bolt integrated connections are used for end connections of the column structural members. The centroid of the steel sleeve and the centroid of the corner fitting are collinear, or the horizontal projection distance between the two centroids is less than one-fifth of the short side length of the steel sleeve. The steel plates of the corner fitting-GFRP-steel plate-steel sleeve-bolt integrated connections are of a linear or I-shaped configuration. The steel plates together with the bolt assemblies are used for end connections of the beam structural members. Preparing GFRP-steel transverse short beams, wherein both ends of the GFRP-steel transverse short beams are configured as "Men"-shaped structures capable of being used for securing the LBL freight container or enabling forklifts to load and unload the LBL freight container from the end. Preparing GFRP-steel composite square cylinders for forklifts, wherein both side surfaces of the GFRP-steel composite square cylinders for forklifts are provided with square or circular holes having an interval width not less than 40 mm and an interval not less than 80 mm, or are provided without holes.

[0028] Step 2: Preparing LBL longitudinal side beams, LBL or GFRP-steel transverse short

beams, LBL or GFRP-steel longitudinal middle beams, LBL corner posts, LBL side posts, LBL diagonal braces, a top LBL plate, a first side LBL plate, and a second side LBL plate. Bolt or pin connection holes are formed at end portions of the LBL longitudinal side beams, the LBL or GFRP-steel transverse short beams, the LBL or GFRP-steel longitudinal middle beams, the LBL corner posts, the LBL diagonal braces, the top LBL plate, the first side LBL plate, and the second side LBL plate, and at connection portions between adjacent members thereof.

[0029] Step 3: Constructing a "Mu"-shaped bottom GFRP-steel-LBL frame structure composed of two GFRP-steel composite square cylinders for forklifts, LBL longitudinal side beams, and two GFRP-steel transverse short beams. The two GFRP-steel composite square cylinders for forklifts are placed in parallel, and the spacing therebetween enables forklift tines to be freely inserted. First longitudinal side beams, second longitudinal side beams, and third longitudinal side beams are symmetrically disposed at both ends of the two GFRP-steel composite square cylinders for forklifts in a spatially perpendicular positional relationship thereto. The second longitudinal side beam is located between the two GFRP-steel composite square cylinders for forklifts. The first longitudinal side beam and the third longitudinal side beam are respectively located at the other ends of the two GFRP-steel composite square cylinders for forklifts. The first longitudinal side beam, the second longitudinal side beam, and the third longitudinal side beam are connected to the end portions of the GFRP-steel composite square cylinders for forklifts by means of fifth GFRP-steel bolt connections. The first longitudinal side beam, the second longitudinal side beam, the third longitudinal side beam, and the two GFRP-steel composite square cylinders for forklifts are collinear and lie in a common plane. One GFRP-steel transverse short beam is vertically disposed between the two first longitudinal side beams, and the other GFRP-steel transverse short beam is vertically disposed between the two third longitudinal side beams. The first longitudinal side beams, the third longitudinal side beams, and the "Men"-shaped GFRP-steel transverse short beams are connected by means of second corner fitting-GFRP-steel plate-steel sleeve-bolt

integrated connections to form a "Square"-shaped outer frame of the bottom GFRP-steel-LBL frame structure. Fifth LBL transverse short beams are mounted on the inner side of the "Square" outer frame in a transverse direction at intervals not exceeding 1.5 meters. LBL or GFRP-steel longitudinal middle beams are mounted on the inner side of the "Square" outer frame in a longitudinal direction in an equally divided form, and are connected to the fifth LBL transverse short beams and the GFRP-steel composite square cylinders for forklifts.

[0030] Step 4: Assembling peripheral LBL corner posts and LBL side posts. The first LBL corner posts at door frame spans and the second LBL corner posts at non-door frame spans are mounted at four corners of the outer frame of the bottom GFRP-steel-LBL frame structure by means of second corner fitting-GFRP-steel plate-steel sleeve-bolt integrated connections. The centroids of the first LBL corner posts and the second LBL corner posts and the corresponding corner fitting centroids are collinear, or the horizontal projection distance between the two centroids is less than one-fifth of the short side length of the LBL corner posts. The first LBL side post, the second LBL side post, the third LBL side post, the fourth LBL side post, and the fifth LBL side post are mounted on the outer frame edges of the bottom GFRP-steel-LBL frame structure by means of second GFRP-steel bolt connections. LBL diagonal braces are mounted between the first longitudinal side beam and the first LBL corner post, and between the first LBL side posts, respectively. The two LBL diagonal braces constitute an inverted "V"-shaped configuration. LBL diagonal braces are mounted between the third longitudinal side beam and the second LBL corner post, and between the fourth LBL side posts, respectively. The two LBL diagonal braces constitute an inverted "V"-shaped configuration. LBL diagonal braces are mounted between the second longitudinal side beam and the second LBL side post, and between the third LBL side posts, respectively. The two LBL diagonal braces constitute an inverted "V"-shaped configuration. If a cargo access door is installed on this side surface, no LBL diagonal brace is installed at this location. A fifth longitudinal side beam is disposed directly above the end

portions of the GFRP-steel composite square cylinders for forklifts. Both ends of the fifth longitudinal side beam are supported on the corresponding second longitudinal side beam and first longitudinal side beam, or the first longitudinal side beam is disposed above and connected thereto by means of "T"-shaped or "Gong"-shaped fourth GFRP-steel bolt connections. Two LBL diagonal braces are disposed on the fifth longitudinal side beam to constitute the "K"-shaped structural system. Both ends of the two LBL diagonal braces are connected to the corresponding fifth longitudinal side beam and the first LBL side post or the second LBL side post by means of diagonal T-shaped GFRP-steel filling plate bolt connections.

[0031] Step 5: Assembling a top LBL frame structure. The second LBL transverse short beam and the fourth longitudinal side beam are connected to tops of the first LBL corner posts by means of first corner fitting-GFRP-steel plate-steel sleeve-bolt integrated connections. The third LBL transverse short beam and the fourth longitudinal side beam are connected to tops of the second LBL corner posts by means of first corner fitting-GFRP-steel plate-steel sleeve-bolt integrated connections. The centroids of the first LBL corner posts and the second LBL corner posts and the corresponding corner fitting centroids are collinear, or the horizontal projection distance between the two centroids is less than one-fifth of the short side length of the LBL corner posts. The fourth longitudinal side beam and the third LBL transverse short beam are connected to tops of the LBL side posts by means of second GFRP-steel bolt connections. LBL diagonal braces are installed between the fourth longitudinal side beam and the first LBL corner post, between the fourth longitudinal side beam and the second LBL corner post, and between the fourth longitudinal side beam and the second LBL transverse short beam, respectively, by means of diagonal T-shaped GFRP-steel filling plate bolt connections. LBL diagonal braces are connected between both ends of the third LBL transverse short beam and the second LBL corner posts by means of diagonal T-shaped GFRP-steel filling plate bolt connections. The fourth LBL transverse short beam is connected between the two fourth longitudinal side beams by means of first GFRP-steel bolt

connections.

[0032] Step 6: Assembling an enclosure structure. LBL plates are mounted on the bottom GFRP-steel-LBL frame structure. Double-leaf end doors are installed between the two first LBL corner posts. Side doors are installed between the second LBL side posts and the third LBL side posts. The top LBL plate, the first side LBL plate, and the second side LBL plate are mounted on the periphery of the LBL frame structure to form the enclosure structure. Anti-corrosion, anti-mold, and anti-ultraviolet treatments are applied to the LBL.

[0033] Further, in Step 4, the two LBL diagonal braces and the fifth longitudinal side beam constituting the "K"-shaped structural system may be selectively installed or omitted.

[0034] Further, in Step 6, the anti-corrosion, anti-mold, and anti-ultraviolet treatments comprise the following steps: applying an organosilicon-polyurethane composite superhydrophobic coating to surfaces of the LBL. The coating is formed by hybridizing polydimethylsiloxane (PDMS)-modified polyurethane (PU) with nano-silica (SiO_2). Through synergistic action of micro-nano hierarchical rough structures and low-surface-energy siloxane groups, a superhydrophobic interface having a static water contact angle (WCA) $\geq 150°$ and a sliding angle (SA) $\leq 10°$ is formed. Meanwhile, resorcinol-formaldehyde resin (RF) is embedded to fill micropore defects, thereby inhibiting microbial attachment and penetration of corrosive media. By means of a spraying process, the anti-corrosion, anti-mold, and anti-ultraviolet treatments are performed to construct a high-performance protective coating on surfaces of the LBL. The coating employs PDMS-modified polyurethane (PDMS-PU) as a matrix, and is modified by adding nano-silica (SiO_2) modified by a silane coupling agent (such as KH-570) and resorcinol-formaldehyde resin (RF) to form a composite coating having unique properties. By precisely controlling proportions of each component, the coating performance is optimized. In the PDMS-PU, the polydimethylsiloxane (PDMS) and polyurethane (PU) are regulated according to soft segment grafting ratios. The modified SiO_2 nanoparticles (content 5%-10%) and RF resin are mixed at a

mass ratio of 8:1:1 to ensure multifunctional performance of the coating. An appropriate amount of modified SiO_2 is added to enhance construction of the micro-nano hierarchical rough structure of the coating. The RF resin is embedded in the coating to fill micropore defects, forming a chemical barrier. The coating possesses excellent comprehensive characteristics: superior superhydrophobic performance, strong mechanical durability, good chemical stability, mold inhibition and bacteriostatic capability, and strong environmental adaptability. The coating can effectively address corrosion, mildew, and biological attachment problems of the freight container under humid, salt spray, and biologically contaminated environments. The organosilicon-polyurethane composite superhydrophobic coating possesses superhydrophobic, anti-corrosion, anti-mold, and anti-ultraviolet properties, and can achieve anti-biofouling and self-cleaning functions.

[0035] Advantageous effects of the present invention: The present invention employs LBL as structural material, thereby enabling the freight container to possess characteristics of light dead weight, high strength, structural safety and reliability, corrosion resistance, impact resistance, fatigue resistance, and freeze-thaw resistance, while reducing the use of mineral materials such as steel and aluminum alloys, thereby being more low-carbon and environmentally friendly. The freight container of the present invention can be loaded and unloaded both by hoisting and by forklifts. The freight container of the present invention is provided with both side doors and top swing doors, thereby achieving high loading efficiency, and satisfying loading and unloading requirements for different cargoes. Compared with metal freight containers of the same dimensions, the freight container of the present invention can achieve a dead weight reduction of more than 20%. The LBL frame freight container has a service life of 8 - 10 years without requiring large-scale anti-corrosion treatment, and maintenance costs can be reduced by more than 50%. Meanwhile, bamboo can absorb substantial quantities of carbon dioxide during its growth process, and carbon emissions during its processing are also relatively low, thereby contributing to the

achievement of low-carbon and environmentally friendly objectives in the freight container industry.

DESCRIPTION OF THE DRAWINGS

[0036] FIG. 1 is a schematic structural diagram of the present invention;

[0037] FIG. 2 is a schematic structural diagram of the present invention with end doors only installed;

[0038] FIG. 3 is a schematic structural diagram of the present invention with end doors, side doors, and top doors simultaneously installed;

[0039] FIG. 4 is a schematic structural diagram of the present invention with peripheral plates removed and the "K"-shaped structural system arranged;

[0040] FIG. 5 is a schematic structural diagram of the present invention with peripheral plates removed and the "K"-shaped structural system omitted;

[0041] FIG. 6 is a schematic structural diagram of the "K"-shaped structural system of the present invention;

[0042] FIG. 7 is a schematic structural diagram of the first corner fitting-GFRP-steel plate-steel sleeve-bolt integrated connection of the present invention;

[0043] FIG. 8 is a schematic structural diagram of the second corner fitting-GFRP-steel plate-steel sleeve-bolt integrated connection of the present invention;

[0044] FIG. 9 is a schematic structural diagram of the diagonal T-shaped GFRP-steel filling plate bolt connection of the present invention;

[0045] FIG. 10 is a schematic structural diagram of the fourth GFRP-steel bolt connection of the present invention;

[0046] Figure labels: 1 denotes LBL corner posts; 1-1 denotes first LBL corner posts; 1-2 denotes second LBL corner posts; 2 denotes LBL side posts; 2-1 denotes a first LBL side post; 2-

2 denotes a second LBL side post; 2-3 denotes a third LBL side post; 2-4 denotes a fourth LBL side post; 2-5 denotes a fifth LBL side post; 3 denotes LBL longitudinal side beams; 3-1 denotes a first longitudinal side beam; 3-2 denotes a second longitudinal side beam; 3-3 denotes a third longitudinal side beam; 3-4 denotes a fourth longitudinal side beam; 3-5 denotes a fifth longitudinal side beam; 4 denotes LBL or GFRP-steel transverse short beams; 4-1 denotes GFRP-steel transverse short beams; 4-2 denotes a second LBL transverse short beam; 4-3 denotes a third LBL transverse short beam; 4-4 denotes a fourth LBL transverse short beam; 4-5 denotes a fifth LBL transverse short beam; 5 denotes LBL or GFRP-steel longitudinal middle beams; 5-1 denotes a first LBL or GFRP-steel longitudinal middle beam; 5-2 denotes a second LBL or GFRP-steel longitudinal middle beam; 5-3 denotes a third LBL or GFRP-steel longitudinal middle beam; 6 denotes corner fitting-GFRP-steel plate-steel sleeve-bolt integrated connections; 6-1 denotes a first corner fitting-GFRP-steel plate-steel sleeve-bolt integrated connection; 6-2 denotes a second corner fitting-GFRP-steel plate-steel sleeve-bolt integrated connection; 7 denotes LBL diagonal braces; 8 denotes GFRP-steel composite square cylinders for forklifts; 9 denotes GFRP-steel sleeve bolt connections; 9-1 denotes column-top GFRP-steel sleeve bolt connections; 9-2 denotes column-bottom GFRP-steel sleeve bolt connections; 10 denotes GFRP-steel bolt connections; 10-1 denotes a first GFRP-steel bolt connection; 10-2 denotes a second GFRP-steel bolt connection; 10-3 denotes a third GFRP-steel bolt connection; 10-4 denotes a fourth GFRP-steel bolt connection; 10-5 denotes a fifth GFRP-steel bolt connection; 11 denotes diagonal T-shaped GFRP-steel filling plate bolt connections; 13 denotes doors; 13-1 denotes end doors; 13-2 denotes side doors; 13-3 denotes top doors; 14 denotes bottom LBL plates; 15 denotes a top LBL plate; 16 denotes a first side LBL plate; 17 denotes a second side LBL plate.

DETAILED DESCRIPTIONS OF THE EMBODIMENTS

[0047] The specific embodiments of the present invention are described in further detail below

with reference to the accompanying drawings.

[0048] Embodiment 1

[0049] A lightweight, high-strength, multi-purpose laminated bamboo lumber (LBL) freight container disclosed by the present invention is shown in FIGS. 1-10. The freight container comprises LBL corner posts 1, LBL side posts 2, LBL longitudinal side beams 3, LBL or glass fiber reinforced plastics (GFRP)-steel transverse short beams 4, LBL or GFRP-steel longitudinal middle beams 5, corner fitting-GFRP-steel plate-steel sleeve-bolt integrated connections 6, LBL diagonal braces 7, GFRP-steel composite square cylinders for forklifts 8, GFRP-steel sleeve bolt connections 9, GFRP-steel bolt connections 10, diagonal T-shaped GFRP-steel filling plate bolt connections 11, doors 13, a "K"-shaped structural system, and peripheral plates. A "Mu"-shaped bottom GFRP-steel-LBL frame structure is formed by two GFRP-steel composite square cylinders for forklifts 8, two first longitudinal side beams 3-1, two second longitudinal side beams 3-2, two third longitudinal side beams 3-3, and two GFRP-steel transverse short beams 4-1. The LBL or GFRP-steel longitudinal middle beams 5 are mounted on the inner side of the bottom GFRP-steel-LBL frame structure by means of GFRP-steel bolt connections 10. The LBL corner posts 1 are mounted at four corners of the bottom GFRP-steel-LBL frame structure by means of corner fitting-GFRP-steel plate-steel sleeve-bolt integrated connections 6 and GFRP-steel sleeve bolt connections 9. The LBL side posts 2 are mounted on the outer frame of the bottom GFRP-steel-LBL frame structure by means of GFRP-steel bolt connections 10. Preferably, the bottom LBL longitudinal side beams 3 are made of LBL, or steel, or FRP profiles, or wood, or a composite of two or more materials selected from bamboo, steel, FRP profiles, and wood.

[0050] The two first longitudinal side beams 3-1 are symmetrically arranged, the two second longitudinal side beams 3-2 are symmetrically arranged, and the two third longitudinal side beams 3-3 are symmetrically arranged. The first longitudinal side beams 3-1, the second longitudinal side beams 3-2, and the third longitudinal side beams 3-3 are sequentially arranged to form a broken

line. The two GFRP-steel composite square cylinders for forklifts 8 are placed in parallel and vertically disposed between the two broken lines. The spacing between the two GFRP-steel composite square cylinders for forklifts 8 enables forklift tines to be freely inserted therebetween. The first longitudinal side beams 3-1, the second longitudinal side beams 3-2, the third longitudinal side beams 3-3, and the two GFRP-steel composite square cylinders for forklifts 8 are collinear and lie in a common plane. An end portion of one GFRP-steel composite square cylinder for forklifts 8 is located between the first longitudinal side beam 3-1 and the second longitudinal side beam 3-2, and an end portion of the other GFRP-steel composite square cylinder for forklifts 8 is located between the second longitudinal side beam 3-2 and the third longitudinal side beam 3-3. The first longitudinal side beam 3-1, the second longitudinal side beam 3-2, and the third longitudinal side beam 3-3 are connected to the end portions of the GFRP-steel composite square cylinders for forklifts 8 by means of fifth GFRP-steel bolt connections 10-5. Notches are formed at both ends of the GFRP-steel transverse short beams 4-1 to constitute a "Men"-shaped structure. One GFRP-steel transverse short beam 4-1 is vertically disposed between the two first longitudinal side beams 3-1 and connected thereto by means of second corner fitting-GFRP-steel plate-steel sleeve-bolt integrated connections 6-2. The other GFRP-steel transverse short beam 4-1 is vertically disposed between the two third longitudinal side beams 3-3 and connected thereto by means of second corner fitting-GFRP-steel plate-steel sleeve-bolt integrated connections 6-2.

[0051] Fifth LBL transverse short beams 4-5 are mounted on the inner side of the outer frame of the bottom GFRP-steel-LBL frame structure in a transverse direction at intervals not exceeding 1.5 meters.

[0052] The LBL or GFRP-steel longitudinal middle beams 5 are equally spaced in a longitudinal direction on the inner side of the outer frame of the bottom GFRP-steel-LBL frame structure, and are connected to the fifth LBL transverse short beams 4-5 and the GFRP-steel composite square cylinders for forklifts 8. A first LBL or GFRP-steel longitudinal middle beam 5-1 of the LBL or

GFRP-steel longitudinal middle beams 5 is mounted between the GFRP-steel transverse short beam 4-1 and the fifth LBL transverse short beam 4-5, or between two fifth LBL transverse short beams 4-5. A second LBL or GFRP-steel longitudinal middle beam 5-2 of the LBL or GFRP-steel longitudinal middle beams 5 is mounted between the fifth LBL transverse short beam 4-5 and the GFRP-steel composite square cylinder for forklifts 8. A third LBL or GFRP-steel longitudinal middle beam 5-3 of the LBL or GFRP-steel longitudinal middle beams 5 is mounted between the fifth LBL transverse short beam 4-5 and the GFRP-steel composite square cylinder for forklifts 8.

[0053] The LBL corner posts 1 comprise two first LBL corner posts 1-1 at door frame spans and two second LBL corner posts 1-2 at non-door frame spans. The two first LBL corner posts 1-1 and the two second LBL corner posts 1-2 are mounted at four corners of the outer frame of the bottom GFRP-steel-LBL frame structure by means of second corner fitting-GFRP-steel plate-steel sleeve-bolt integrated connections 6-2. The centroids of the first LBL corner posts 1-1 and the second LBL corner posts 1-2 and the corresponding corner fitting centroids are collinear, or the horizontal projection distance between the two centroids is less than one-fifth of the short side length of the LBL corner posts 1.

[0054] The LBL side posts 2 comprise a first LBL side post 2-1, a second LBL side post 2-2, a third LBL side post 2-3, a fourth LBL side post 2-4, and a fifth LBL side post 2-5. The first LBL side post 2-1, the second LBL side post 2-2, the third LBL side post 2-3, the fourth LBL side post 2-4, and the fifth LBL side post 2-5 are mounted on the outer frame edges of the bottom GFRP-steel-LBL frame structure by means of second GFRP-steel bolt connections 10-2.

[0055] LBL diagonal braces 7 are mounted between the first longitudinal side beam 3-1 and the first LBL corner post 1-1, and between the first LBL side posts 2-1, respectively. The two LBL diagonal braces 7 constitute an inverted "V"-shaped configuration. LBL diagonal braces 7 are mounted between the third longitudinal side beam 3-3 and the second LBL corner post 1-2, and between the fourth LBL side posts 2-4, respectively. The two LBL diagonal braces 7 constitute an

inverted "V"-shaped configuration. LBL diagonal braces 7 are mounted between the second longitudinal side beam 3-2 and the second LBL side post 2-2, and between the third LBL side posts 2-3, respectively. The two LBL diagonal braces 7 constitute an inverted "V"-shaped configuration. If a cargo access door 13 is installed on this side surface, no LBL diagonal brace 7 is installed at this location.

[0056] The "K"-shaped structural system comprises a fifth longitudinal side beam 3-5 and two LBL diagonal braces 7 disposed on the fifth longitudinal side beam 3-5. The fifth longitudinal side beam 3-5 is disposed directly above the end portions of the GFRP-steel composite square cylinders for forklifts 8. Both ends of the fifth longitudinal side beam 3-5 are supported on the corresponding second longitudinal side beam 3-2 and first longitudinal side beam 3-1, or the first longitudinal side beam 3-1 is disposed above and connected thereto by means of "T"-shaped or "Gong"-shaped fourth GFRP-steel bolt connections 10-4. Both ends of the two LBL diagonal braces 7 are connected to the corresponding fifth longitudinal side beam 3-5 and the first LBL side post 2-1 or the second LBL side post 2-2 by means of diagonal T-shaped GFRP-steel filling plate bolt connections 11. Preferably, as shown in FIGS. 4 and 5, the two LBL diagonal braces 7 and the fifth longitudinal side beam 3-5 constitute the "K"-shaped structural system, which may be arranged or omitted depending on the material characteristics of the bottom longitudinal side beams.

[0057] A second LBL transverse short beam 4-2 of the LBL or GFRP-steel transverse short beams 4 is connected to tops of the two first LBL corner posts 1-1 by means of first corner fitting-GFRP-steel plate-steel sleeve-bolt integrated connections 6-1. A third LBL transverse short beam 4-3 of the LBL or GFRP-steel transverse short beams 4 is connected to tops of the two second LBL corner posts 1-2 by means of first corner fitting-GFRP-steel plate-steel sleeve-bolt integrated connections 6-1. The centroids of the first LBL corner posts 1-1 and the second LBL corner posts 1-2 and the corresponding corner fitting centroids are collinear, or the horizontal projection distance between the two centroids is less than one-fifth of the short side length of the LBL corner

posts 1. A fourth longitudinal side beam 3-4 of the LBL longitudinal side beams 3 is connected to tops of the first LBL corner post 1-1 and the second LBL corner post 1-2 on the same side by means of first corner fitting-GFRP-steel plate-steel sleeve-bolt integrated connections 6-1. A fourth LBL transverse short beam 4-4 of the LBL or GFRP-steel transverse short beams 4 is connected between the two fourth longitudinal side beams 3-4 by means of first GFRP-steel bolt connections 10-1.

[0058] LBL diagonal braces 7 are connected between the fourth longitudinal side beam 3-4 and the first LBL corner post 1-1, between the fourth longitudinal side beam 3-4 and the second LBL corner post 1-2, and between the fourth longitudinal side beam 3-4 and the second LBL transverse short beam 4-2, respectively, by means of diagonal T-shaped GFRP-steel filling plate bolt connections 11. LBL diagonal braces 7 are connected between both ends of the third LBL transverse short beam 4-3 and the second LBL corner posts 1-2 by means of diagonal T-shaped GFRP-steel filling plate bolt connections 11.

[0059] The peripheral plates comprise bottom LBL plates 14 mounted on the bottom GFRP-steel-LBL frame structure, a top LBL plate 15, a first side LBL plate 16, and a second side LBL plate 17 mounted on the periphery of the LBL frame structure to form an enclosure structure.

[0060] The doors comprise end doors 13-1, side doors 13-2, and top doors 13-3. The end doors 13-1 are mounted between the first LBL corner posts 1-1. The upper side doors 13-2 are mounted between the second LBL side posts 2-2 and the third LBL side posts 2-3. The top doors 13-3 are mounted on the top LBL plate 15. In actual use, one or more end doors 13-1, side doors 13-2, and top doors 13-3 may be selectively installed according to usage requirements. That is, the doors 13 may be provided at one, two, or three positions selected from the top, the side, and the end. Preferably, the doors 13 are made of a metallic material, or are made of one or more composite materials selected from LBL, bamboo scrimber, bamboo woven plywood, wood, FRP, and straw.

[0061] Preferably, the LBL in the present invention may also be replaced by one of bamboo

scrimber, bamboo woven plywood, bamboo-plastic composite, bamboo particle composite, bamboo chip profile, engineered wood, ordinary wood, and straw, or may be replaced by a composite of multiple materials selected from LBL, bamboo scrimber, bamboo woven plywood, bamboo-plastic composite, bamboo particle composite, bamboo chip profile, engineered wood, ordinary wood, and straw.

[0062] Preferably, the GFRP in the present invention may be formed from one of basalt fiber, carbon fiber, and aramid fiber, or may be replaced by a composite of multiple materials selected from GFRP, basalt fiber, carbon fiber, and aramid fiber. If a relatively long service life is not required in actual use, GFRP may also be omitted.

[0063] Preferably, the number and arrangement of the LBL diagonal braces 7 in the present invention may be increased or decreased according to weight allowance and service conditions.

[0064] Preferably, the lightweight, high-strength, multi-purpose LBL freight container of the present invention may also be used as a dwelling.

[0065] The lightweight, high-strength, multi-purpose LBL freight container of the present invention possesses the advantages of light dead weight and high strength, excellent mechanical properties, a stable structural system, resource conservation, environmental protection, and suitability for prefabricated production and use.

[0066] Embodiment 2

[0067] Embodiment 2 differs from Embodiment 1 primarily in that only end doors 13-1 are provided, as shown in FIG. 2.

[0068] Embodiment 3

[0069] Embodiment 3 differs from Embodiment 1 primarily in that end doors 13-1, side doors 13-2, and top doors 13-3 are simultaneously provided, as shown in FIG. 3.

[0070] Embodiment 4

[0071] A manufacturing method for a lightweight, high-strength, multi-purpose LBL freight

container disclosed by the present invention comprises the following steps:

[0072] Step 1: Preparing integrated corner fitting-GFRP-steel plate-steel sleeve-bolt integrated connections 6 having end holes, side holes, top holes, or bottom holes. The corner fitting-GFRP-steel plate-steel sleeve-bolt integrated connections 6 are capable of being used for connecting beam structural members, column structural members, and hoisting the LBL freight container. The steel sleeve portions and bolt assemblies of the corner fitting-GFRP-steel plate-steel sleeve-bolt integrated connections 6 are used for end connections of the column structural members. The centroid of the steel sleeve and the centroid of the corner fitting are collinear, or the horizontal projection distance between the two centroids is less than one-fifth of the short side length of the steel sleeve. The steel plates of the corner fitting-GFRP-steel plate-steel sleeve-bolt integrated connections 6 are of a linear or I-shaped configuration. The steel plates together with the bolt assemblies are used for end connections of the beam structural members. Preparing GFRP-steel transverse short beams 4-1, wherein both ends of the GFRP-steel transverse short beams 4-1 are configured as "Men"-shaped structures capable of being used for securing the LBL freight container or enabling forklifts to load and unload the LBL freight container from the end face. Preparing GFRP-steel composite square cylinders for forklifts 8, wherein both side surfaces of the GFRP-steel composite square cylinders for forklifts 8 are provided with square or circular holes having an interval width not less than 40 mm and an interval not less than 80 mm, or are provided without holes.

[0073] Step 2: Preparing LBL longitudinal side beams 3, LBL or GFRP-steel transverse short beams 4, LBL or GFRP-steel longitudinal middle beams 5, LBL corner posts 1, LBL side posts 2, LBL diagonal braces 7, a top LBL plate 15, a first side LBL plate 16, and a second side LBL plate 17. Bolt or pin connection holes are formed at end portions of the LBL longitudinal side beams 3, the LBL or GFRP-steel transverse short beams 4, the LBL or GFRP-steel longitudinal middle beams 5, the LBL corner posts 1, the LBL diagonal braces 7, the top LBL plate 15, the first side

LBL plate 16, and the second side LBL plate 17, and at connection portions between adjacent members thereof.

[0074] Step 3: Constructing a "Mu"-shaped bottom GFRP-steel-LBL frame structure composed of two GFRP-steel composite square cylinders for forklifts 8, LBL longitudinal side beams 3, and two GFRP-steel transverse short beams 4-1. The two GFRP-steel composite square cylinders for forklifts 8 are placed in parallel, and the spacing therebetween enables forklift tines to be freely inserted. First longitudinal side beams 3-1, second longitudinal side beams 3-2, and third longitudinal side beams 3-3 are symmetrically disposed at both ends of the two GFRP-steel composite square cylinders for forklifts 8 in a spatially perpendicular positional relationship thereto. The second longitudinal side beam 3-2 is located between the two GFRP-steel composite square cylinders for forklifts 8. The first longitudinal side beam 3-1 and the third longitudinal side beam 3-3 are respectively located at the other ends of the two GFRP-steel composite square cylinders for forklifts 8. The first longitudinal side beam 3-1, the second longitudinal side beam 3-2, and the third longitudinal side beam 3-3 are connected to the end portions of the GFRP-steel composite square cylinders for forklifts 8 by means of fifth GFRP-steel bolt connections 10-5. The first longitudinal side beam 3-1, the second longitudinal side beam 3-2, the third longitudinal side beam 3-3, and the two GFRP-steel composite square cylinders for forklifts 8 are collinear and lie in a common plane. One GFRP-steel transverse short beam 4-1 is vertically disposed between the two first longitudinal side beams 3-1, and the other GFRP-steel transverse short beam 4-1 is vertically disposed between the two third longitudinal side beams 3-3. The first longitudinal side beams 3-1, the third longitudinal side beams 3-3, and the "Men"-shaped GFRP-steel transverse short beams 4-1 are connected by means of second corner fitting-GFRP-steel plate-steel sleeve-bolt integrated connections 6-2 to form a "Square"-shaped outer frame of the bottom GFRP-steel-LBL frame structure. Fifth LBL transverse short beams 4-5 are mounted on the inner side of the "Square" outer frame in a transverse direction at intervals not exceeding 1.5 meters. LBL or GFRP-

steel longitudinal middle beams 5 are mounted on the inner side of the "Square" outer frame in a longitudinal direction in an equally divided form, and are connected to the fifth LBL transverse short beams 4-5 and the GFRP-steel composite square cylinders for forklifts 8.

[0075] Step 4: Assembling peripheral LBL corner posts 1 and LBL side posts 2. The first LBL corner posts 1-1 at door frame spans and the second LBL corner posts 1-2 at non-door frame spans are mounted at four corners of the outer frame of the bottom GFRP-steel-LBL frame structure by means of second corner fitting-GFRP-steel plate-steel sleeve-bolt integrated connections 6-2. The centroids of the first LBL corner posts 1-1 and the second LBL corner posts 1-2 and the corresponding corner fitting centroids are collinear, or the horizontal projection distance between the two centroids is less than one-fifth of the short side length of the LBL corner posts 1. The first LBL side post 2-1, the second LBL side post 2-2, the third LBL side post 2-3, the fourth LBL side post 2-4, and the fifth LBL side post 2-5 are mounted on the outer frame edges of the bottom GFRP-steel-LBL frame structure by means of second GFRP-steel bolt connections 10-2. LBL diagonal braces 7 are mounted between the first longitudinal side beam 3-1 and the first LBL corner post 1-1, and between the first LBL side posts 2-1, respectively. The two LBL diagonal braces 7 constitute an inverted "V"-shaped configuration. LBL diagonal braces 7 are mounted between the third longitudinal side beam 3-3 and the second LBL corner post 1-2, and between the fourth LBL side posts 2-4, respectively. The two LBL diagonal braces 7 constitute an inverted "V"-shaped configuration. LBL diagonal braces 7 are mounted between the second longitudinal side beam 3-2 and the second LBL side post 2-2, and between the third LBL side posts 2-3, respectively. The two LBL diagonal braces 7 constitute an inverted "V"-shaped configuration. If a cargo access door 13 is installed on this side surface, no LBL diagonal brace 7 is installed at this location. A fifth longitudinal side beam 3-5 is disposed directly above the end portions of the GFRP-steel composite square cylinders for forklifts 8. Both ends of the fifth longitudinal side beam 3-5 are supported on the corresponding second longitudinal side beam 3-2 and first longitudinal side beam

3-1, or the first longitudinal side beam 3-1 is disposed above and connected thereto by means of "T"-shaped or "Gong"-shaped fourth GFRP-steel bolt connections 10-4. Two LBL diagonal braces 7 are disposed on the fifth longitudinal side beam 3-5 to constitute the "K"-shaped structural system. Both ends of the two LBL diagonal braces 7 are connected to the corresponding fifth longitudinal side beam 3-5 and the first LBL side post 2-1 or the second LBL side post 2-2 by means of diagonal T-shaped GFRP-steel filling plate bolt connections 11.

[0076] Step 5: Assembling a top LBL frame structure. The second LBL transverse short beam 4-2 and the fourth longitudinal side beam 3-4 are connected to tops of the first LBL corner posts 1-1 by means of first corner fitting-GFRP-steel plate-steel sleeve-bolt integrated connections 6-1. The third LBL transverse short beam 4-3 and the fourth longitudinal side beam 3-4 are connected to tops of the second LBL corner posts 1-2 by means of first corner fitting-GFRP-steel plate-steel sleeve-bolt integrated connections 6-1. The centroids of the first LBL corner posts 1-1 and the second LBL corner posts 1-2 and the corresponding corner fitting centroids are collinear, or the horizontal projection distance between the two centroids is less than one-fifth of the short side length of the LBL corner posts 1. The fourth longitudinal side beam 3-4 and the third LBL transverse short beam 4-3 are connected to tops of the LBL side posts 2 by means of second GFRP-steel bolt connections 10-2. LBL diagonal braces 7 are installed between the fourth longitudinal side beam 3-4 and the first LBL corner post 1-1, between the fourth longitudinal side beam 3-4 and the second LBL corner post 1-2, and between the fourth longitudinal side beam 3-4 and the second LBL transverse short beam 4-2, respectively, by means of diagonal T-shaped GFRP-steel filling plate bolt connections 11. LBL diagonal braces 7 are connected between both ends of the third LBL transverse short beam 4-3 and the second LBL corner posts 1-2 by means of diagonal T-shaped GFRP-steel filling plate bolt connections 11. The fourth LBL transverse short beam 4-4 is connected between the two fourth longitudinal side beams 3-4 by means of first GFRP-steel bolt connections 10-1.

[0077] Step 6: Assembling an enclosure structure. Bottom LBL plates 14 are mounted on the bottom GFRP-steel-LBL frame structure. Double-leaf end doors 13-1 are installed between the two first LBL corner posts 1-1. Side doors 13-2 are installed between the second LBL side posts 2-2 and the third LBL side posts 2-3. The top LBL plate 15, the first side LBL plate 16, and the second side LBL plate 17 are mounted on the periphery of the LBL frame structure to form the enclosure structure. Anti-corrosion, anti-mold, and anti-ultraviolet treatments are applied to the LBL.

[0078] The two LBL diagonal braces 7 and the fifth longitudinal side beam 3-5 constituting the "K"-shaped structural system in Step 4 may be selectively installed or omitted.

[0079] The anti-corrosion, anti-mold, and anti-ultraviolet treatments in Step 6 comprise the following steps: applying an organosilicon-polyurethane composite superhydrophobic coating to surfaces of the LBL. The coating is formed by hybridizing polydimethylsiloxane (PDMS)-modified polyurethane (PU) with nano-silica (SiO_2). Through synergistic action of micro-nano hierarchical rough structures and low-surface-energy siloxane groups, a superhydrophobic interface having a static water contact angle (WCA) $\geq 150°$ and a sliding angle (SA) $\leq 10°$ is formed. Meanwhile, resorcinol-formaldehyde resin (RF) is embedded to fill micropore defects, thereby inhibiting microbial attachment and penetration of corrosive media.

[0080] Preferably, a high-performance protective coating, namely the organosilicon-polyurethane composite superhydrophobic coating, is constructed on surfaces of the LBL by means of a spraying process. Strictly in accordance with the formulation, polydimethylsiloxane-modified polyurethane (PDMS-PU) prepolymer, KH-570-modified nano-silica (SiO_2) particles, resorcinol-formaldehyde resin (RF), and other primary raw materials, as well as ethyl acetate solvent, are accurately weighed. Prior to coating operations, surfaces of the LBL are lightly sanded along the bamboo grain direction using sandpaper to remove burrs and grease, and then wiped clean with ethanol to ensure a surface roughness Ra = 1.5-2.0 μm, a cleanliness $\geq 95\%$, and

complete dryness, thereby providing an ideal substrate for coating adhesion. An F2-type spray gun is selected for spraying operations. Prior to spraying, the spray gun pressure is adjusted to 0.5 MPa, the distance between the nozzle and the LBL is maintained at 15 cm, and two coats are uniformly sprayed, each having a wet film thickness of approximately 50 μm. After spraying, the coating is first dried at room temperature (25°C ± 2°C) for 24 hours, and then cured in an oven at 60°C for 2 hours, to form a superhydrophobic coating having a total thickness of 80-100 μm. After the coating has dried and cured, comprehensive performance testing is conducted for properties such as superhydrophobicity, anti-corrosion, and anti-mold performance. If the performance fails to meet the standards, factors such as raw material proportions, spraying pressure, and curing conditions are promptly analyzed and the process is adjusted accordingly.

[0081] The organosilicon-polyurethane composite superhydrophobic coating possesses superhydrophobic, anti-corrosion, and anti-mold properties, and can achieve anti-biofouling and self-cleaning functions.

[0082] The present invention discloses a preparation method for a freight container using LBL as a structural material. The objects thereof are to reduce dead weight, ensure structural safety and reliability, provide corrosion resistance, impact resistance, fatigue resistance, freeze-thaw resistance, and ultraviolet resistance, while developing and utilizing biomass material resources, reducing the use of mineral materials such as steel and aluminum alloys, and being more low-carbon and environmentally friendly.

CLAIMS

WHAT IS CLAIMED IS:

1. A lightweight, high-strength, multi-purpose laminated bamboo lumber (LBL) freight container, wherein: it comprises LBL corner posts 1, LBL side posts 2, LBL longitudinal side beams 3, LBL or glass fiber reinforced plastics GFRP-steel transverse short beams 4, LBL or GFRP-steel longitudinal middle beams 5, corner fitting-GFRP-steel plate-steel sleeve-bolt integrated connections 6, LBL diagonal braces 7, GFRP-steel composite square cylinders for forklifts 8, GFRP-steel sleeve bolt connections 9, GFRP-steel bolt connections 10, diagonal T-shaped GFRP-steel filling plate bolt connections 11, doors 13, a "K"-shaped structural system, and peripheral plates. A "Mu"-shaped bottom GFRP-steel-LBL frame structure is formed by two GFRP-steel composite square cylinders for forklifts 8, two first longitudinal side beams 3-1, two second longitudinal side beams 3-2, two third longitudinal side beams 3-3, and two GFRP-steel transverse short beams 4-1. The LBL or GFRP-steel longitudinal middle beams 5 are mounted on the inner side of the bottom GFRP-steel-LBL frame structure by means of GFRP-steel bolt connections 10. The LBL corner posts 1 are mounted at four corners of the bottom GFRP-steel-LBL frame structure by means of corner fitting-GFRP-steel plate-steel sleeve-bolt integrated connections 6 and GFRP-steel sleeve bolt connections 9. The LBL side posts 2 are mounted on the outer frame of the bottom GFRP-steel-LBL frame structure by means of GFRP-steel bolt connections 10.

2. The lightweight, high-strength, multi-purpose LBL freight container according to claim 1, wherein: the two first longitudinal side beams 3-1 are symmetrically arranged, the two second longitudinal side beams 3-2 are symmetrically arranged, and the two third longitudinal side beams 3-3 are symmetrically arranged. The first longitudinal side beams 3-1, the second longitudinal side beams 3-2, and the third longitudinal side beams 3-3 are sequentially arranged to form a broken line. The two GFRP-steel composite square cylinders for forklifts 8 are placed in parallel and

vertically disposed between the two broken lines. The spacing between the two GFRP-steel composite square cylinders for forklifts 8 enables forklift tines to be freely inserted therebetween. The first longitudinal side beams 3-1, the second longitudinal side beams 3-2, the third longitudinal side beams 3-3, and the two GFRP-steel composite square cylinders for forklifts 8 are collinear and lie in a common plane. An end portion of one GFRP-steel composite square cylinder for forklifts 8 is located between the first longitudinal side beam 3-1 and the second longitudinal side beam 3-2, and an end portion of the other GFRP-steel composite square cylinder for forklifts 8 is located between the second longitudinal side beam 3-2 and the third longitudinal side beam 3-3. The first longitudinal side beam 3-1, the second longitudinal side beam 3-2, and the third longitudinal side beam 3-3 are connected to the end portions of the GFRP-steel composite square cylinders for forklifts 8 by means of fifth GFRP-steel bolt connections 10-5. Notches are formed at both ends of the GFRP-steel transverse short beams 4-1 to constitute a "Men"-shaped structure. One GFRP-steel transverse short beam 4-1 is vertically disposed between the two first longitudinal side beams 3-1 and connected thereto by means of second corner fitting-GFRP-steel plate-steel sleeve-bolt integrated connections 6-2. The other GFRP-steel transverse short beam 4-1 is vertically disposed between the two third longitudinal side beams 3-3 and connected thereto by means of second corner fitting-GFRP-steel plate-steel sleeve-bolt integrated connections 6-2.

3. The lightweight, high-strength, multi-purpose LBL freight container according to claim 2, wherein: fifth LBL transverse short beams 4-5 are mounted on the inner side of the outer frame of the bottom GFRP-steel-LBL frame structure in a transverse direction at intervals not exceeding 1.5 meters.

4. The lightweight, high-strength, multi-purpose LBL freight container according to claim 2, wherein: the LBL or GFRP-steel longitudinal middle beams 5 are equally spaced in a longitudinal direction on the inner side of the outer frame of the bottom GFRP-steel-LBL frame structure, and are connected to the fifth LBL transverse short beams 4-5 and the GFRP-steel composite square

cylinders for forklifts 8.

5. The lightweight, high-strength, multi-purpose LBL freight container according to claim 2, wherein: the LBL corner posts 1 comprise two first LBL corner posts 1-1 at door frame spans and two second LBL corner posts 1-2 at non-door frame spans. The two first LBL corner posts 1-1 and the two second LBL corner posts 1-2 are mounted at four corners of the outer frame of the bottom GFRP-steel-LBL frame structure by means of second corner fitting-GFRP-steel plate-steel sleeve-bolt integrated connections 6-2. The centroids of the first LBL corner posts 1-1 and the second LBL corner posts 1-2 and the corresponding corner fitting centroids are collinear, or the horizontal projection distance between the two centroids is less than one-fifth of the short side length of the LBL corner posts 1.

6. The lightweight, high-strength, multi-purpose LBL freight container according to claim 5, wherein: the LBL side posts 2 comprise a first LBL side post 2-1, a second LBL side post 2-2, a third LBL side post 2-3, a fourth LBL side post 2-4, and a fifth LBL side post 2-5. The first LBL side post 2-1, the second LBL side post 2-2, the third LBL side post 2-3, the fourth LBL side post 2-4, and the fifth LBL side post 2-5 are mounted on the outer frame edges of the bottom GFRP-steel-LBL frame structure by means of second GFRP-steel bolt connections 10-2.

7. The lightweight, high-strength, multi-purpose LBL freight container according to claim 6, wherein: LBL diagonal braces 7 are mounted between the first longitudinal side beam 3-1 and the first LBL corner post 1-1, and between the first LBL side posts 2-1, respectively. The two LBL diagonal braces 7 constitute an inverted "V"-shaped configuration. LBL diagonal braces 7 are mounted between the third longitudinal side beam 3-3 and the second LBL corner post 1-2, and between the fourth LBL side posts 2-4, respectively. The two LBL diagonal braces 7 constitute an inverted "V"-shaped configuration. LBL diagonal braces 7 are mounted between the second longitudinal side beam 3-2 and the second LBL side post 2-2, and between the third LBL side posts 2-3, respectively. The two LBL diagonal braces 7 constitute an inverted "V"-shaped configuration.

If a cargo access door 13 is installed on this side surface, no LBL diagonal brace 7 is installed at this location.

8. The lightweight, high-strength, multi-purpose LBL freight container according to claim 6, wherein: The "K"-shaped structural system comprises a fifth longitudinal side beam 3-5 and two LBL diagonal braces 7 disposed on the fifth longitudinal side beam 3-5. The fifth longitudinal side beam 3-5 is disposed directly above end portions of the GFRP-steel composite square cylinders for forklifts 8. Both ends of the fifth longitudinal side beam 3-5 are supported on the corresponding second longitudinal side beam 3-2 and first longitudinal side beam 3-1, or the first longitudinal side beam 3-1 is disposed above and connected thereto by means of "T"-shaped or "Gong"-shaped fourth GFRP-steel bolt connections 10-4. Both ends of the two LBL diagonal braces 7 are connected to the corresponding fifth longitudinal side beam 3-5 and the first LBL side post 2-1 or the second LBL side post 2-2 by means of diagonal T-shaped GFRP-steel filling plate bolt connections 11.

9. The lightweight, high-strength, multi-purpose LBL freight container according to claim 6, wherein: a second LBL transverse short beam 4-2 of the LBL or GFRP-steel transverse short beams 4 is connected to tops of the two first LBL corner posts 1-1 by means of first corner fitting-GFRP-steel plate-steel sleeve-bolt integrated connections 6-1. A third LBL transverse short beam 4-3 of the LBL or GFRP-steel transverse short beams 4 is connected to tops of the two second LBL corner posts 1-2 by means of first corner fitting-GFRP-steel plate-steel sleeve-bolt integrated connections 6-1. The centroids of the first LBL corner posts 1-1 and the second LBL corner posts 1-2 and the corresponding corner fitting centroids are collinear, or the horizontal projection distance between the two centroids is less than one-fifth of the short side length of the LBL corner posts 1. A fourth longitudinal side beam 3-4 of the LBL longitudinal side beams 3 is connected to tops of the first LBL corner post 1-1 and the second LBL corner post 1-2 on the same side by means of first corner fitting-GFRP-steel plate-steel sleeve-bolt integrated connections 6-1. A fourth LBL transverse

short beam 4-4 of the LBL or GFRP-steel transverse short beams 4 is connected between the two fourth longitudinal side beams 3-4 by means of first GFRP-steel bolt connections 10-1.

10. The lightweight, high-strength, multi-purpose LBL freight container according to claim 6, wherein: LBL diagonal braces 7 are connected between the fourth longitudinal side beam 3-4 and the first LBL corner post 1-1, between the fourth longitudinal side beam 3-4 and the second LBL corner post 1-2, and between the fourth longitudinal side beam 3-4 and the second LBL transverse short beam 4-2, respectively, by means of diagonal T-shaped GFRP-steel filling plate bolt connections 11. LBL diagonal braces 7 are connected between both ends of the third LBL transverse short beam 4-3 and the second LBL corner posts 1-2 by means of diagonal T-shaped GFRP-steel filling plate bolt connections 11.

11. The lightweight, high-strength, multi-purpose LBL freight container according to claim 6, wherein: the peripheral plates comprise bottom LBL plates 14 mounted on the bottom GFRP-steel-LBL frame structure, a top LBL plate 15, a first side LBL plate 16, and a second side LBL plate 17 mounted on the periphery of the LBL frame structure to form an enclosure structure.

12. The lightweight, high-strength, multi-purpose LBL freight container according to claim 6, wherein: the doors comprise end doors 13-1, side doors 13-2, and top doors 13-3. The end doors 13-1 are mounted between the first LBL corner posts 1-1. The side doors 13-2 are mounted between the second LBL side posts 2-2 and the third LBL side posts 2-3. The top doors 13-3 are mounted on the top LBL plate 15.

13. The lightweight, high-strength, multi-purpose LBL freight container according to claim 1, wherein: the LBL may be formed from one of bamboo scrimber, bamboo woven plywood, bamboo-plastic composite, bamboo particle composite, bamboo chip profile, engineered wood, ordinary wood, and straw, or may be replaced by a composite of multiple materials selected from LBL, bamboo scrimber, bamboo woven plywood, bamboo-plastic composite, bamboo particle composite, bamboo chip profile, engineered wood, ordinary wood, and straw.

14. The lightweight, high-strength, multi-purpose LBL freight container according to claim 1, wherein: the GFRP may be formed from one of basalt fiber, carbon fiber, and aramid fiber, or may be replaced by a composite of multiple materials selected from GFRP, basalt fiber, carbon fiber, and aramid fiber. Alternatively, GFRP may be omitted depending on service life requirements.

15. The lightweight, high-strength, multi-purpose LBL freight container according to claim 1, wherein: the doors 13 are made of a metallic material, or are made of one or more composite materials selected from LBL, bamboo scrimber, bamboo woven plywood, wood, FRP, and straw.

16. The lightweight, high-strength, multi-purpose LBL freight container according to claim 1, wherein: the LBL longitudinal side beams 3 are made of LBL, or steel, or FRP profiles, or wood, or a composite of two or more materials selected from bamboo, steel, FRP profiles, and wood.

17. The lightweight, high-strength, multi-purpose LBL freight container according to claim 1, wherein: the two LBL diagonal braces 7 and the fifth longitudinal side beam 3-5 constitute the "K"-shaped structural system, which may be arranged or omitted depending on the material characteristics of the bottom longitudinal side beams.

18. The lightweight, high-strength, multi-purpose LBL freight container according to claim 1, wherein: the cargo access doors 13 may be provided at one, two, or three positions selected from the top, the side, and the end.

19. The lightweight, high-strength, multi-purpose LBL freight container according to claim 1, wherein: the lightweight, high-strength, multi-purpose LBL freight container may be used as a dwelling.

20. The lightweight, high-strength, multi-purpose LBL freight container and a manufacturing method thereof according to claim 1, wherein: the number and arrangement of the LBL diagonal braces 7 are increased or decreased according to weight allowance and service conditions.

21. A manufacturing method for a lightweight, high-strength, multi-purpose LBL freight container, wherein: it comprises the following steps:

Step 1: Preparing integrated corner fitting-GFRP-steel plate-steel sleeve-bolt integrated connections 6 having end holes, side holes, top holes, or bottom holes. The corner fitting-GFRP-steel plate-steel sleeve-bolt integrated connections 6 are capable of being used for connecting beam structural members, column structural members, and hoisting the LBL freight container. The steel sleeve portions and bolt assemblies of the corner fitting-GFRP-steel plate-steel sleeve-bolt integrated connections 6 are used for end connections of the column structural members. The centroid of the steel sleeve and the centroid of the corner fitting are collinear, or the horizontal projection distance between the two centroids is less than one-fifth of the short side length of the steel sleeve. The steel plates of the corner fitting-GFRP-steel plate-steel sleeve-bolt integrated connections 6 are of a linear or I-shaped configuration. The steel plates together with the bolt assemblies are used for end connections of the beam structural members. Preparing GFRP-steel transverse short beams 4-1, wherein both ends of the GFRP-steel transverse short beams 4-1 are configured as "Men"-shaped structures capable of being used for securing the LBL freight container or enabling forklifts to load and unload the LBL freight container from the end face. Preparing GFRP-steel composite square cylinders for forklifts 8, wherein both side surfaces of the GFRP-steel composite square cylinders for forklifts 8 are provided with square or circular holes having an interval width not less than 40 mm and an interval not less than 80 mm, or are provided without holes.

Step 2: Preparing LBL longitudinal side beams 3, LBL or GFRP-steel transverse short beams 4, LBL or GFRP-steel longitudinal middle beams 5, LBL corner posts 1, LBL side posts 2, LBL diagonal braces 7, a top LBL plate 15, a first side LBL plate 16, and a second side LBL plate 17. Bolt or pin connection holes are formed at end portions of the LBL longitudinal side beams 3, the LBL or GFRP-steel transverse short beams 4, the LBL or GFRP-steel longitudinal middle beams 5, the LBL corner posts 1, the LBL diagonal braces 7, the top LBL plate 15, the first side LBL plate 16, and the second side LBL plate 17, and at connection portions between adjacent members

thereof.

Step 3: Constructing a "Mu"-shaped bottom GFRP-steel-LBL frame structure composed of two GFRP-steel composite square cylinders for forklifts 8, LBL longitudinal side beams 3, and two GFRP-steel transverse short beams 4-1. The two GFRP-steel composite square cylinders for forklifts 8 are placed in parallel, and the spacing therebetween enables forklift tines to be freely inserted. First longitudinal side beams 3-1, second longitudinal side beams 3-2, and third longitudinal side beams 3-3 are symmetrically disposed at both ends of the two GFRP-steel composite square cylinders for forklifts 8 in a spatially perpendicular positional relationship thereto. The second longitudinal side beam 3-2 is located between the two GFRP-steel composite square cylinders for forklifts 8. The first longitudinal side beam 3-1 and the third longitudinal side beam 3-3 are respectively located at the other ends of the two GFRP-steel composite square cylinders for forklifts 8. The first longitudinal side beam 3-1, the second longitudinal side beam 3-2, and the third longitudinal side beam 3-3 are connected to the end portions of the GFRP-steel composite square cylinders for forklifts 8 by means of fifth GFRP-steel bolt connections 10-5. The first longitudinal side beam 3-1, the second longitudinal side beam 3-2, the third longitudinal side beam 3-3, and the two GFRP-steel composite square cylinders for forklifts 8 are collinear and lie in a common plane. One GFRP-steel transverse short beam 4-1 is vertically disposed between the two first longitudinal side beams 3-1, and the other GFRP-steel transverse short beam 4-1 is vertically disposed between the two third longitudinal side beams 3-3. The first longitudinal side beams 3-1, the third longitudinal side beams 3-3, and the "Men"-shaped GFRP-steel transverse short beams 4-1 are connected by means of second corner fitting-GFRP-steel plate-steel sleeve-bolt integrated connections 6-2 to form a "Square"-shaped outer frame of the bottom GFRP-steel-LBL frame structure. Fifth LBL transverse short beams 4-5 are mounted on the inner side of the "Square" outer frame in a transverse direction at intervals not exceeding 1.5 meters. LBL or GFRP-steel longitudinal middle beams 5 are mounted on the inner side of the "Square" outer frame in a

longitudinal direction in an equally divided form, and are connected to the fifth LBL transverse short beams 4-5 and the GFRP-steel composite square cylinders for forklifts 8.

Step 4: Assembling peripheral LBL corner posts 1 and LBL side posts 2. The first LBL corner posts 1-1 at door frame spans and the second LBL corner posts 1-2 at non-door frame spans are mounted at four corners of the outer frame of the bottom GFRP-steel-LBL frame structure by means of second corner fitting-GFRP-steel plate-steel sleeve-bolt integrated connections 6-2. The centroids of the first LBL corner posts 1-1 and the second LBL corner posts 1-2 and the corresponding corner fitting centroids are collinear, or the horizontal projection distance between the two centroids is less than one-fifth of the short side length of the LBL corner posts 1. The first LBL side post 2-1, the second LBL side post 2-2, the third LBL side post 2-3, the fourth LBL side post 2-4, and the fifth LBL side post 2-5 are mounted on the outer frame edges of the bottom GFRP-steel-LBL frame structure by means of second GFRP-steel bolt connections 10-2. LBL diagonal braces 7 are mounted between the first longitudinal side beam 3-1 and the first LBL corner post 1-1, and between the first LBL side posts 2-1, respectively. The two LBL diagonal braces 7 constitute an inverted "V"-shaped configuration. LBL diagonal braces 7 are mounted between the third longitudinal side beam 3-3 and the second LBL corner post 1-2, and between the fourth LBL side posts 2-4, respectively. The two LBL diagonal braces 7 constitute an inverted "V"-shaped configuration. LBL diagonal braces 7 are mounted between the second longitudinal side beam 3-2 and the second LBL side post 2-2, and between the third LBL side posts 2-3, respectively. The two LBL diagonal braces 7 constitute an inverted "V"-shaped configuration. If a cargo access door 13 is installed on this side surface, no LBL diagonal brace 7 is installed at this location. A fifth longitudinal side beam 3-5 is disposed directly above the end portions of the GFRP-steel composite square cylinders for forklifts 8. Both ends of the fifth longitudinal side beam 3-5 are supported on the corresponding second longitudinal side beam 3-2 and first longitudinal side beam 3-1, or the first longitudinal side beam 3-1 is disposed above and connected thereto by means of

"T"-shaped or "Gong"-shaped fourth GFRP-steel bolt connections 10-4. Two LBL diagonal braces 7 are disposed on the fifth longitudinal side beam 3-5 to constitute the "K"-shaped structural system. Both ends of the two LBL diagonal braces 7 are connected to the corresponding fifth longitudinal side beam 3-5 and the first LBL side post 2-1 or the second LBL side post 2-2 by means of diagonal T-shaped GFRP-steel filling plate bolt connections 11.

Step 5: Assembling a top LBL frame structure. The second LBL transverse short beam 4-2 and the fourth longitudinal side beam 3-4 are connected to tops of the first LBL corner posts 1-1 by means of first corner fitting-GFRP-steel plate-steel sleeve-bolt integrated connections 6-1. The third LBL transverse short beam 4-3 and the fourth longitudinal side beam 3-4 are connected to tops of the second LBL corner posts 1-2 by means of first corner fitting-GFRP-steel plate-steel sleeve-bolt integrated connections 6-1. The centroids of the first LBL corner posts 1-1 and the second LBL corner posts 1-2 and the corresponding corner fitting centroids are collinear, or the horizontal projection distance between the two centroids is less than one-fifth of the short side length of the LBL corner posts 1. The fourth longitudinal side beam 3-4 and the third LBL transverse short beam 4-3 are connected to tops of the LBL side posts 2 by means of second GFRP-steel bolt connections 10-2. LBL diagonal braces 7 are installed between the fourth longitudinal side beam 3-4 and the first LBL corner post 1-1, between the fourth longitudinal side beam 3-4 and the second LBL corner post 1-2, and between the fourth longitudinal side beam 3-4 and the second LBL transverse short beam 4-2, respectively, by means of diagonal T-shaped GFRP-steel filling plate bolt connections 11. LBL diagonal braces 7 are connected between both ends of the third LBL transverse short beam 4-3 and the second LBL corner posts 1-2 by means of diagonal T-shaped GFRP-steel filling plate bolt connections 11. The fourth LBL transverse short beam 4-4 is connected between the two fourth longitudinal side beams 3-4 by means of first GFRP-steel bolt connections 10-1.

Step 6: Assembling an enclosure structure. Bottom LBL plates 14 are mounted on the bottom

GFRP-steel-LBL frame structure. Double-leaf end doors 13-1 are installed between the two first LBL corner posts 1-1. Side doors 13-2 are installed between the second LBL side posts 2-2 and the third LBL side posts 2-3. The top LBL plate 15, the first side LBL plate 16, and the second side LBL plate 17 are mounted on the periphery of the LBL frame structure to form the enclosure structure. Anti-corrosion, anti-mold, and anti-ultraviolet treatments are applied to the LBL.

22.The manufacturing method for a lightweight, high-strength, multi-purpose LBL freight container according to claim 21, wherein: the two LBL diagonal braces 7 and the fifth longitudinal side beam 3-5 constituting the "K"-shaped structural system in Step 4 may be selectively installed or omitted.

23.The manufacturing method for a lightweight, high-strength, multi-purpose LBL freight container according to claim 21, wherein: the anti-corrosion, anti-mold, and anti-ultraviolet treatments in Step 6 comprise the following steps: applying an organosilicon-polyurethane composite superhydrophobic coating to surfaces of the LBL. The coating is formed by hybridizing polydimethylsiloxane (PDMS)-modified polyurethane (PU) with nano-silica (SiO2). Through synergistic action of micro-nano hierarchical rough structures and low-surface-energy siloxane groups, a superhydrophobic interface having a static water contact angle (WCA) $\geq 150°$ and a sliding angle (SA) $\leq 10°$ is formed. Meanwhile, resorcinol-formaldehyde resin (RF) is embedded to fill micropore defects, thereby inhibiting microbial attachment and penetration of corrosive media.