

STRUCTURAL FASTENER FOR CONSTRUCTION STRUCTURES

Cross Reference to Related Application(s)

- 5 The present disclosure claims the benefit of Singapore Patent Application No. 10202008263P filed on 27 August 2020, which is incorporated in its entirety by reference herein.

Technical Field

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The present disclosure generally relates to a structural fastener for construction structures. More particularly, the present disclosure describes various embodiments of a structural fastener and a method for fastening a connection between construction structures.

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Background

During in-situ construction, construction structures are connected and assembled into construction assemblies such as buildings or other frame structures. For example, cranes are used to lift one construction structure, such as a construction beam or column, to be connected to another construction structure. In a known construction assembly 100 as shown in Figures 1A and 1B, there is a conventional connection 110 formed between construction structures 120 that are assembled together. The construction structures 120 may include a horizontal beam 122 and a vertical column 124 as shown. The beam 122 has an endplate 130 and stiffeners 132. The conventional connection 110 comprises connection holes 134 through the endplate 130 and the column 124 so that the beam 122 can be fastened to the column 124 via the connection holes 134. Bolts 140 are inserted through the connection holes 134 and locked with nuts 142 to fasten the conventional connection 110. Ring springs 144 made of shape memory alloy may be used to secure the bolts 140 in the connection holes 134. To ensure proper fitting between the bolts 140 and the connection holes 134, their diameters should correspond to each other with suitable tolerances. However, this also means that the bolts 140 must be force fitted through the

connection holes 134 for the whole length of the bolts 140. This is labour-intensive and time-consuming especially if the bolts 140 are long and/or there are many bolts 140 required, such as to fasten the conventional connection 110 between large construction structures 120.

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Therefore, in order to address or alleviate at least one of the aforementioned problems and/or disadvantages, there is a need to provide an improved structural fastener for construction structures.

10 Summary

According to a first aspect of the present disclosure, there is a structural fastener for fastening a connection between construction structures. The structural fastener comprises: an elongated body comprising a plurality of stepped sections, each stepped section defining a cross-sectional diameter; and the cross-sectional diameters decreasing along the stepped sections from a head end portion to a tail end portion of the elongated body, wherein the structural fastener is configured to insert into the connection beginning from the tail end portion; and wherein the stepped sections are arranged to engage with respective sets of aligned connection holes of the construction structures, each set of aligned connection holes having hole diameters corresponding to the cross-sectional diameters of the respective stepped section.

According to a second aspect of the present disclosure, there is a construction assembly comprising: a plurality of assembled construction structures, each construction structure comprising a plurality of connection plates, each connection plate comprising a set of connection holes, and for each construction structure, the connection holes having hole diameters decreasing across the connection plates of the construction structure; a connection between the assembled construction structures, the connection comprising a plurality of sets of aligned connection holes; and a set of structural fasteners inserted into the connection, each structural fastener comprising an elongated body comprising a plurality of stepped sections, each stepped section defining a cross-sectional diameter, the cross-sectional diameters

decreasing along the stepped sections from a head end portion to a tail end portion of the elongated body, wherein for each structural fastener, the stepped sections are engaged with respective sets of aligned connection holes, each set of aligned connection holes having hole diameters corresponding to the cross-sectional diameters of the respective stepped section.

According to a third aspect of the present disclosure, there is a method for fastening a connection between construction structures. The method comprises: assembling a plurality of construction structures, each construction structure comprising a plurality of connection plates, each connection plate comprising a set of connection holes, and for each construction structure, the connection holes having hole diameters decreasing across the connection plates of the construction structure; forming a connection between the assembled construction structures, the connection comprising a plurality of sets of aligned connection holes; and arranging a set of structural fasteners for fastening the connection, each structural fastener comprising an elongated body comprising a plurality of stepped sections, each stepped section defining a cross-sectional diameter, the cross-sectional diameters decreasing along the stepped sections from a head end portion to a tail end portion of the elongated body; for each structural fastener, partially inserting the structural fastener into the connection until the stepped sections stop at respective sets of aligned connection holes, each set of aligned connection holes having hole diameters corresponding to the cross-sectional diameters of the respective stepped sections; and for each partially inserted structural fastener, fully inserting the structural fastener into the connection, thereby engaging the stepped sections with the respective sets of aligned connection holes.

A structural fastener for fastening a connection between construction structures according to the present disclosure is thus disclosed herein. Various features, aspects, and advantages of the present disclosure will become more apparent from the following detailed description of the embodiments of the present disclosure, by way of non-limiting examples only, along with the accompanying drawings.

Brief Description of the Drawings

Figures 1A and 1B are illustrations of a known construction assembly comprising construction structures and a conventional connection between them.

- 5 Figure 2 is an illustration of a structural fastener for fastening a connection between construction structures, in accordance with embodiments of the present disclosure.

Figures 3A to 3C are illustrations of a construction assembly comprising construction structures and a connection fastened with the structural fastener of Figure 2, in
10 accordance with embodiments of the present disclosure.

Figure 4 is a flowchart illustration of a method for fastening a connection between construction structures using the structural fastener of Figure 2, in accordance with
15 embodiments of the present disclosure.

Figures 5A to 5D are illustrations of assembling a construction assembly comprising construction structures and using the structural fasteners of Figure 2, in accordance
with embodiments of the present disclosure.

20 **Detailed Description**

For purposes of brevity and clarity, descriptions of embodiments of the present disclosure are directed to a structural fastener for fastening a connection between construction structures, in accordance with the drawings. While aspects of the present
25 disclosure will be described in conjunction with the embodiments provided herein, it will be understood that they are not intended to limit the present disclosure to these embodiments. On the contrary, the present disclosure is intended to cover alternatives, modifications and equivalents to the embodiments described herein, which are included within the scope of the present disclosure as defined by the appended claims.

30 Furthermore, in the following detailed description, specific details are set forth in order to provide a thorough understanding of the present disclosure. However, it will be recognized by an individual having ordinary skill in the art, i.e. a skilled person, that the present disclosure may be practiced without specific details, and/or with multiple

details arising from combinations of aspects of particular embodiments. In a number of instances, known systems, methods, procedures, and components have not been described in detail so as to not unnecessarily obscure aspects of the embodiments of the present disclosure.

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In embodiments of the present disclosure, depiction of a given element or consideration or use of a particular element number in a particular figure or a reference thereto in corresponding descriptive material can encompass the same, an equivalent, or an analogous element or element number identified in another figure or descriptive material associated therewith.

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References to “an embodiment / example”, “another embodiment / example”, “some embodiments / examples”, “some other embodiments / examples”, and so on, indicate that the embodiment(s) / example(s) so described may include a particular feature, structure, characteristic, property, element, or limitation, but that not every embodiment / example necessarily includes that particular feature, structure, characteristic, property, element or limitation. Furthermore, repeated use of the phrase “in an embodiment / example” or “in another embodiment / example” does not necessarily refer to the same embodiment / example.

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The terms “comprising”, “including”, “having”, and the like do not exclude the presence of other features / elements / steps than those listed in an embodiment. Recitation of certain features / elements / steps in mutually different embodiments does not indicate that a combination of these features / elements / steps cannot be used in an embodiment.

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As used herein, the terms “a” and “an” are defined as one or more than one. The use of “/” in a figure or associated text is understood to mean “and/or” unless otherwise indicated. The recitation of a particular numerical value or value range herein is understood to include or be a recitation of an approximate numerical value or value range. The term “set” is defined as a non-empty finite organization of elements that mathematically exhibits a cardinality of at least one (e.g. a set as defined herein can correspond to a unit, singlet, or single-element set, or a multiple-element set), in

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accordance with known mathematical definitions. The terms “first”, “second”, “third”, etc. are used merely as labels or identifiers and are not intended to impose numerical requirements on their associated terms. The term “each other” represents a reciprocal relation between two or more elements.

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Representative or exemplary embodiments of the present disclosure describe a structural fastener 200 as shown in Figure 2. The structural fastener 200 includes an elongated body 210 having a plurality of stepped sections 220, each stepped section 220 defining a cross-sectional diameter. The cross-sectional diameters of the stepped
10 sections 220 are decreasing along the stepped sections 220 from a head end portion 212 to a tail end portion 214 of the elongated body 210. More specifically, each stepped section 220 has a fixed cross-sectional diameter, and the cross-sectional diameters decrease in a stepwise manner along the elongated body 210. The stepped section 220 that is nearest the head end portion 212 has the largest cross-sectional
15 diameter, while the stepped section 220 that is nearest the tail end portion 214 has the smallest cross-sectional diameter.

In some embodiments as shown in Figure 2, the elongated body 210 has three stepped sections 220 – a first stepped section 222, a second stepped section 224,
20 and a third stepped section 226 arranged from the head end portion 212 to the tail end portion 214 of the elongated body 210. In one embodiment, the first stepped section 222 has a cross-sectional diameter of 60 mm, the second stepped section 224 has a cross-sectional diameter of 55 mm, and the third stepped section 226 has a cross-sectional diameter of 50 mm. The elongated body 210 may have an overall length of
25 300 mm.

With reference to Figure 3A, the structural fastener 200 is configured for fastening a connection 310 between construction structures 320 of an exemplary construction assembly 300. The connection 310 is preferably a simple shear connection such as a
30 pinned joint. The construction structures 320 may include any construction structures or members used in the construction or building industry, such as but not limited to, beams, columns, slabs, and footings. More specifically, the structural fastener 200 is configured to insert into the connection 310 beginning from the tail end portion 214 of

the elongated body 210. The stepped sections 220 are arranged to engage with respective sets of aligned connection holes 330 of the construction structures 320. Each set of aligned connection holes 330 has hole diameters corresponding to the cross-sectional diameters of the respective stepped section 220. Each construction
5 structure 320 includes a plurality connection plates 340 with the connection holes 330.

Figure 3B shows a sectional view of the construction assembly 300 including the construction structures 320 assembled together and the connection 310 fastened with the structural fastener 200. More specifically, the construction assembly 300 includes
10 a plurality of assembled construction structures 320, each construction structure 320 includes a plurality of connection plates 340, and each connection plate 340 includes a set of connection holes 330. The construction structure 320 may be fabricated with the connection plates 340 off site in a factory or manufacturing facility, before the construction structures 320 are assembled via the connection plates 340 on site using
15 the structural fasteners 200. The connection plates 340 may include fin plates, flange plates, or continuity plates. For each construction structure 320, the connection holes 330 have hole diameters decreasing across the connection plates 340 of the construction structure 320. Each connection hole 330 has a fixed hole diameter, and the hole diameters decrease in a stepwise manner across the connection plates 340.

20 The construction assembly 300 further includes the connection 310 between the assembled construction structures 320. The connection 310 includes a plurality of sets of aligned connection holes 330. The construction assembly 300 further includes a set of the structural fasteners 200 inserted into the connection 310, specifically through
25 the aligned connection holes 330. For each structural fastener 200, the stepped sections 220 are engaged with respective sets of aligned connection holes 330, each set of aligned connection holes 330 having hole diameters corresponding to the cross-sectional diameters of the respective stepped section 220.

30 The corresponding hole diameters of the connection holes 330 and cross-sectional diameters of the stepped sections 220 are elaborated as follows, with reference to Figures 3 and 4. The construction assembly 300 includes a first construction structure 320A and a second construction structure 320B. The first construction structure 320A

includes a plurality of first connection plates 340A, and each first connection plate 340A includes a set of first connection holes 330A. The first connection holes 330A have hole diameters decreasing across the first connection plates 340A. The second construction structure 320B includes a plurality of second connection plates 340B, and
5 each second connection plate 340B includes a set of second connection holes 330B. The second connection holes 330B have hole diameters decreasing across the second connection plates 340B.

When the first and second connection structures 320A, 320B are assembled to each
10 other, the first connection holes 330A and second connection holes 330B become aligned. The connection 310 thus includes a plurality of sets of aligned connection holes 330. Each set of aligned connection holes 330 is formed from at least one first connection plate 340A and/or at least one second connection plate 340B, and includes at least one first connection hole 330A and/or at least one second connection hole
15 330B. As shown in Figures 3 and 4, the connection 310 includes a first set 332 of aligned connection holes 330, a second set 334 of aligned connection holes 330, and a third set 336 of aligned connection holes 330.

Further with reference to Figure 3C showing the connection 310 fastened with the
20 structural fastener 200, the structural fastener 200 has the first stepped section 222, second stepped section 224, and third stepped section 226. The cross-sectional diameter of the first stepped section 222 corresponds to the hole diameters of the first set 332 of aligned connection holes 330, with suitable tolerances. The cross-sectional diameter of the second stepped section 224 corresponds to the hole diameters of the
25 second set 334 of aligned connection holes 330, with suitable tolerances. The cross-sectional diameter of the third stepped section 226 corresponds to the hole diameters of the third set 336 of aligned connection holes 330, with suitable tolerances. The tolerances are dimensioned to achieve suitable engineering fits, such as interference or force fits between the stepped sections 220 and aligned connection holes 330. For
30 example, the tolerances may be 0.025 mm based on the cross-sectional diameters of the stepped sections 220 mentioned above.

When the structural fastener 200 is inserted into the aligned holes 330 to fasten the connection 310, the first stepped section 222 engages with the first set 332 of aligned connection holes 330, the second stepped section 224 engages with the second set 334 of aligned connection holes 330, and the third stepped section 226 engages with the third set 336 of aligned connection holes 330. The structural fastener 200 is thus fastened into the connection 310 and thereby secures the assembled construction structures 320.

In various embodiments of the present disclosure with reference to Figure 4, there is a method 400 for fastening a connection 310 between construction structures 320. The method 400 includes a step 410 of assembling a plurality of the construction structures 320, each construction structure 320 having a plurality of connection plates 340, each connection plate 340 having a set of connection holes 330, and for each construction structure 320, the connection holes 330 having hole diameters decreasing across the connection plates 340 of the construction structure 320.

The method 400 includes a step 420 of forming the connection 310 between the assembled construction structures 320, the connection 320 including a plurality of sets of aligned connection holes 330. The method 400 includes a step 430 of arranging a set of structural fasteners 200 for fastening the connection 310, each structural fastener including an elongated body 210 having a plurality of stepped sections 220, each stepped section 220 defining a cross-sectional diameter, the cross-sectional diameters decreasing along the stepped sections 220 from a head end portion 212 to a tail end portion 214 of the elongated body 210.

The method 400 includes a step 440 of, for each structural fastener 200, partially inserting the structural fastener 200 into the connection 310 until the stepped sections 220 stop at respective sets of aligned connection holes 330, each set of aligned connection holes 330 having hole diameters corresponding to the cross-sectional diameters of the respective stepped sections 220. The method 400 includes a step 450 of, for each partially inserted structural fastener 200, fully inserting the structural fastener 200 into the connection 310, thereby engaging the stepped sections 220 with the respective sets of aligned connection holes 330.

To elaborate on the partial and full insertion of the structural fastener 200, when the structural fastener 200 is being inserted into the connection 310 beginning from the tail end portion 214 of the elongated body 210, the third stepped section 226 reaches
5 the first set 332 of aligned connection holes 330 first. Since the cross-sectional diameter of the third stepped section 226 is smaller than the hole diameters of the first set 332 of aligned connection holes 330, the third stepped section 226 can be inserted through the first set 332 of aligned connection holes 330 easily.

10 The third stepped section 226 then reaches the second set 334 of aligned connection holes 330, and the second stepped section 224 reaches the first set 332 of aligned connection holes 330. Since the cross-sectional diameter of the third stepped section 226 is smaller than the hole diameters of the second set 334 of aligned connection holes 330, the third stepped section 226 can be inserted through the second set 334
15 of aligned connection holes 330 easily. Similarly, since the cross-sectional diameter of the second stepped section 224 is smaller than the hole diameters of the first set 332 of aligned connection holes 330, the second stepped section 224 can be inserted through the first set 332 of aligned connection holes 330 easily.

20 The third stepped section 226 then reaches the third set 336 of aligned connection holes 330, the second stepped section 224 reaches the second set 334 of aligned connection holes 330, and the first stepped section 222 reaches the first set 332 of aligned connection holes 330. At this point, the structural fastener 200 is partially inserted into the connection 310 and the first to third stepped sections 222,224,226
25 have stopped at the first to third sets 332,334,336 of aligned connection holes 330.

Since the cross-sectional diameters of the first to third stepped sections 222,224,226 correspond to the hole diameters of the first to third sets 332,334,336 of aligned connection holes 330, respectively, the first to third stepped sections 222,224,226
30 cannot be easily inserted through the first to third sets 332,334,336 of aligned connection holes 330. In order to fully insert the structural fastener 200 into the connection 310, the first to third stepped sections 222,224,226 are force fitted through the first to third sets 332,334,336 of aligned connection holes 330, respectively. This

can be done by any forceful means known in the construction or building industry, such as hammering the structural fastener 200 at the head end portion 212. As the structural fastener 200 is already partially inserted into the connection 310, the structural fastener 200 is held in place and aligned with the connection holes 330 for
5 said hammering.

Therefore, the structural fastener 200 is first partially slotted into the connection 310 for a substantial length portion of the elongated body 210. The stepped sections 220 can be loosely fitted into the aligned connection holes 310 until each stepped section
10 220 stops at the respective set of aligned connection holes 310. The structural fastener 200 is then fully inserted into the connection 310 for the remaining length of the elongated body 210. This is done by force fitting each stepped section 220 into the respective set of aligned connection holes 310 in a single displacement action, such as by hammering.

15 An advantage of the structural fastener 200 with differential cross-sectional diameters for the stepped sections 220 is that this single displacement action is only for a short length corresponding to the length of a stepped section 220 or a set of aligned connection holes 310. By force fitting the structural fastener 200 for a much shorter
20 length portion compared to the whole length of conventional bolts 140 like the conventional connection 110, the construction assembly 300 can be assembled and fastened using the method 400 much more quickly and with lower labour intensity. Even if the structural fastener 200 is long, the structural fastener 200 can have more stepped sections 220 and the length for the single displacement action is still based
25 on the length of the stepped section 220. The time taken to fasten a structural fastener 200 is not significantly affected by its overall length.

In some embodiments, the head end portion 212 of the elongated body 210 has a larger cross-sectional diameter than the largest stepped section 210 and is configured
30 to prevent continued displacement of the structural fastener 200 into the connection 310 after the stepped sections 220 have been engaged with the respective sets of aligned connection holes 330. The head end portion 212 is also designed to withstand

the force fitting, e.g. hammering, to fully insert the structural fastener 200 into the connection 310.

5 In some embodiments, the tail end portion 214 of the elongated body 210 includes a locking hole 230 for receiving a locking pin 232. The structural fastener 200 may further include the locking pin 232 for insertion into the locking hole 230 to secure the structural fastener 200 inserted into the connection 310. Specifically, when the structural fastener 200 is fully inserted into the connection 310, the locking pin 232 is inserted into the locking hole 230 to prevent the structural fastener 200 from moving
10 out of the connection 310 in the opposite direction. The locking pin 232 may be a split pin or a cotter key. The head end portion 212 and locking pin 232 may cooperate to secure the structural fastener 200 within the connection 310. The head end portion 212 may include a similar locking hole for receiving another locking pin.

15 Figures 5A to 5D illustrate the assembling of a construction assembly 300 such as a building structural frame. The construction assembly 300 includes a plurality of construction structures 320 being assembled. For example, a horizontal beam is being assembled with a vertical column. Each construction structure 320 includes a plurality of connection plates 340, and each connection plate 340 includes an array of
20 connection holes 330. A connection 310 is formed between the construction structures 320 when they are assembled together. The connection 310 includes a plurality of sets of aligned connection holes 330. Structural fasteners 200 are then inserted into the connection 310, the stepped sections 220 inserted partially and then fully through the respective sets of aligned connection holes 330, as described in the method 400
25 above. Each structural fastener 200 may be fully inserted into the connection 310 before inserting the next structural fastener 200. Alternatively, all the structural fasteners 200 may be first partially inserted into the connection 310 and then fully inserted into the connection 310. The locking pins 232 are inserted into the respective locking holes 230 after the structural fasteners 200 have been fastened into the
30 connection 310.

The connection 310 can thus be fastened with the structural fasteners 200 on site without screwing bolts and nuts and welding. The differential cross-sectional diameters

of the stepped sections 220 and the differential hole diameters of the aligned connection holes 330 allow the structural fastener 200 to be loosely inserted for a substantial length portion and then force fitted for the short remaining length. Each connection 310 of the construction assembly 300 can be more quickly fastened, saving
5 construction time for the construction assembly 300 and thereby improving efficiency and productivity.

Moreover, if the size of the construction structures 320 is large, structural fasteners 200 that are longer and with larger cross-sectional diameters can be used without
10 significantly affecting the time taken to fasten the structural fasteners 200. Comparatively, the conventional connection 110 cannot use bolts 140 that have large cross-sectional diameters because there would be more contact area with the connection holes and greater frictional forces to overcome when the bolts 140 are force fitted through the connection holes for the whole length of the bolts 140. The
15 differential cross-sectional diameters of the structural fastener 200 addresses this problem by reducing the length portion for the force fitting. The structural fasteners 200 can thus have larger cross-sectional diameters than conventional bolts 140 and this strengthens the connection 310 between the construction structures 320. Fewer larger-diameter structural fasteners 200 can be used to achieve similar or better
20 structural integrity than using many smaller-diameter conventional bolts 140. Since fewer structural fasteners 200 are required to the force fitted into the connection 310, the construction time for the construction assembly 300 can be further reduced. Fewer structural fasteners 200 can also mitigate risk of alignment problems in the connection 310 that may occur on site during assembly, which would in turn improve efficiency
25 and productivity.

The structural fastener 200 can be fabricated by various manufacturing methods using various materials. In some embodiments, the structural fastener 200 is moulded or machined from a structurally rigid material such as but not limited to stainless steel,
30 mild steel, or aluminium. In some embodiments, the structural fastener 200 or a product comprising it may be formed by a manufacturing process that includes an additive manufacturing process. A common example of additive manufacturing is three-dimensional (3D) printing; however, other methods of additive manufacturing are

available. Rapid prototyping or rapid manufacturing are also terms which may be used to describe additive manufacturing processes.

As used herein, “additive manufacturing” refers generally to manufacturing processes wherein successive layers of material(s) are provided on each other to “build-up” layer-by-layer or “additively fabricate”, a 3D component. This is compared to some subtractive manufacturing methods (such as milling or drilling), wherein material is successively removed to fabricate the part. The successive layers generally fuse together to form a monolithic component which may have a variety of integral sub-components. In particular, the manufacturing process may allow an example of the disclosure to be integrally formed and include a variety of features not possible when using prior manufacturing methods.

Additive manufacturing methods described herein enable manufacture to any suitable size and shape with various features which may not have been possible using prior manufacturing methods. Additive manufacturing can create complex geometries without the use of any sort of tools, moulds, or fixtures, and with little or no waste material. Instead of machining components from solid billets of plastic or metal, much of which is cut away and discarded, the only material used in additive manufacturing is what is required to shape the part.

Suitable additive manufacturing techniques in accordance with the present disclosure include, for example, Fused Deposition Modelling (FDM), Selective Laser Sintering (SLS), 3D printing such as by inkjets and laserjets, Stereolithography (SLA), Direct Selective Laser Sintering (DSLS), Electron Beam Sintering (EBS), Electron Beam Melting (EBM), Laser Engineered Net Shaping (LENS), Electron Beam Additive Manufacturing (EBAM), Laser Net Shape Manufacturing (LNS), Direct Metal Deposition (DMD), Digital Light Processing (DLP), Continuous Digital Light Processing (CDLP), Direct Selective Laser Melting (DSLML), Selective Laser Melting (SLM), Direct Metal Laser Melting (DMLM), Direct Metal Laser Sintering (DMLS), Material Jetting (MJ), NanoParticle Jetting (NPJ), Drop On Demand (DOD), Binder Jetting (BJ), Multi Jet Fusion (MJF), Laminated Object Manufacturing (LOM), and other known processes.

The additive manufacturing processes described herein may be used for forming components using any suitable material. For example, the material may be metal, plastic, polymer, composite, or any other suitable material that may be in solid, liquid, powder, sheet material, wire, or any other suitable form or combinations thereof. More specifically, according to exemplary embodiments of the present disclosure, the additively manufactured components described herein may be formed in part, in whole, or in some combination of materials suitable for use in additive manufacturing processes and which may be suitable for the fabrication of examples described herein.

As noted above, the additive manufacturing process disclosed herein allows a single component to be formed from multiple materials. Thus, the examples described herein may be formed from any suitable mixtures of the above materials. For example, a component may include multiple layers, segments, or parts that are formed using different materials, processes, and/or on different additive manufacturing machines. In this manner, components may be constructed which have different materials and material properties for meeting the demands of any particular application. In addition, although the components described herein are constructed entirely by additive manufacturing processes, it should be appreciated that in alternate embodiments, all or a portion of these components may be formed via casting, machining, and/or any other suitable manufacturing process. Indeed, any suitable combination of materials and manufacturing methods may be used to form these components.

Additive manufacturing processes typically fabricate components based on 3D information, for example a 3D computer model (or design file), of the component. Accordingly, examples described herein not only include products or components as described herein, but also methods of manufacturing such products or components via additive manufacturing and computer software, firmware or hardware for controlling the manufacture of such products via additive manufacturing.

The structure of the product may be represented digitally in the form of a design file. A design file, or computer aided design (CAD) file, is a configuration file that encodes

one or more of the surface or volumetric configuration of the shape of the product. That is, a design file represents the geometrical arrangement or shape of the product.

- Design files can take any now known or later developed file format. For example, design files may be in the Stereolithography or "Standard Tessellation Language" (.stl) format which was created for Stereolithography CAD programs of 3D Systems, or the Additive Manufacturing File (.amf) format, which is an American Society of Mechanical Engineers (ASME) standard that is an extensible markup-language (XML) based format designed to allow any CAD software to describe the shape and composition of any 3D object to be fabricated on any additive manufacturing printer. Further examples of design file formats include AutoCAD (.dwg) files, Blender (.blend) files, Parasolid (.x_t) files, 3D Manufacturing Format (.3mf) files, Autodesk (3ds) files, Collada (.dae) files and Wavefront (.obj) files, although many other file formats exist.
- Design files can be produced using modelling (e.g. CAD modelling) software and/or through scanning the surface of a product to measure the surface configuration of the product. Once obtained, a design file may be converted into a set of computer executable instructions that, once executed by a processor, cause the processor to control an additive manufacturing apparatus to produce a product according to the geometrical arrangement specified in the design file. The conversion may convert the design file into slices or layers that are to be formed sequentially by the additive manufacturing apparatus. The instructions (otherwise known as geometric code or "G-code") may be calibrated to the specific additive manufacturing apparatus and may specify the precise location and amount of material that is to be formed at each stage in the manufacturing process. As discussed above, the formation may be through deposition, through sintering, or through any other form of additive manufacturing method.

- The code or instructions may be translated between different formats, converted into a set of data signals and transmitted, received as a set of data signals and converted to code, stored, etc., as necessary. The instructions may be an input to the additive manufacturing system and may come from a part designer, an intellectual property (IP) provider, a design company, the operator or owner of the additive manufacturing

system, or from other sources. An additive manufacturing system may execute the instructions to fabricate the product using any of the technologies or methods disclosed herein.

- 5 Design files or computer executable instructions may be stored in a (transitory or non-transitory) computer readable storage medium (e.g., memory, storage system, etc.) storing code, or computer readable instructions, representative of the product to be produced. As noted, the code or computer readable instructions defining the product that can be used to physically generate the object, upon execution of the code or
- 10 instructions by an additive manufacturing system. For example, the instructions may include a precisely defined 3D model of the product and can be generated from any of a large variety of well-known CAD software systems such as AutoCAD®, TurboCAD®, DesignCAD 3D Max, etc. Alternatively, a model or prototype of the product may be scanned to determine the 3D information of the product. Accordingly,
- 15 by controlling an additive manufacturing apparatus according to the computer executable instructions, the additive manufacturing apparatus can be instructed to print out the product.

- In light of the above, embodiments include methods of manufacture via additive
- 20 manufacturing. This includes the steps of obtaining a design file representing the product and instructing an additive manufacturing apparatus to manufacture the product according to the design file. The additive manufacturing apparatus may include a processor that is configured to automatically convert the design file into computer executable instructions for controlling the manufacture of the product. In
- 25 these embodiments, the design file itself can automatically cause the production of the product once input into the additive manufacturing apparatus. Accordingly, in this embodiment, the design file itself may be considered computer executable instructions that cause the additive manufacturing apparatus to manufacture the product. Alternatively, the design file may be converted into instructions by an external
- 30 computing system, with the resulting computer executable instructions being provided to the additive manufacturing apparatus.

Given the above, the design and manufacture of implementations of the subject matter and the operations described in this specification can be realized using digital electronic circuitry, or in computer software, firmware, or hardware, including the structures disclosed in this specification and their structural equivalents, or in combinations of one or more of them. For instance, hardware may include processors, microprocessors, electronic circuitry, electronic components, integrated circuits, etc. Implementations of the subject matter described in this specification can be realized using one or more computer programs, i.e., one or more modules of computer program instructions, encoded on computer storage medium for execution by, or to control the operation of, data processing apparatus. Alternatively or in addition, the program instructions can be encoded on an artificially generated propagated signal, e.g., a machine-generated electrical, optical, or electromagnetic signal that is generated to encode information for transmission to suitable receiver apparatus for execution by a data processing apparatus. A computer storage medium can be, or be included in, a computer-readable storage device, a computer-readable storage substrate, a random or serial access memory array or device, or a combination of one or more of them. Moreover, while a computer storage medium is not a propagated signal, a computer storage medium can be a source or destination of computer program instructions encoded in an artificially generated propagated signal. The computer storage medium can also be, or be included in, one or more separate physical components or media (e.g., multiple CDs, disks, or other storage devices).

Although additive manufacturing technology is described herein as enabling fabrication of complex objects by building objects point-by-point, layer-by-layer, typically in a vertical direction, other methods of fabrication are possible and within the scope of the present subject matter. For example, although the discussion herein refers to the addition of material to form successive layers, one skilled in the art will appreciate that the methods and structures disclosed herein may be practiced with any additive manufacturing technique or other manufacturing technology.

In the foregoing detailed description, embodiments of the present disclosure in relation to a structural fastener for fastening a connection between construction structures are described with reference to the provided figures. The description of the various

embodiments herein is not intended to call out or be limited only to specific or particular representations of the present disclosure, but merely to illustrate non-limiting examples of the present disclosure. The present disclosure serves to address at least one of the mentioned problems and issues associated with the prior art. Although only
5 some embodiments of the present disclosure are disclosed herein, it will be apparent to a person having ordinary skill in the art in view of this disclosure that a variety of changes and/or modifications can be made to the disclosed embodiments without departing from the scope of the present disclosure. Therefore, the scope of the disclosure as well as the scope of the following claims is not limited to embodiments
10 described herein.

Claims

1. A structural fastener for fastening a connection between construction structures, the structural fastener comprising:
 - 5 an elongated body comprising a plurality of stepped sections, each stepped section defining a cross-sectional diameter; and
the cross-sectional diameters decreasing along the stepped sections from a head end portion to a tail end portion of the elongated body,
wherein the structural fastener is configured to insert into the connection
10 beginning from the tail end portion; and
wherein the stepped sections are arranged to engage with respective sets of aligned connection holes of the construction structures, each set of aligned connection holes having hole diameters corresponding to the cross-sectional diameters of the respective stepped section.
- 15 2. The structural fastener according to claim 1, wherein the tail end portion comprises a locking hole for receiving a locking pin.
3. The structural fastener according to claim 2, further comprising the locking pin
20 for insertion into the locking hole to secure the structural fastener inserted into the connection.
4. The structural fastener according to claim 3, wherein the locking pin is a split
pin.
- 25 5. The structural fastener according to any one of claims 1 to 4, wherein the elongated body comprises a first stepped section, a second stepped section, and a third stepped section arranged from the head end portion to the tail end portion.
- 30 6. The structural fastener according to claim 5, wherein the first stepped section has a cross-sectional diameter of 60 mm, the second stepped section has a cross-sectional diameter of 55 mm, and the third stepped section has a cross-sectional diameter of 50 mm.

7. The structural fastener according to any one of claims 1 to 6, wherein the elongated body has an overall length of 300 mm.
- 5 8. A computer program comprising computer executable instructions that, when executed by a processor, cause the processor to control an additive manufacturing apparatus to manufacture a product comprising the structural fastener according to any one of claims 1 to 7.
- 10 9. A method of manufacturing a product via additive manufacturing, the method comprising:
- obtaining an electronic file representing a geometry of the product wherein the product comprises the structural fastener according to any one of claims 1 to 7; and
- 15 controlling an additive manufacturing apparatus to manufacture, over one or more additive manufacturing steps, the product according to the geometry specified in the electronic file.
10. A construction assembly comprising:
- 20 a plurality of assembled construction structures, each construction structure comprising a plurality of connection plates, each connection plate comprising a set of connection holes, and for each construction structure, the connection holes having hole diameters decreasing across the connection plates of the construction structure;
- 25 a connection between the assembled construction structures, the connection comprising a plurality of sets of aligned connection holes; and
- a set of structural fasteners inserted into the connection, each structural fastener comprising an elongated body comprising a plurality of stepped sections, each stepped section defining a cross-sectional diameter, the cross-sectional diameters decreasing along the stepped sections from a head end
- 30 portion to a tail end portion of the elongated body,
- wherein for each structural fastener, the stepped sections are engaged with respective sets of aligned connection holes, each set of aligned connection

holes having hole diameters corresponding to the cross-sectional diameters of the respective stepped section.

11. The construction assembly according to claim 10, wherein the tail end portion
5 of each structural fastener comprises a locking hole for receiving a locking pin.

12. The construction assembly according to claim 11, further comprising a set of locking pins, each locking pin inserted into the locking hole of the respective structural fastener to secure the structural fastener inserted into the connection.

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13. The construction assembly according to claim 11 or 12, wherein each locking pin is a split pin.

14. The construction assembly according to any one of claims 10 to 13, wherein
15 the elongated body of each structural fastener comprises a first stepped section, a second stepped section, and a third stepped section arranged from the head end portion to the tail end portion.

15. The construction assembly according to claim 14, wherein the first stepped
20 section has a cross-sectional diameter of 60 mm, the second stepped section has a cross-sectional diameter of 55 mm, and the third stepped section has a cross-sectional diameter of 50 mm.

16. The construction assembly according to any one of claims 10 to 15, wherein
25 the elongated body of each structural fastener has an overall length of 300 mm.

17. A method for fastening a connection between construction structures, the method comprising:
assembling a plurality of construction structures, each construction
30 structure comprising a plurality of connection plates, each connection plate comprising a set of connection holes, and for each construction structure, the connection holes having hole diameters decreasing across the connection plates of the construction structure;

forming a connection between the assembled construction structures,
the connection comprising a plurality of sets of aligned connection holes; and

arranging a set of structural fasteners for fastening the connection, each
structural fastener comprising an elongated body comprising a plurality of
stepped sections, each stepped section defining a cross-sectional diameter, the
cross-sectional diameters decreasing along the stepped sections from a head
end portion to a tail end portion of the elongated body;

for each structural fastener, partially inserting the structural fastener into
the connection until the stepped sections stop at respective sets of aligned
connection holes, each set of aligned connection holes having hole diameters
corresponding to the cross-sectional diameters of the respective stepped
sections; and

for each partially inserted structural fastener, fully inserting the structural
fastener into the connection, thereby engaging the stepped sections with the
respective sets of aligned connection holes.

18. The method according to claim 17, further comprising, for each structural
fastener, inserting a locking pin into a locking hole of the structural fastener to secure
the structural fastener inserted into the connection.