

BOLLARD

The present disclosure relates to a bollard and a kit of parts for making a bollard.

- 5 Bollards are commonly used to restrict the movement of vehicles. For example, bollards may be sited at the boundary of a road and a pedestrianised area, so as to prevent vehicles entering the pedestrian area. As another example, bollards may be sited near a building, so as to prevent vehicles approaching the building too closely.
- 10 One particular application of bollards is for hostile vehicle mitigation, in which bollards are intended to prevent vehicles being deliberately driven at people, buildings or other objects. Various standards, such as International Standard ISO/IWA 14-1:2013 and British Standard PAS 68:2013, specify the criteria for testing and determining the impact performance of vehicle security barriers for use in hostile vehicle mitigation.
- 15 Such standards require that bollards for use in hostile vehicle mitigation should be capable of stopping heavy vehicles and/or vehicles driven at high speed.

- Some known bollards comprise a metal base with a metal post welded thereto. In use, the post extends upwards to restrict the movement of vehicles. The base is placed
- 20 upon the ground or buried underground, and supports the post in an upright position. A disadvantage of bollards with this construction is that welding creates heat affected zones, which can weaken the post and thereby reduce its ability to withstand vehicular impacts. Another disadvantage of bollards with this construction is that they are difficult to move and store. This disadvantage arises because the post is welded to the
- 25 base in a factory, rather than at the site at which the bollard is installed. However, once the post has been welded to the base, the resulting bollard is heavy and its shape does not allow bollards to be stacked (or otherwise packed in a space-efficient manner) during transportation and storage.

30 Summary

- In accordance with a first aspect, a bollard comprises: a post, wherein the post has a peripheral wall defining an internal volume; a socket configured to receive and support the post; and a ballast material disposed within the internal volume of the post, wherein
- 35 the post and/or socket comprise a formation extending into the internal volume of the

post, and wherein the formation is configured to exert a force upon the ballast material when the bollard receives an impact.

5 Each formation enables the bollard to resist the impact, by transferring the force of the impact to the ballast material. The ballast material increases the rigidity of the post, thus reducing the tendency of the post to deform under the impact. The formation(s) and the ballast material act together to prevent the post being detached from the socket by the impact.

10 Each formation may comprise a surface which can exert a load upon the ballast material when the bollard receives an impact. In some examples disclosed herein, the surfaces are shaped and/or oriented to exert a compressive load on the ballast material when the bollard receives an impact. In such examples, the ballast material has a sufficiently high compressive strength to withstand the compressive load exerted by the
15 formations when the bollard receives an impact from a vehicle with a given mass and speed.

The post optionally comprises a formation extending from the peripheral wall into the internal volume of the post. The presence of a formation on the post stiffens the post,
20 reducing its tendency to deform under the impact and thereby improving the overall ability of the post to withstand the impact. The formation may be attached (e.g., welded) to the peripheral wall along substantially all of its peripheral edge.

The formation on the post optionally comprises an opening through which a formation on the socket extends into the internal volume of the post. This permits assembly of
25 the bollard.

The formation on the post optionally comprises a substantially circular ring. The ring provides a large surface which can bear against the ballast material in an impact. The
30 ring thus helps to withstand the load applied to the bollard by the impact. The formation on the post may comprise a plurality of such rings.

The socket optionally comprises at least one formation.

At least one formation on the socket may comprise a first portion extending from a bottom wall of the socket in a direction substantially parallel to a height of the socket. The first portion of the formation may be a cylindrical wall or a bar. When the socket has a longitudinal axis, the term "parallel to a height of the socket" means "parallel to the longitudinal axis of the socket". However, it will be appreciated that the socket may have an irregular shape that lacks a longitudinal axis.

The formation on the socket optionally further comprises a second portion disposed at an end of the first portion that is distal from the bottom wall of the socket, the second portion extending away from the first portion and towards the peripheral wall of the post.

The second portion may comprise a substantially circular ring. The ring provides a large surface which can bear against the ballast material in an impact. The ring thus helps to withstand the load applied to the bollard by the impact. The formation on the socket may comprise a plurality of such rings.

Alternatively or in addition, the second portion may comprise a hook.

At least one formation on the socket may be an arch-shaped formation extending from a bottom wall of the socket in a direction substantially parallel to a height of the socket.

At least one formation on the socket may be a planar formation extending from a bottom wall of the socket in a direction substantially parallel to a height of the socket.

At least one formation on the socket may be a box-shaped formation extending from a bottom wall of the socket in a direction substantially parallel to a height of the socket.

At least one formation on the socket may be an inverted frustum extending from a bottom wall of the socket in a direction substantially parallel to a height of the socket.

At least one formation on the socket may be a T-shaped formation extending from a bottom wall of the socket in a direction substantially parallel to a height of the socket.

The ballast material optionally comprises a cement. As used herein, the term "cement" refers to a material that sets (in other words, solidifies and hardens) and, in so doing, adheres to other materials. The cement may be, or may comprise, a hydraulic cement (such as Portland cement) or any other suitable hydraulic or non-hydraulic cement.

5 The ballast material may thus be a composite material comprising a cement mixed with one or other materials, such as sand or aggregate. For example, the ballast material may be concrete, grout (e.g., a non-shrink grout) or mortar. The ability of a cement to set and adhere to other materials improves the bollard's ability to withstand impacts. Materials comprising cement have a high compressive strength, which further improves

10 the bollard's ability to withstand impacts.

Alternatively or additionally, the ballast material may comprise other materials with mechanical properties that enable the bollard withstand an impact from a vehicle with a given mass and speed. For example, the ballast material may be, or may comprise,

15 tarmac or asphalt. As another example, the ballast material may be, or may comprise, an epoxy resin. Other materials with a sufficient compressive strength and/or adhesive strength may be used.

The socket optionally comprises a bottom wall having a bore extending therethrough.

20 The bore optionally extends through a formation on the socket. The presence of a bore allows electrical cables to be routed through the bollard.

The socket is optionally attached to a base, the base extending substantially perpendicular to the post. The post thus extends from the base. The socket may transfer the load into the base. The base thus helps the bollard resist the impact. A

25 number of such bollards may extend from the base.

The socket may be welded to the base. The post is preferably not welded to the base, to avoid creating a heat affected zone that could cause failure of the bollard in an

30 impact.

The bollard may be provided in a disassembled form. More specifically, the bollard may be supplied as a kit of parts which can be assembled into a bollard at the location at which the bollard is to be installed. The bollard disclosed herein is particularly suited

35 to being supplied as a kit of parts, because the post is not welded to the socket or the

base. The post is instead secured to the base by the ballast material, which can easily be achieved on a construction site. By supplying the bollard as a kit of parts, its component parts can be more easily transported and stored than if the bollard were to be supplied in an assembled form.

5

In accordance with a second aspect, a kit of parts for making a bollard is provided, the kit of parts comprising a post and a socket as disclosed herein. The kit of parts optionally further comprises a base attached to the socket.

10

Brief Description of the Drawings

Embodiments will now be described, purely by way of example, with reference to the accompanying drawings, in which like features are denoted by like reference signs, and in which:

15

Figure 1 is a side cross-sectional view of a first example of a bollard in accordance with the present disclosure;

Figure 2 is a perspective cross-sectional view of the bollard shown in Figure 1;

Figure 3 is a top view of the bollard shown in Figures 1 and 2;

20

Figure 4 is a side cross-sectional view of the bollard of Figures 1 to 3 when installed;

Figure 5 is a side cross-sectional view of a second example of a bollard in accordance with the present disclosure;

Figure 6 is a perspective cross-sectional view of the bollard shown in Figure 5;

25

Figure 7 is a side cross-sectional view of a third example of a bollard in accordance with the present disclosure;

Figure 8 is a perspective cross-sectional view of the bollard shown in Figure 7;

Figure 9 is a side cross-sectional view of a fourth example of a bollard in accordance with the present disclosure;

30

Figure 10 is a perspective cross-sectional view of the bollard shown in Figure 9;

Figure 11 is a perspective cross-sectional view of a fifth example of a bollard in accordance with the present disclosure;

Figure 12 is a side cross-sectional view of a sixth example of a bollard in accordance with the present disclosure;

Figure 13 is a perspective cross-sectional view of the bollard shown in Figure 12;

Figure 14 is a perspective cross-sectional view of a seventh example of a bollard in accordance with the present disclosure;

5 Figure 15 is a side cross-sectional view of an eighth example of a bollard in accordance with the present disclosure;

Figure 16 is a perspective cross-sectional view of the bollard shown in Figure 15;

10 Figure 17 is a side cross-sectional view of a ninth example of a bollard in accordance with the present disclosure;

Figure 18 is a perspective cross-sectional view of the bollard shown in Figure 17;

Figure 19 is a perspective cross-sectional view of a tenth example of a bollard in accordance with the present disclosure; and

15 Figure 20 is a perspective cross-sectional view of an eleventh example of a bollard in accordance with the present disclosure.

Detailed Description

20 Figures 1 to 4 show a first example of a bollard 100. The bollard 100 comprises a post 110 and a socket 120. Only the lower portion of the post 110 is shown in Figures 1 and 2, as indicated by the dashed line in Figure 1. The post 110 is elongate, and may be of any height. The height of the post 110 is considered to be its length along the longitudinal axis of the post 110, which is parallel to the x axis shown in Figure 1. The
25 height of the post 110 may be chosen based on the size of a vehicle that the bollard 100 is designed to stop. The post 110 comprises a peripheral wall 112, which defines an internal volume 114. In other words, the post 110 is hollow until a ballast material 140 is placed within its internal volume 114, as described in more detail below. The peripheral wall 112 may have any thickness. The thickness of the peripheral wall 112
30 may be chosen to give the post 110 sufficient rigidity to withstand a vehicular impact. The post 110 further comprises a formation 116 extending into the internal volume 114. More specifically, the formation 116 extends from an internal surface of the peripheral wall 112, in a direction substantially perpendicular to both the peripheral wall 112 and the height of the post 110. To put this another way, the formation 116 extends in the
35 y-z plane towards the longitudinal axis of the post 110.

The socket 120 comprises an outer wall 122, an inner wall 124 and a bottom wall 128. The outer wall 122 and inner wall 124 extend from the bottom wall 128 in a direction substantially parallel to the height of the socket 120. The height of the socket 120 is considered to be its length along the longitudinal axis of the socket 120, which is parallel to the x axis shown in Figure 1. The bottom wall 128 joins the outer wall 122 to the inner wall 124. The outer wall 122 and bottom wall 128 define an internal volume (not labelled) of the socket 120, within which the post 110 can be received. The inner wall 124 comprises a ring 125. The ring 125 extends from an external surface of the inner wall 124, in a direction substantially perpendicular to both the inner wall 124 and the height of the socket 120. In other words, the ring 126 extends from the inner wall 124 towards the outer wall 122 of the socket 120. The inner wall 124 and ring 126 collectively make up a formation 125 that extends into the internal volume 114 of the post 110 when the post 110 is fitted into the socket 120.

The post 110 and socket 120 each have an annular cross-section when viewed from above, which can be seen most clearly in Figure 3. The internal diameter of the outer wall 122 of the socket 120 is larger than the external diameter of the post 110, such that one end of the post 110 fits within the socket 120. In this manner, the socket 120 supports the post 110, and holds the post 110 in an upstanding position. The formations 116, 125 also have an annular cross-section when viewed from above, as shown in Figure 3. The internal diameter of the formation 116 is greater than the external diameter of the formation 125, such that the formation 125 can pass through formation 116 when the post 110 is inserted into the socket 120.

A bore 130 extends through the inner wall 124 and the bottom wall 128. The bore 130 allows an electrical cable (not shown) to be routed through the bollard 100. For example, an electrical cable can be routed from the ground under the bollard 100 to one or more lights located on and/or within the post 110. In this manner, the bollard 100 can be illuminated for improved visibility. As another example, the electrical cable can be routed from the ground under the bollard 100 to an electrical outlet (e.g. an electrical socket) on or within the post 110. In this manner, the bollard 100 can be used to charge an electric vehicle or to power other electric devices. It will be appreciated that the bore 130 is not essential to the safety-related functionality of the bollard 100 and, therefore, the bore 130 may be omitted.

A ballast material 140 is disposed within the internal volume 114 of the post 110. The ballast material 140 is indicated by a shaded region in Figure 1, but is omitted from Figures 2 and 3 for the sake of clarity. As shown in Figure 1, the ballast material 140 fills the lower portion of the internal volume 114 of the post 110. At the very least, the ballast material 140 covers both formations 116, 126. In this manner, both formations 116, 126 are embedded within the ballast material 140. The ballast material 140 may optionally fill the internal volume 114 of the post 110 such that it is level with the top of the socket 120, or above the top of the socket 120 as shown in Figure 1. The ballast material 140 may even fill the whole of the internal volume 114 of the post 110. The ballast material 140 may comprise a cement, such that the ballast material sets and adheres to other materials, such as the post 110 and the socket 120. The ballast material 140 may be concrete or grout, for example.

The post 110 and socket 120 may be formed from metal. The metal may be steel or any other metal with sufficient strength to withstand a vehicular impact. The peripheral wall 112 of the post 110, the outer wall 122 of the socket 120 and the inner wall 124 of the socket 120 may be fabricated using any suitable forming process, such as bending a metal sheet, casting or extrusion. Similarly, the bottom wall 128 of the socket 120 the formation 116, and the ring 126 may be fabricated using any suitable forming process, such as laser cutting or stamping from a metal sheet, casting or extrusion.

To fabricate the post 110, the formation 116 is inserted into the internal volume 114 and welded around either or both of its outer circumferential edges, such that the formation 116 is rigidly attached to the inner surface of the peripheral wall 122. Although the formation 116 is recessed from the lower end of the peripheral wall 122 in the example shown in Figures 1 and 2, the formation 116 could be flush with the lower end of the peripheral wall 122.

To fabricate the socket 110, the ring 126 is slid along the inner wall 124 and welded around either or both of its inner circumferential edges, such that the ring 126 is rigidly attached to the outer surface of the inner wall 124. The outer wall 122 and the inner wall 124 are then welded to the bottom wall 128, thereby forming the socket 120. Although the ring 126 is recessed from the upper end of the inner wall 122 in the

example shown in Figures 1 and 2, it will be appreciated that the ring 126 could be flush with the upper end of the inner wall 124.

5 The bollard may further comprise a base 150 to which the socket 120 is fixed, as shown in Figure 4. The purpose of the base 150 is to hold the post 110 and the socket 120 in an upstanding position. The base 150 has an opening 154 with a size and shape corresponding to that of the socket 120, such that the socket 120 fits within the opening 154 in the base 150. The base 150 may be formed from metal, such that the socket 120 can be fixed to the base 150 by welding. In more detail, the socket 120
10 may be inserted into the opening 154 in the base, and then fixed to the base 150 by welding around some or all of the periphery of outer wall 122. The socket 120 may be welded to the lower surface of the base 150, in the regions indicated by reference signs 152a, 152b. Alternatively or additionally, the socket 120 may be welded to the upper surface of the base 150. The post 110 is not welded to either the socket 120 or the base 150, so as to avoid creating a heat affected zone that would weaken the post 110.
15 Although welding may create a heat affected zone in the socket 120 and/or the base 150, it has been found that heat affected zones in these components do not weaken the bollard 100. Welding the socket 120 to the base 150 contributes to the structural integrity of the bollard 100, improving the ability of the bollard 100 to withstand
20 vehicular impacts.

The base 150 may have a substantially rectangular cross-section in the x-y plane, as illustrated in Figure 4. The height of the base 150 along the x axis may be less than the dimensions of the base along the y and z axes. The height of the base 150 may
25 also be less than the height of the socket 120. The base 150 may therefore be relatively shallow along the x axis, which avoids the need to create a deep excavation when installing the base 150 under the surface of the ground. The base 150 may have a square, rectangular, polygonal, circular or irregular peripheral shape when viewed in the y-z plane.

30 An example of a process of installing the bollard 100 will now be described with reference to Figure 4. The site at which the bollard 100 is to be installed is first prepared, for example by digging a trench in the ground. The socket 120 and base 150 are placed within the trench, and the post 110 is then pushed or dropped into the
35 socket 120. The ballast material 140 is then added to the internal volume 114 of the

post 110. For example, the ballast material 140 may be poured or injected into the internal volume 114 through an opening in the top 118 or peripheral wall 112 of the post 110. Finally, the base 150 is covered by a ground surface 160. The ground surface 160 comprises one or more layers of material that collectively form a road, pavement (sidewalk) or the like. For example, the ground surface 160 may comprise concrete, tarmac, aggregates, paving slabs and/or other suitable materials. The top of the ground surface 160 may be level with the top of the socket 120. Alternatively, the top of the ground surface 160 could be below the top of the socket 120 (such that part of the socket 120 protrudes from the ground surface 160) or above the top of the socket 120 (such that the ground surface 160 makes contact with the peripheral wall 112 of the post).

The base 150 need not be installed within a trench or covered by a ground surface 160. In particular, the base 150 could be placed on top of an existing ground surface and left uncovered. This can allow the bollard 100 to be installed more quickly, or installed in a location where it is not possible to dig a trench in which to locate the base 150.

The operating principle of the bollard 100 will now be described with reference to Figure 1. Consider a vehicle travelling towards the bollard 100 in the direction indicated by the arrow v (i.e. in a direction substantially parallel to the y axis). When the vehicle impacts the bollard 100, the vehicle exerts a force on the post 110. The force exerted on the post 110 can be resolved into components along the x , y and z axes. The lower end of the post 110 is constrained by the socket 120 (which, in turn, is constrained by the base 150 and/or the ground) and, therefore, the components of the force in the y and z axes can be ignored for the purposes of understanding the operating principle of the bollard 100. Even though the vehicle travels parallel to the y axis before impacting the bollard 100, the impact causes the vehicle to exert a force on the post 110 along the x axis (i.e. in a direction substantially parallel to the longitudinal axis of the post 110). The x component of the force exerted by the vehicle on the post 110 is indicated by the arrow F in Figure 1, and will be referred to as "force F " in this document. Force F arises due to deformation of the post 110 and/or deformation of the vehicle, either of which could allow the vehicle to ride upwards on the post.

In the absence of the formations 116, 125, a sufficiently large force F would pull the post 110 out of the socket 120, and the bollard 100 may fail to stop the vehicle. The formations 116, 125 resist the tendency of the force F to pull the post 110 out of the socket 120. More specifically, the force F causes each of the formations 116, 125 to exert a reaction force upon the ballast material 140. The reaction force exerted by the formation 116 upon the ballast material 140 is indicated as $R1$ in Figure 1, and the reaction force exerted by the formation 125 upon the ballast material 140 is indicated as $R2$. The reaction forces $R1$, $R2$ will act as compressive forces upon the ballast material 140, which has a high compressive strength. Hence, the formations 116, 125 and ballast material 140 together prevent the post 110 being pulled out of the socket 120 by the force F imparted by a vehicular impact. The ballast material 140 and formation 116 also contribute to the ability of the bollard 100 to withstand a vehicular impact by increasing the rigidity of the post 110, and thereby reducing deformation of the post 110; this reduces the tendency of the vehicle to move upwards on the post 110, which in turn reduces the magnitude of force F .

Whilst Figure 1 shows the reaction forces $R1$, $R2$ acting at the right hand side of the bollard 100, it should be appreciated that the reaction forces $R1$, $R2$ will be distributed over the formations 116, 125. More specifically, because formations 116, 125 encircle the longitudinal axis of the bollard 100, the formation 116 will exert reaction force $R1$ over substantially all of its annular surface(s), and the formation 126 will exert reaction force $R2$ over substantially all of the annular surface(s) of the ring 126. The magnitude and/or direction of the reaction forces $R1$, $R2$ at different points on the formations 116, 125 will vary.

Adhesion of the ballast material 140 to the internal surface of the post 110, the outward-facing surface of the inner wall 124 and the inward facing surface of the bore 130 may also contribute to the reaction forces exerted upon the ballast material 140. However, the reaction force resulting from adhesion of the ballast material 140 to these surfaces makes a lesser contribution to resisting the applied force F than the reaction forces $R1$, $R2$ exerted by the formations 116, 125.

Multiple bollards 100 may be arranged into one or more rows, such the bollards collectively act as a barrier to vehicles. In such examples, the base 150 of each bollard 100 may optionally be joined to the base(s) of one or more adjacent bollards. Joining

the bases 150 of bollards 100 allows the force of a vehicular impact to be transferred to adjacent bollards, thus improving the bollards' overall ability to withstand the impact.

Many different constructions of bollard are possible, all having substantially the same operating principle as discussed above. A few non-limiting examples of such bollards will now be described with reference to Figures 5 to 20. The following explanations of Figures 5 to 20 will focus on the differences with respect to the first example of the bollard 100 shown in Figures 1 to 4 and, therefore, features that are substantially the same as those described in relation to the first example will not be described again.

Figures 5 and 6 show a second example of a bollard 200. The bollard 200 comprises a post 110 and a socket 220. The post 110 is the same as that described in relation to bollard 100. The socket 220 comprises an outer wall 222, an inner wall 224 and a bottom wall 228. The outer wall 222 and inner wall 224 extend from the bottom wall 228 in a direction substantially parallel to the height of the socket 220. The bottom wall 228 joins the outer wall 222 to the inner wall 224. The outer wall 222 and bottom wall 228 define an internal volume (not labelled) of the socket 220, within which the post 110 can be received. The inner wall 224 comprises two rings 226, 227. Each ring 226, 227 extends from an external surface of the inner wall 224, in a direction substantially perpendicular to the height of the socket 220. In other words, the rings 226, 227 extend from the inner wall 224 towards the outer wall 222 of the socket 220. The inner wall 224 and rings 226, 227 collectively make up a formation 225 that extends into the internal volume 114 of the post 110 when the post 110 is fitted into the socket 220. The internal diameter of the formation 116 is greater than the external diameter of the formation 225, such that the formation 225 can pass through formation 116 when the post 110 is inserted into the socket 220. A ballast material 140 is disposed within the internal volume 114 of the post 110. The ballast material 140 is indicated by a shaded region in Figure 5, but is omitted from Figure 6 for the sake of clarity.

The presence of two rings 226, 227 improves the ability of the formation 225 to resist the tendency of an applied force F to pull the post 110 out of the socket 220. This is because the force F causes each of the rings 226, 227 to exert a reaction force upon the ballast material 140. That is, when a vehicle impacts the bollard 200, the formation 116 on the post 110 exerts a reaction force $R1$ upon the ballast material 140, the first ring 226 exerts a reaction force $R2$ upon the ballast material 140, and the second ring

227 exerts a reaction force R_3 upon the ballast material 140. The presence of two rings 226, 227 increases the total reaction force that the formation 225 can exert upon the ballast material 140, and also spreads the reaction force over a greater area so as to avoid failure of the formation 225 and/or the ballast material 140. Furthermore, when the lower ring 227 is positioned proximal to (e.g., at a similar height to, and with a small radial gap therebetween) the formation 116 on the post 112 as shown in Figures 5 and 6, the rigidity of the post 110 is further increased and deformation of the post 110 is further reduced; this further reduces the tendency of the vehicle to move upwards on the post 110, which further reduces the magnitude of force F .

Figures 7 and 8 show a third example of a bollard 300. The bollard 300 comprises a post 310 and a socket 320. The post 310 comprises a peripheral wall 312, which defines an internal volume 314. The post 310 is substantially the same as the post 110 described above, except post 310 does not comprise a formation 116 extending into its own internal volume 314. The socket 320 comprises an outer wall 322, a bottom wall 328 and an arch-shaped formation 325. The arch-shaped formation 325 is a single cylindrical bar that is formed (e.g., by bending a metal bar, or by casting a metal) so as to have two straight legs 324, 327 and an arcuate portion 326 therebetween. In other words, the arcuate portion 326 extends between the legs 324, 327 in a direction substantially perpendicular to the longitudinal axes of the post 310 and socket 320. The lower ends of each leg 324, 327 are attached (e.g., by welding) to the bottom wall 328 of the socket 320. The formation 325 extends into the internal volume 314 of the post 310 when the post 310 is fitted into the socket 320. A ballast material 140 is disposed within the internal volume 314 of the post 310. The ballast material 140 is indicated by a shaded region in Figure 7, but is omitted from Figure 8 for the sake of clarity.

When a vehicle impacts the bollard 300, the formation 325 exerts a reaction force R_2 upon the ballast material 140. The reaction force R_2 is primarily exerted by the arcuate portion 326 of the formation 325. This is because the arcuate portion 326 is oriented substantially perpendicular to the longitudinal axes of the post 310 and socket 320, which causes the arcuate portion 326 to exert a compressive force upon the ballast material 140. Hence, the formation 325 and ballast material 140 together prevent the post 310 being pulled out of the socket 320 by the force F imparted by a vehicular impact. Although the post 310 does not comprise a formation 116 in this example,

adhesion of the ballast material 140 to the internal surface of the post 310 causes the post 310 to exert a reaction force (not illustrated) upon the ballast material 140. However, the reaction force resulting from adhesion of the ballast material 140 to the internal surface of the post 310 makes a lesser contribution to resisting the applied force F than the reaction force R_2 exerted by the formation 325. Whilst Figure 3 shows the reaction force R_2 acting at the centre of the formation 325, it should be appreciated that the reaction force R_2 will be distributed over the surface of the arcuate portion 326. The magnitude and/or direction of the reaction force at different points on the arcuate portion 326 may vary.

Figures 9 and 10 show a fourth example of a bollard 400. The bollard 400 comprises a post 310 and a socket 420. The post 310 is the same as that described in relation to bollard 300. The socket 420 comprises an outer wall 422, a bottom wall 428 and an arch-shaped formation 425. The arch-shaped formation 425 comprises four bars 424a-d that are formed (e.g., by bending a metal bar, or by casting a metal) such that each bar 424a-d has a straight leg and an arcuate portion at its uppermost end. The legs extend substantially parallel to the height of the post 310 and socket 420. The arcuate portions of each bar 424a-d extend in a direction substantially perpendicular to the longitudinal axes of the post 310 and socket 420. The arcuate portions of each bar 424a-d are attached (e.g., by welding) to each other at, or near, the longitudinal axis of the socket 420. The lower ends of the legs of each bar 424a-d are attached (e.g., by welding) to the bottom wall 428. The legs of each bar 424a-d are eccentric with respect to the longitudinal axis of the socket 420, and are substantially equally spaced apart from each other, such that the formation 425 is rotationally symmetric about the longitudinal axis of the socket 420. The formation 425 extends into the internal volume 314 of the post 310 when the post 310 is fitted into the socket 420. A ballast material 140 is disposed within the internal volume 314 of the post 310. The ballast material 140 is indicated by a shaded region in Figure 9, but is omitted from Figure 10 for the sake of clarity.

The operating principle of the fourth example bollard 400 is similar to that of the third example bollard 300, so will not be described again in detail. When a vehicle impacts the bollard 400, the formation 425 exerts a reaction force R_2 upon the ballast material 140. The reaction force R_2 is primarily exerted by the arcuate portions of the bars 424a-d. The presence of multiple arcuate portions in the fourth example bollard 400

improves the ability of the formation 425 to resist the tendency of an applied force F to pull the post 310 out of the socket 420. This is because the formation 425 has a large surface area perpendicular to the axes of the post 310 and socket 420. This increases the total reaction force that the formation 425 can exert upon the ballast material 140, and also spreads the reaction force over a greater area so as to avoid failure of the formation 425 and/or the ballast material 140. Although Figure 9 shows the reaction force R_2 acting at the centre of the formation 425, it should be appreciated that the reaction force R_2 will be distributed over the surface of the arcuate portions. The magnitude and/or direction of the reaction force at different points on the arcuate portions may vary. It will be appreciated the same operating principle will apply if the formation 425 were to be implemented with three bars, or with five or more bars. Hence, variations on the fourth example bollard 400 with three or more bars 424 fall within the scope of the invention as defined by the claims.

Figure 11 shows a fifth example of a bollard 500. The bollard 500 comprises a post 310 and a socket 520. The post 310 is the same as that described in relation to bollard 300. The socket 520 comprises an outer wall 522, a bottom wall 528 and two arch-shaped formations 525a, 525b. Each arch-shaped formation 525a, 525b is substantially the same as the arch-shaped formation 325 discussed above in relation to the third example bollard 300, except the first formation 525a has longer legs than the second formation 525b. Hence, the first formation 525a extends further into the internal volume 314 of the post 310 than the second formation 525b when the post 310 is fitted into the socket 520. The first formation 525a is oriented perpendicular to the second arch-shaped formation 525b with respect to the longitudinal axis of the socket 520. The two formations 525a, 525b are not joined to each other. Instead, the apex of the arcuate portion of the first arch-shaped formation 525a lies above the apex of the arcuate portion of the second arch-shaped formation 525b. A ballast material is disposed within the internal volume 314 of the post 310, but is not shown in Figure 11 for the sake of clarity.

The operating principle of the fifth example bollard 500 is similar to that of the third example bollard 300. The presence of two formations 525a, 525b in the fifth example bollard 500 improves the ability of the bollard 500 to resist the tendency of an applied force (not illustrated) to pull the post 310 out of the socket 520. This is because the two formations 525a, 525b collectively have a larger surface area perpendicular to the

axes of the post 310 and socket 520 than the single formation 325 of the third example bollard 300. This increases the total reaction force that the formations 525a, 525b can exert upon the ballast material, and also spreads the reaction force over a greater area so as to avoid failure of the formations 525a, 525b and/or the ballast material. It will be appreciated the same operating principle will apply if the fifth example bollard 500 were to be implemented with three or more arch-shaped formations. Hence, variations on the fifth example bollard 500 with three or more arch-shaped formations fall within the scope of the invention as defined by the claims.

Figures 12 and 13 show a sixth example of a bollard 600. The bollard 600 comprises a post 310 and a socket 620. The post 310 is the same as that described in relation to bollard 300. The socket 620 comprises an outer wall 622, a bottom wall 628 and four formations 625a-d. Each formation 625a-d has a straight leg and an arcuate portion at its uppermost end. As shown in Figures 12 and 13, each formation 625a-d has the shape of a hook. The legs of each formation 625a-d extend substantially parallel to the height of the post 310 and socket 620. The arcuate portions of each formation 625a-d extend in a direction substantially perpendicular to the longitudinal axes of the post 310 and socket 320. Unlike the bars 424a-d of the fourth example bollard 400, the formations 625a-d of the sixth example bollard 600 extend outwards towards the outer wall 622 of the socket 620. The arcuate portions of the formations 625a-d are not joined to each other. The lower ends of the legs of each formation 625a-d are attached (e.g., by welding) to the bottom wall 628. The legs of each formation 625a-d are eccentric with respect to the longitudinal axis of the socket 620, and are substantially equally spaced apart from each other, such that the formations 625a-d are rotationally symmetric about the longitudinal axis of the socket 620. The formations 625a-d extend into the internal volume 314 of the post 310 when the post 310 is fitted into the socket 620. The formations need not have the exact shape shown in Figures 12 and 13. For example, the “hook” at the end of each formation 625a-d may have a greater (or lesser) angular extent, or the arcuate portion could be replaced by a straight portion extending at an angle (e.g., at ninety degrees or any other suitable angle) from the leg of a formation 625a-d. A ballast material 140 is disposed within the internal volume 314 of the post 310. The ballast material 140 is indicated by a shaded region in Figure 12, but is omitted from Figure 13 for the sake of clarity.

The operating principle of the sixth example bollard 600 is similar to that of the third example bollard 300. When a vehicle impacts the bollard 600, each formation 625a-d exerts a respective reaction force R2-R4 upon the ballast material 140. (The reaction force exerted by formation 625d is not shown in the figures.) The reaction forces R2-R4 are primarily exerted by the arcuate portions of the formations 625a-d. The presence of multiple arcuate portions improves the ability of the bollard 600 to resist the tendency of an applied force F to pull the post 310 out of the socket 620. This is because the four formations 625a-d collectively have a larger surface area perpendicular to the axes of the post 310 and socket 620 than the single formation 325 of the third example bollard 300. This increases the total reaction force that the formations 625a-d can exert upon the ballast material 140, and also spreads the reaction force over a greater area so as to avoid failure of the formations 625a-d and/or the ballast material 140. Although Figure 12 shows the reaction forces R2-R4 acting at the ends of the formation 625a-d, it should be appreciated that the reaction forces will be distributed over the surfaces of the arcuate portions. The magnitude and/or direction of the reaction force at different points on the arcuate portions may vary.

A further advantage of the sixth example bollard 600 is that the formations 625a-d are simple to fabricate. For example, the formations 625a-d can easily be fabricated by cutting and bending a metal bar. Furthermore, the formations 625a-d do not need to have a precise shape or dimensions, and each formation 625a-d has only a single point of attachment to the bottom wall 628. It will be appreciated the same operating principle will apply if the sixth example bollard 600 were to be implemented with a different number of formations 625. Hence, variations on the sixth example bollard 600 with any number of formations 625 (in other words, with one or more formations 625) fall within the scope of the invention as defined by the claims.

Figure 14 shows a seventh example of a bollard 700. The bollard 700 comprises a post 310 and a socket 720. The post 310 is the same as that described in relation to bollard 300. The socket 720 comprises an outer wall 722, a bottom wall 728 and an arch-shaped formation 725. The formation 725 is a single member that is formed (e.g., by laser cutting or stamping a metal sheet, or by casting a metal) so as to have two straight legs 724, 727 and a straight arm 726 therebetween. In other words, the arm 726 extends between the legs 724, 727 in a direction substantially perpendicular to the longitudinal axes of the post 310 and socket 720. The lower ends of each leg 724, 727

are attached (e.g., by welding) to the bottom wall 728 of the socket 720. The formation 725 extends into the internal volume 314 of the post 310 when the post 310 is fitted into the socket 720. A ballast material is disposed within the internal volume 314 of the post 310, but is not shown in Figure 14 for the sake of clarity.

5

The operating principle of the seventh example bollard 700 is the same as that of the third example bollard 300. A further advantage of the seventh example bollard 700 is that the formation 725 can be easily fabricated by laser cutting or stamping a metal sheet.

10

Figures 15 and 16 show an eighth example of a bollard 800. The bollard 800 comprises a post 310 and a socket 820. The post 310 is the same as that described in relation to bollard 300. The socket 820 comprises an outer wall 822, a bottom wall 828 and a planar formation 825. The planar formation 825 is in the shape of a trapezium when viewed in the x-y plane. The formation 825 comprises a plurality of through holes 826 (in this case, six through holes). The formation 825 extends into the internal volume 314 of the post 310 when the post 310 is fitted into the socket 820. More specifically, the two parallel surfaces of the trapezium extend in a direction substantially perpendicular to the longitudinal axes of the post 310 and socket 820, whilst the two non-parallel surfaces of the trapezium extend generally along the length of the post 310 and socket 820 but at an angle to the longitudinal axes thereof. The lower parallel surface of the trapezium is attached (e.g., by welding) to the bottom wall 828 of the socket 820. A ballast material 140 is disposed within the internal volume 314 of the post 310. The ballast material 140 is indicated by a shaded region in Figure 15, but is omitted from Figure 16 for the sake of clarity.

25

When a vehicle impacts the bollard 800, the formation 825 exerts a reaction force (not illustrated in the drawings) upon the ballast material 140. The reaction force is primarily exerted by the non-parallel surfaces of the trapezium and by the internal surfaces of the holes 828. Adhesion of the ballast material 140 to the other surfaces of the formation 825 may also contribute to the reaction force. The operating principle of the eighth example bollard 800 is otherwise similar to that of the third example bollard 300, so need not be described in detail. A further advantage of the eighth example bollard 800 is that the formation 825 can be easily fabricated by laser cutting or stamping a metal sheet. The formation 825 need not have a trapezium shape.

35

However, it is beneficial for the formation to have at least one surface (such as the non-parallel surfaces of the trapezium) that faces towards the bottom wall 828 of the socket 820 in order to exert a reaction force upon the ballast material. The formation 825 could have any number of through holes 826 (including only one through hole), or may not have holes at all. Alternatively, the through holes 826 could be replaced or supplemented by protrusions extending from the formation 825.

Figures 17 and 18 show a ninth example of a bollard 900. The bollard 900 comprises a post 310 and a socket 920. The post 310 is the same as that described in relation to bollard 300. The socket 920 comprises an outer wall 922, a bottom wall 928 and a box-shaped formation 925. The box-shaped formation 925 has four walls extending substantially parallel to the height of the post 310 and socket 920. The formation 925 comprises a plurality of through holes 926 (in this case, three through holes on each wall). The formation 925 extends into the internal volume 314 of the post 310 when the post 310 is fitted into the socket 920. The lower edges of the formation 925 are attached (e.g., by welding) to the bottom wall 928 of the socket 920. A ballast material 140 is disposed within the internal volume 314 of the post 310. The ballast material 140 is indicated by a shaded region in Figure 17, but is omitted from Figure 18 for the sake of clarity.

When a vehicle impacts the bollard 900, the formation 925 exerts a reaction force (not illustrated in the drawings) upon the ballast material 140. The reaction force is primarily exerted by the internal surfaces of the holes 928. Adhesion of the ballast material 140 to the other surfaces of the formation 925 may also contribute to the reaction force. The operating principle of the ninth example bollard 900 is otherwise similar to that of the third example bollard 300, so need not be described again in detail. A further advantage of the ninth example bollard 900 is that the formation 925 can be easily fabricated by laser cutting or stamping a metal sheet, followed by bending the resulting cut-out portion. The formation 925 need not have exactly four walls, and could have two, three, five or more walls. The formation 925 could have any number of through holes 926 (including only one through hole), or may not have holes at all. Alternatively, the through holes 926 could be replaced or supplemented by protrusions extending from the formation 925.

Figure 19 shows a tenth example of a bollard 1000. The bollard 1000 comprises a post 310 and a socket 1020. The post 310 is the same as that described in relation to bollard 300. The socket 1020 comprises an outer wall 1022, a bottom wall 1028 and a formation 1025. The formation 1025 is in the form of an inverted frustum. That is, the formation 1025 is frustoconical and tapers towards the bottom wall 1028 of the socket 1020. The formation 1025 comprises a bore 1030, which has the same functionality as the bore 130 of the first example bollard 100. The formation 1025 extends into the internal volume 314 of the post 310 when the post 310 is fitted into the socket 1020. The lower edge of the formation 1025 is attached (e.g., by welding) to the bottom wall 1028 of the socket 1020. A ballast material is disposed within the internal volume 314 of the post 310, but is not shown in Figure 19 for the sake of clarity.

When a vehicle impacts the bollard 1000, the formation 1025 exerts a reaction force (not illustrated in the drawings) upon the ballast material. The reaction force is primarily exerted by the tapering surfaces of the formation 1025. The operating principle of the tenth example bollard 1000 is otherwise similar to that of the third example bollard 300, so need not be described again in detail. The bore 1030 may be omitted from the formation 1025.

Figure 20 shows an eleventh example of a bollard 1100. The bollard 1100 comprises a post 310 and a socket 1120. The post 310 is the same as that described in relation to bollard 300. The socket 1120 comprises an outer wall 1122, a bottom wall 1128 and a formation 1125. The formation 1125 is T-shaped. That is, the formation 1125 comprises a straight leg 1124 extending in a direction substantially parallel to the longitudinal axes of the post 310 and socket 1120, and a straight crosspiece 1123 extending in a direction substantially perpendicular to those axes. The lower end of the leg 1124 is attached (e.g., by welding) to the bottom wall 1028 of the socket 1120, and the upper end of the leg 1124 is attached (e.g., by welding) to the centre of the crosspiece 1123. The formation 1125 extends into the internal volume 314 of the post 310 when the post 310 is fitted into the socket 1120. A ballast material is disposed within the internal volume 314 of the post 310, but is not shown in Figure 20 for the sake of clarity.

When a vehicle impacts the bollard 1100, the formation 1125 exerts a reaction force (not illustrated in the drawings) upon the ballast material 140. The reaction force is

primarily exerted by the crosspiece 1123 of the formation 1125. The operating principle of the eleventh example bollard 1100 is otherwise similar to that of the third example bollard 300, so need not be described again in detail.

- 5 Any of the bollards disclosed herein can comprise a base to which their respective sockets are fixed, as described in relation to Figure 4. Furthermore, any of the bollards disclosed herein can be installed in the manner described in relation to Figure 4.

10 Eleven non-limiting examples of bollards in accordance with the present disclosure have thus been described. It will be appreciated that numerous variations upon these examples are possible within the scope of the invention. For example, any of the bollards may comprise a hole (such as a bore) extending through the bottom wall of their sockets to allow an electrical cable (not shown) to be routed through the bollard. As another example, a single socket may have any one or more of the different types
15 of formation 125, 225, 325, 425, 525, 625, 725, 825, 925, 1025, 1125 in combination; in such examples, different types of formation may be attached to different positions on the bottom wall of the socket.

20 The posts 110 and 310 are interchangeable. More specifically, the third to eleventh example bollards may comprise post 110 instead of post 310. The presence of a formation 116 on the post 110 can further improve the third to eleventh example bollards' ability to withstand a vehicular impact. Conversely, the first and second example bollards may comprise post 310 instead of post 110. Post 110 may be modified by including multiple formations 116 at different points along the height of the
25 post 110.

30 In the examples of bollards illustrated herein, the formations 125, 225, 325, 425, 525, 625, 725, 825, 925, 1025, 1125 do not extend beyond the top of the socket 120, 220, 320, 420, 520, 620, 720, 820, 920, 1020, 1120. In other words, the height of the socket along the x axis is greater than the height of the formation(s) along the x axis. This is advantageous because it facilitates space-efficient packing of the sockets during storage and transportation, and also reduces the risk of the formations being damaged during storage, transportation and installation. However, the invention is not limited to such arrangements, and the formations could protrude out of the socket.

35

It is expressly contemplated that any of the sockets 120, 220, 320, 420, 520, 620, 720, 820, 920, 1020, 1120 may not comprise an outer wall 122, 222, 322, 422, 522, 622, 722, 822, 922, 1022, 1122. In such implementations, ground surface 160 would contact the exterior of the peripheral wall of the post 110, 310 when the bollard is installed. The bottom wall 128, 228, 328, 428, 528, 628, 728, 828, 928, 1028, 1128 of the socket 120, 220, 320, 420, 520, 620, 720, 820, 920, 1020, 1120 be welded or otherwise secured to the lower surface of the base 150.

All of the examples of bollards illustrated herein have a circular cross-section when viewed from above. The invention is not limited to bollards with circular cross-sections. The techniques disclosed herein can also be applied to bollards with oval, square, rectangular, polygonal, or irregular cross-sections.

It will be understood that the invention has been described above purely by way of example, and that modifications of detail can be made within the scope of the claims.

CLAIMS

1. A bollard comprising:
a post, wherein the post has a peripheral wall defining an internal volume;
5 a socket configured to receive and support the post; and
a ballast material disposed within the internal volume of the post,
wherein the post and/or socket comprise a formation extending into the internal
volume of the post, and wherein the formation is configured to exert a force upon the
ballast material when the bollard receives an impact.
- 10 2. A bollard in accordance with claim 1, wherein the post comprises a formation
extending from the peripheral wall into the internal volume of the post.
- 15 3. A bollard in accordance with claim 2, wherein the formation on the post
comprises an opening through which a formation on the socket extends into the
internal volume of the post.
- 20 4. A bollard in accordance with claim 2 or claim 3, wherein the formation on the
post comprises a substantially circular ring.
5. A bollard in accordance with any of the preceding claims, wherein the socket
comprises at least one formation.
- 25 6. A bollard in accordance with claim 5, wherein at least one formation on the
socket comprises a first portion extending from a bottom wall of the socket in a
direction substantially parallel to a height of the socket.
- 30 7. A bollard in accordance with claim 6, wherein the formation on the socket
further comprises a second portion disposed at an end of the first portion that is distal
from the bottom wall of the socket, the second portion extending away from the first
portion and towards the peripheral wall of the post.
- 35 8. A bollard in accordance with claim 7, wherein the second portion comprises a
substantially circular ring.

9. A bollard in accordance with claim 7, wherein the second portion comprises a hook.
10. A bollard in accordance with any of claims 5 to 9, wherein at least one formation on the socket is an arch-shaped formation extending from a bottom wall of the socket in a direction substantially parallel to a height of the socket.
11. A bollard in accordance with any of claims 5 to 10, wherein at least one formation on the socket is a planar formation extending from a bottom wall of the socket in a direction substantially parallel to a height of the socket.
12. A bollard in accordance with any of claims 5 to 11, wherein at least one formation on the socket is a box-shaped formation extending from a bottom wall of the socket in a direction substantially parallel to a height of the socket.
13. A bollard in accordance with any of claims 5 to 12, wherein at least one formation on the socket is an inverted frustum extending from a bottom wall of the socket in a direction substantially parallel to a height of the socket.
14. A bollard in accordance with any of claims 5 to 13, wherein at least one formation on the socket is a T-shaped formation extending from a bottom wall of the socket in a direction substantially parallel to a height of the socket.
15. A bollard in accordance with any of the preceding claims, wherein the ballast material comprises a cement.
16. A bollard in accordance with any of the preceding claims, wherein the socket comprises a bottom wall having a bore extending therethrough.
17. A bollard in accordance with claim 16, wherein the bore extends through a formation on the socket.
18. A bollard in accordance any of the preceding claims, wherein the socket is attached to a base, the base extending substantially perpendicular to the post.

19. A kit of parts for making a bollard in accordance with any of the preceding claims, the kit of parts comprising the post and the socket.

5 20. A kit of parts in accordance with claim 19, the kit of parts further comprising a base attached to the socket.