Title of the Invention: Raising bollards
Abstract Title: Raisable security bollard

The security bollard, for preventing vehicular access, comprises an enclosure 12 and an impact post that comprises a foot box 14 within which at least one spring steel impact element 16 is partially received. A pivot element 18 is configured to allow pivotal movement of the foot box with respect to the enclosure between a first position in which the post is fully contained within the enclosure in a horizontal orientation and a second position in which at least one impact element extends substantially vertically from the enclosure, with an actuator 42,44 acting to pivot the post between the two positions. Load spreader bars 20,22 may be located on the enclosure. The pivot element may comprise a pin rotatably located in sidewalls of the enclosure and attached to an external surface of the foot box. The actuator may be hydraulic or comprise an electric motor. The enclosure is preferably embedded in concrete.
Raising Bollards

This invention relates to raising bollards, in particular this invention relates to raising security bollards that can withstand a large impact from a vehicle.

With the rising incidence of terrorist attack it is beneficial for sensitive premises, or those that are otherwise considered at high risk to be surrounded by a barrier that is impenetrable to vehicles. While there are a number of solutions for providing static security systems there is often a need for vehicles to pass the barrier, for example for carrying out maintenance in areas not usually accessible but the main gateway to the premises. In such instances it is desirable for a raising bollard that can be moved between a retracted position and a raised position to be provided.

Raising bollards are well known in the art. The most basic of these simply comprise a plate having a plain steel post pivotally attached thereto. When the bar is raised a pin or the like is inserted to maintain the post in an upright position. While effective for preventing inadvertent access such bollards are not secure and will simply be broken or ripped from the ground by vehicular impact. Although these bollards obstruct an entranceway they cannot be considered as security bollards. As used herein security bollards are considered to be bollards that will withstand BSI PAS 68-2010 testing.

Other known raising bollards that can be considered security bollards comprise deep subterranean housings into which a bollard is vertically retractable by means of a hydraulic ram. While it is possible to manufacture such bollards to withstand considerable impact this requires a deep footing, typically in excess of two times the above ground height of the bollard and large powerful hydraulic rams. Typically these types of bollards that are designed to withstand high impact, i.e. being rammed by a vehicle which could be 7500kg or more, extend around two meters into the ground. An example of such a bollard is the SCIMITAR SB970 CR security bollard marketed by Avon Barrier Company Ltd. which requires a 2000mm deep hole to be excavated for the bollard foundation in order to meet the impact requirements.

Such raising bollards that meet tough BSI PAS68-2010 requirements are typically prohibitively expensive, not only in capital cost but also in installation due to the deep foundations that are needed. Foundations of in excess of one meter are required for
known solutions and such foundation depth frequently interferes with other services, for example subterranean services, for example communication cables, sewers, drains, gas etc. As such installation of known bollards, in particular in built up areas is inherently problematic.

It is the purpose of the present invention to provide an improved security bollard that overcomes some of the problems of the known solutions.

According to the invention there is provided a raising security bollard comprising: an enclosure; an impact post comprising a foot box and at least one spring steel impact member partially received in said foot box, a pivot member configured to allow pivotal movement of said foot box with respect to said enclosure between a first position in which the post is fully contained within the enclosure in a substantially horizontal orientation and a second position in which said at least one impact member extends substantially vertically from said enclosure; and actuator means for pivoting said impact post between said first and second positions. The foot box provides a strong base to the post and the use of a spring steel impact post allows for impact energy to be adsorbed.

In use the enclosure is embedded in the ground, preferably in a solid bedding material such as concrete.

The raising security preferably further comprises a first spring steel load spreader bar traverse the enclosure and extending to either side thereof, said load spreader bar located in a position adjacent an upper surface of said enclosure such that, when the impact post is in its second position the foot box substantially abuts the first load spreader bar. The impact post has an impact acing side and the first load spreader bar may substantially abut the foot box on a side of the impact post opposite the impact facing side.

The raising security bollard preferably further comprises a second spring steel load spreader bar traverse the bollard enclosure and extending to either side thereof, said load spreader bar located adjacent an lower surface of said bollard enclosure in a position such that, when the bollard is in its second position, the foot box substantially
abuts the second load spreader bar. The second load spreader bar preferably substantially abuts the foot box on the impact facing side of the impact post.

The first and second load spreader bars provide resistance to the turning motion imparted on the post when it is subject to an impact and are provided at the points of greatest force concentration, i.e. substantially at ground level on the side away from the impact such that the first load spreader bar resists movement of the post in the direction away from the impact at ground level and substantially at the lowermost point of the post on the side facing the impact to resist movement of the lowermost end of the impact post towards the impact as the impact attempts to pivot the post backwards against the first load spreader bar. The use of spring steels for these elements enables energy to be adsorbed in the bars and distributed along the length of the load spreader bars into the material, e.g. concrete, in which the enclosure is embedded.

In one arrangement the foot box is separated from the second load spreader bar by sheet of steel. This does not impact upon the function of the post as the load is directly transmitted from the foot box to the load spreader place via the sheet of steel. This sheet of steel may be part of an attachment to the foot box.

In one arrangement the bollard may further comprises a load spreader bar enclosure extending to either side of the enclosure in which said second load spreader bar is slideably located. The load spreader bar enclosure may extend a sufficient distance to one side of the enclosure such that the second load spreader bar can be slid into said load spreader bar enclosure to allow maintenance access to said foot box when said post is in its second position, for example it may enable access to the steel plate mentioned above such that the steel plate can be removed.

The pivot member may be located vertically above the second impact bar. In one arrangement the pivot member can comprise a pivot pin rotatable located in sidewalls of the enclosure and may be attached to an external surface of the foot box. The pivot pin is may be attached to the foot box by a removable spring steel clamp plate, said spring steel clamp plate dimensioned such that tightening it against said foot box deforms the spring steel clamp plate so as to clamp said pivot pin thereeto. A part of the spring steel clamp plate may form the steel sheet that separates the foot box from the second load spreader bar.
The pivot pin may comprise two end sections, each of which are insertable into a recess in the enclosure side walls, and a central joining section, and wherein said spring steel clamp plate clamps said pivot pin sections together. In this manner the end sections of the pivot pin, which extends into the sidewalls of the enclosure to pivot therein (preferably in bearings) can be inserted from the interior of the enclosure thereby enabling maintenance of the pivot pin after the enclosure is embedded in, for example concrete, and the central joining section can then be applied.

In one arrangement the actuator means may comprise at least one hydraulic actuator. The actuator means may comprise a hydraulic wedge for performing an initial rotation of said impact post towards said second position and a hydraulic ram for performing a further rotation of said impact post into said second position. The hydraulic wedge and said hydraulic ram may be connected to a common supply of hydraulic fluid such that the resistance against said hydraulic ram in said first position causes preferential flow of hydraulic fluid to said hydraulic wedge to cause said initial rotation and, as said resistance against said hydraulic ram reduces due to said initial rotation said hydraulic fluid flows to said hydraulic ram so as to cause said second rotation. The security bollard may comprise a hydraulic pump having a connection means extending therefrom for attachment to a portable pump drive.

In another arrangement the actuator means may comprises a first drive cog attached to said pivot member, an electrically powered motor having a second drive cog, and a chain connecting said first and second drive cogs.

The enclosure may be elongate and may comprises two elongate side walls, an elongate bottom face, two end faces and a lid extending at least partially along a substantially open top face. The lid may comprise a support bar attached to a lower surface thereof such that when said lid is in a closed position said support bar is closely received in recesses in the upper edge of both side faces of the enclosure such that with the impact post in the second position the support bar is substantially adjacent the impact facing side of the impact post. After impact the support bar prevents substantial recoil of the spring steel impact post which could otherwise damage the lid.
The enclosure may further comprise at least one torque plate extending perpendicular to each side face in a vertical orientation and/or at least one torque plate extending perpendicular to each side face in a horizontal orientation.

The raising security bollard can comprise a concrete bed in which said enclosure is embedded such that the upper surface of said bollard enclosure is substantially flush with a top face of the concrete bed. In one arrangement the upper surface of the enclosure protrudes slightly from the top of said concrete bed and said concrete bed is provided with a chamfer leading up from its top face to the upper surface of the enclosure. A rebar (steel reinforcing bar) cage may be provided surrounding said bollard enclosure within said concrete bed.

Specific embodiments of the invention are described below, without limitation, with reference to the accompanying drawings in which:

Figure 1 is a side view of a raising security bollard of the invention;

Figure 2 is a top view of a raising security bollard of the invention;

Figure 3 is a top view of a foot box of the impact post of the invention;

Figure 4 is a diagram of a pivot pin of the invention;

Figure 5 is a side view of a pivot pin clamp plate of the invention;

Figure 6 is a perspective view of the bollard and its foundation with the bollard in its second position;

Figure 7 is a perspective view of a rebar cage for use in the foundation; and

Figure 8 is a partial top view of an electrical drive mechanism for the invention.

Referring to Figures 1 to 5 a raising security bollard 10 is shown. The bollard comprises an enclosure 12 which is a substantially open topped rectangular box approximately
400mm deep and 300mm wide. The length can vary dependant upon the length of the bollard but may be in the region of 1500mm to 2000mm.

An impact post comprising a foot box 14 and a plurality of impact members 16 is pivotally located in the enclosure by a pivot pin 18. The impact post can rotate about a central axis of the pivot pin 18 between a first position in which it is substantially horizontal and is contained within the enclosure 12 and a vertical position (as shown in Figure 1) in which the impact members 16 extend vertically from the foot box 14. The impact post has an impact facing side "A". In use the raising bollard is installed such that in the second position the impact facing side "A" faces the direction from which an impact is expected to occur.

Two load spreader bars 20, 22, both made of spring steel, are provided as part of the enclosure 12. A first load spreader bar 20 is provided substantially adjacent to and extending traverse the top of the enclosure 12 and projecting to either side thereof. As can be seen, when the impact post is rotated into the second position the side of the foot box 14 opposite the impact facing side "A" abuts the load spreader bar 20. A second load spreader bar 22 is provided substantially adjacent to and extending traverse the bottom of the enclosure 12, and projecting to either side thereof. The second load spreader bar 22 is housed in a load spreader bar enclosure 24 that extends from either side of the enclosure 12. The load spreader bar is a close fit within the load spreader bar enclosure 24 but is able to slide along its longitudinal axis when the impact post is not fully in its second position. The load spreader bar enclosure 24 is of sufficient length on at least one side of the enclosure 12 that the load spreader bar 22 can be moved into it in a manner such that the front of the foot box 14 can be accessed as necessary for maintenance with the impact post in, or substantially in, the second position, without being obscured by the second load spreader bar 22.

As shown the impact members are of different heights, increasing in height towards the impact facing side "A" of the impact post. This enables a graduated spring stiffness increasing towards the bottom of the post. The impact members 16 are not attached to one another in the area extending above the foot box 14. As can be seen in Figure 3 the foot box 14 is substantially rectangular. The foot box is made of steel section and has a bottom plate welded thereto. Spacer plates are located inside the foot box. These may be integrally formed as part of the section extrusion or may be placed in the interior of
the box 14. The impact members 16 are inserted into the box and the spaces between
the impact members and the foot box 14 are filled with grout so as to secure them in
place.

5 The pivot pin 18 is attached to the impact facing side "A" of the foot box 14 by a spring
steel clamp plate 26. The clamp plate 26 is bolted to tapped holes in the foot box 14
and is made slightly undersize in comparison to the pivot pin 18 such that tightening of
the clamp plate 26 to the foot box 14 securely clamps the pivot pin thereto.

10 The pivot pin 18 comprises three sections, two end sections 28 and a central section
30. The sections are slotted such that they can fit together to form a continuous
cylindrical pin 18, although it will be appreciated that, providing the end portions, which
rotate in bushes (omitted for clarity) provided in the side walls of the enclosure 12, are
circular in cross section the central section of the pin 18, and the associated shape of
the clamp plate 26 may be varied without departing from the invention. As shown the
end sections 28 have internal passageways 34 therein and grease nipples 32, such
that grease can be distributed to the end portions of the pin that, in use, are located for
rotation within the abovementioned bushes.

20 As shown in Figure 1 a part of the clamp plate 26 extends between the foot box 14 and
the second load spreader bar 22 24 to, under impact, transmit force from the foot box
14 to the load spreader bar 22.

25 A two part lid is provided to the enclosure 14 comprising a hinged lid 36 which can be
rotated to open the main part of the enclosure, and a removable lid 38, removable once
the hinged lid 36 is opened, covering the area of the enclosure 12 from which the
impact post projects when it is in the second position. In this manner with the impact
post in its first position both lid parts 36, 38 are in place and the impact post is fully
enclosed. Latches may be provided to prevent unauthorised access. With the impact
post in the second position the removable lid 38 can be placed in the area of the
enclosure vacated by the impact post and the hinged lid can be replaced, thereby
covering the recess of the enclosure 12. It will be appreciated that the removable lid 38
may also be hinged but as, in the open position it may present a trip hazard it is
preferably removable.
Located on the underside of the hinged lid 36 is a support bar 40 that, with the lid 36 in the closed position, traverses the enclosure 12 and locates in recesses on either side thereof. The support bar 40 is made of steel, preferably spring steel. In use, after an impact, the support members will recoil in the direction of the impact facing side "A". As the hinged lid 36 is relatively thin there is a risk that the recoil could damage the lid. The support bar 40, which is located at the edge of the lid 36 immediately adjacent the impact facing side "A" of the impact post when it is in the second position, receives any recoil impact and distributes it into the sidewalls of the enclosure 12.

Located within the enclosure 12 are two hydraulic actuators 42, 44, a hydraulic pump 46, and hydraulic pipes 48 connecting the hydraulic pump and the actuators.

One of the hydraulic actuators is a hydraulic wedge 42 and the other hydraulic actuator is a hydraulic ram 44. The hydraulic pump 46 may be electronically driven but in the arrangement shown is adapted for manual operation. A gearbox 50 is provided having an output attached to the hydraulic pump 46 and an input shaft that can be connected to a hand held cordless drill, for example by a standard hex socket arrangement. In use an operator attaches the socket of the cordless drill to the shaft (which will have a hexagonal profile), and by powering the drill can operate the hydraulic pump 46. This enables each security bollard to be individually manually raised or lowered without the need for power or control wiring or the like being routed to the bollards. This is particularly advantageous in remote locations.

With the impact post in the first position, the angle of the hydraulic ram 44, which is pivotally fixed at one end to the bottom of the enclosure 12, is not sufficient to lift the impact post. Although the pivot pin 18 could be located higher and the enclosure 12 extend in the upwards direction, or the enclosure extended in a downwards direction to obtain an angle sufficient for the hydraulic 44 ram to move the impact post from its first position, to do so would require the enclosure to penetrate deeper into the ground. Deeper excavations for installing the bollard 10 not only are more costly but increase the likelihood of interfering with pre-existing subterranean installations such as service pipes or cables and are therefore undesirable.

In order to raise the impact post from as shallow as possible an enclosure 12 a hydraulic wedge 42 is provided. Both the wedge 42 and the ram 44 are connected to
the same hydraulic pump 46. When the pump 46 is operated the hydraulic fluid takes
the path of least resistance. As the ram 44 has a high initial resistance the wedge
operates first and its vertical height increases. As the wedge 42 expands it bears upon
the foot box 14, or alternatively on a plate or block attached thereto, and causes an
initial rotation of the impact post about the axis of the pivot pin. As the impact post
rotates and raises from the enclosure the resistance to the extension of the ram 44
decreases and fluid starts to flow to the ram 44 thereby extending it. This may occur
once the wedge is fully extended or may occur part way through the extension of the
wedge 42. Continued pumping of hydraulic fluid causes the hydraulic ram 44 to
continue to extend, thereby rotating the impact post until it is full in its second position
as depicted in Figure 1.

Reverse operation of the pump 46 will lower the impact post from the second position
back into the first position. The bollard can therefore be raised and lowered as
required.

It will be appreciated that the pivot pin is located with respect to the foot box 14 such
that rotation of the foot box about the axis of the pivot pin does not interfere with the
first 20 or second 22 load spreader bars, and that with the impact post in the second
position the foot box 14 is immediately adjacent and in direct or indirect contact with the
load spreader bars 20, 22.

A drain pipe 52 is provided at either end of the enclosure 12 so that any water ingress
may drain therefrom. Water may be extracted, for example by a pump but preferably,
as the depth of the enclosure 12 is less than the depth of most drains, a tube or pipe
can be provided to route any water from the drain pipe 52 to a municipal drain under
the influence of gravity.

Further plates 54, 56 one extending vertically and one extending horizontally extend
from either side of the enclosure 12. These plates assist in anchoring the enclosure 12
in the bed of concrete or other material in which they are embedded and also assist in
distributing the forces of any impact through the bed.

Referring now to Figures 6 and 7, as described above, in use the bollard is set in a
concrete foundation 58. Although the foundation could be of any size it is preferable to
maintain the foundation as small as possible for ease of installation. In the embodiment described in these Figures the enclosure 12 is 1800mm long by 300mm wide and is located in a foundation 58 which is 2000mm long by 1000mm wide and is only 400mm deep. By maintaining the foundation only 400mm deep it can be installed without interfering with pre-existing subterranean cables, sewers etc which are usually laid deeper than 400mm. In order to strengthen the foundation 58 a rebar (reinforced steel bar) cage 60 is provided. Figure 7 shows a preferred rebar cage as tested. The rebar cage comprises four rectangular rebar loops 62, 2000mm by 290mm, six rectangular rebar loops 64, 16mm by 300mm, and eight rebar rods 66, 800mm long. The cage 60 is welded together as shown.

To install the bollard a trench 450mm deep, by 2000mm long and 1000mm across is dug. 50mm of binding is laid in the bottom of the trench and is levelled off. The enclosure 12 and the rebar 30 are then placed in the trench. The rebar 60 is attached to the enclosure 12 prior to placing it in the trench, although it will be appreciated that they may be placed separately in the trench. The enclosure 12 is inclined in the trench so that its rear edge is approximately 20mm higher than its front edge. This enables water to preferentially run to one and, and therefore exit through the drain pipe 52. The trench is then filled with concrete which is tapered off to the rim of the enclosure.

The above design has been tested at the Motor Industry Research Association (MIRA) testing centre in the UK and meets the BSI PAS 68-2010 requirements by stopping a 7500kg vehicle class N2 at 48km/h.

As an alternative to the hydraulic raising arrangement described above, alternatively an electric drive may be used. As shown in Figure 8 the electrical drive, for example a motor 68 and gearbox 72 arrangement, may be attached to the outer side surface of the enclosure 12. A drive cog 70 is attached to the gear box 72 to be driven by the motor 68. The pin 18 comprising end sections 28, 28a and a central portion 30 (as described above) has a driven cog 74 attached to the end section 28a which protrudes through the side wall of the enclosure 12. A chain 76 connects the drive cog 70 and the driven cog 74 to rotate the pin 18 about its central axis. The pin 18 is clamped to the foot box as described above and accordingly rotation of the pin 18 by the motor 68 rotates the foot box, and therefore the impact post, in the enclosure. It will be
appreciated that a secondary enclosure (omitted for clarity) will surround the motor, chain and cogs to prevent dirt ingress there into.
CLAIMS:

1. A raising security bollard comprising:
   an enclosure;
   an impact post comprising a foot box and at least one spring steel impact
   member partially received in said foot box,
   a pivot member configured to allow pivotal movement of said foot box with
   respect to said enclosure between a first position in which the post is fully contained
   within the enclosure in a substantially horizontal orientation and a second position in
   which said at least one impact member extends substantially vertically from said
   enclosure; and
   actuator means for pivoting said impact post between said first and second
   positions

2. The raising security bollard according to claim 1 further comprising a spring
   steel first load spreader bar traverse the enclosure and extending to either side thereof,
   said first load spreader bar located in a position adjacent an upper surface of said
   enclosure such that, when the impact post is in its second position the foot box
   substantially abuts the first load spreader bar.

3. The raising security bollard of claim 2 wherein the impact post has an impact
   facing side and wherein the first load spreader bar substantially abuts the foot box on a
   side of the impact post opposite the impact facing side.

4. The raising security bollard according to any one of claims 1 to 3 further
   comprising:
   a spring steel second load spreader bar traverse the bollard enclosure and
   extending to either side thereof, said second load spreader bar located adjacent an
   lower surface of said bollard enclosure in a position such that, when the bollard is in its
   second position, the foot box substantially abuts the second load spreader bar.

5. The raising security bollard of claim 4 wherein the second load spreader bar
   substantially abuts the foot box on the impact facing side of the impact post.
The raising bollard according to claim 4 or claim 5 wherein the foot box is separated from the second load spreader bar by a sheet of steel.

The raising security bollard according to claim 5 or 6 further comprising a load spreader bar enclosure extending to either side of the enclosure in which said second load spreader bar is slideably located.

The raising security bollard according to claim 7 wherein the load spreader bar enclosure extends a sufficient distance to one side of the enclosure such that the second load spreader bar can be slid into said load spreader bar enclosure to allow maintenance access to said foot box when said post is in its second position.

The raising security bollard according to any one of claims 4 to 8 wherein the pivot member is located vertically above the second impact bar.

The raising security bollard according to any one of the preceding claims wherein the pivot member comprises a pivot pin rotateably located in sidewalls of the enclosure and is attached to an external surface of the foot box.

The raising security bollard according to claim 10 wherein the pivot pin is attached to the foot box by a removable spring steel clamp plate, said spring steel clamp plate dimensioned such that tightening it against said foot box deforms the spring steel clamp plate so as to clamp said pivot pin thereto.

The raising security bollard according to claim 11 wherein said pivot pin comprises two end sections, each of which are insertable into a recess in the enclosure side walls, and a central joining section, and wherein said spring steel clamp plate clamps said pivot pin sections together.

The raising security bollard according to any one of the preceding claims wherein the actuator means comprises at least one hydraulic actuator.

The raising bollard according to claim 13 wherein said actuator means comprises a hydraulic wedge for performing an initial rotation of said impact post
towards said second position and a hydraulic ram for performing a further rotation of said impact post into said second position.

15 The raising security bollard according to claim 12 wherein said hydraulic wedge and said hydraulic ram are connected to a common supply of hydraulic fluid and wherein the resistance against said hydraulic ram in said first position causes preferential flow of hydraulic fluid to said hydraulic wedge to cause said initial rotation and, as said resistance against said hydraulic ram reduces due to said initial rotation said hydraulic fluid flows to said hydraulic ram so as to cause said second rotation.

16 The raising security bollard according to any one of claims 13 to 15 comprising a hydraulic pump having a connection means extending therefrom for attachment to a portable pump drive.

17 The raising bollard according to any one of claims 1 to 12 wherein said actuator means comprises a first drive cog attached to said pivot member, an electrically powered motor having a second drive cog, and a chain connecting said first and second drive cogs.

18 The raising security bollard according to any one of the preceding claims wherein said enclosure is elongate and comprises two elongate side walls, an elongate bottom face, two end faces and a lid extending at least partially along a substantially open top face.

19 The raising bollard according to claim 18 wherein said lid comprises a support bar attached to a lower surface thereof such that when said lid is in a closed position said support bar is closely received in recesses in the upper edge of both side faces of the enclosure such that with the impact post in the second position the support bar is substantially adjacent the impact facing side of the impact post.

20 The raising security bollard according to claim 18 or claim 19 wherein said enclosure comprises at least one torque plate extending perpendicular to each side face in a vertical orientation.
21 The raising security bollard according to any one of claims 18 to 20 wherein said enclosure comprises at least one torque plate extending perpendicular to each side face in a horizontal orientation.

22 The raising security bollard according to any one of the preceding claims further comprising a concrete bed in which said enclosure is embedded such that the upper surface of said bollard enclosure is substantially flush with a top of the concrete bed.

23 The raising security bollard according to claim 22 wherein the upper surface of the enclosure protrudes slightly from the top of said concrete bed and said concrete bed is provided with a chamfer leading up from its top to the upper surface of the enclosure.

24 The raising security bollard according to claim 22 or claim 23 further comprising a rebar cage surrounding said bollard enclosure within said concrete bed.
Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

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<th>Category</th>
<th>Relevant to claims</th>
<th>Identity of document and passage or figure of particular relevance</th>
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<tr>
<td>A</td>
<td>-</td>
<td>US2006/233609 B2 (GELFAND et al.) See in particular paras 33 and 34, noting use of actuators</td>
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<td>A</td>
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<td>GB2304770 B (BROUGHTON-HALL) Whole document relevant, in particular figs 3 and 4.</td>
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<tr>
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<td>GB2282838 B (HILL) See final para on page 8 to the first para on page 11, regarding the second embodiment, and figs 3 and 5.</td>
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<tr>
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<td>GB2467411 A (GERRARD &amp; GERRARD) See fig 1, noting use of load spreader bars.</td>
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Categories:

- **X**: Document indicating lack of novelty or inventive step
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Field of Search:
Search of GB, EP, WO & US patent documents classified in the following areas of the UKC:\textsuperscript{X}:

Worldwide search of patent documents classified in the following areas of the IPC

E01F

The following online and other databases have been used in the preparation of this search report

WPI, EPODOC

International Classification:

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