

Method of Replacing Bearings and System Thereof

Technical field of the invention

The invention relates generally to viaducts, more specifically to a
5 method and a system to replace bearings of a viaduct, such as a viaduct for an
elevated railway (e.g. mass rail transit or light rail transit).

Background of the invention

An elevated railway is a rapid transit railway with tracks above street
10 level on a viaduct or other elevated structures (e.g. constructed from steel, cast
iron, concrete, or bricks). The railway may be broad-gauge, standard-gauge or
narrow-gauge railway, light rail, or a monorail. Elevated railways are normally
found in urban areas where there would otherwise be multiple level crossings.
Space around the piers supporting the viaduct is typically heavily congested and
15 used by roads, footpaths, utilities, public spaces, waterways or private property.
Usually, the tracks of the elevated railways that run on viaducts can be seen from
street level.

Mass rapid transit (MRT) system is one type of the rail systems which
is used for transporting passengers in urban areas. It is known by various other
20 names such as mass transit, subway, underground railway or metro. Some extent
of the MRT may be built above ground through a viaduct. A viaduct is a bridge
composed of several small spans for crossing traffic lanes or other low ground,
or forming an overpass or a flyover. The MRT viaducts are mostly single span
box girders system simply supported on either fixed, guided or free bearings,
25 which in turn are supported on pierheads.

Many of these viaducts have been built in the last 50 years. While they
are built for long design lives (e.g. up to 100 years), some mechanical

components, and in particular the structural bearings supporting the spans on the piers, have shorter useful lives due to being subject to wear by continuous movements (triggered by variations in temperature, span loading and vibrations from the rail operation) and corrosion. As a result, bearings have to be replaced
5 in regular intervals.

The seating of the span on the pierhead often has half-joint details, which made bearing replacement extremely difficult because there is no or very limited space (e.g. sufficient access to the empty space of the half joint is only at the transverse to the longitudinal axis of the span i.e. "front" and "back" entrances
10 but not through the lateral sides) to jack up the span through the half joint location using the conventional methods. Hence, many solutions are proposed to jack up the span from the pierhead while reacting on the ground below, or the pilecap below or being supported on pier.

The methods of jacking up from pilecap and pier are deemed not
15 optimum as they require much investment, longer preparation time, more space for access and access to areas occupied by other uses. These inevitably cause disruption to the existing traffic below, and these solutions are also more costly.

It therefore remains a need to find some other alternatives or more efficient means to replace the old bearings.

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Summary of the invention

The inventors of the present invention have found solutions to the above-discussed problems by providing a method and a system by jacking up loads through a half joint area for replacement of bearings/bearing assembly. In
25 particular, thanks to the present invention, bearings replacement can be performed through the half joint area which has a very limited space and dimension (e.g. space where an access for the placement of load lifting device and/or load carrying device can only be achieved through the front and/or back side of the half joint but not through the lateral sides), thereby reducing the overall

cost, time, traffic disruption while increasing the efficiency of bearings replacement. As explained, half joint is referred to an area of empty space formed by the arrangement of the structural components of the construction. The half joint comprises an empty space usually rectangular in dimension, wherein the
5 empty space of the half joint has an access only from the direction transverse to the longitudinal axis of the span. As a result of such an arrangement of the structural components, the top, bottom and both lateral sides of the half joint are formed from these structural components. In other words, the access to the empty space of the half joint can only be made through the direction transverse to the
10 longitudinal axis of the span i.e. "front" and "back" entrances. Present invention proposes jacking up of the span is performed through the half joint area and not through ground nor pilecap, pier nor through creating a temporary platform e.g. installing cross beam for the placement of bearing replacement device. Due to the flexibility and accessibility of the present invention, the bearing replacement
15 work can be done within a shorter period of time e.g. within between 5 hours to two nights. This allows works to be carried when the train is non-operational (e.g. between 12 am and 5 am). Alternatively, if stability components e.g. load stability devices are further provided, trains are allowed to pass while the bearing replacement work is in operation.

20 In a first aspect, it relates to a method of replacing bearings through a half joint area of a viaduct comprising a plurality of axially arranged elongated spans, wherein each of the elongated span is supported on at least three or four bearings, forming supporting bases of the span, such that the centre of gravity of the elongated span and/or the resulting force of all actions on the span (e.g. rail
25 loading, wind and other external actions) lies within an area inscribed by the supporting bases of the span; wherein the half joint area is a substantially rectangular empty space approximately located at at least one longitudinal end of the elongated span, resulted from the span being supported on the bearings which in turn are supported on at least one or two neighbouring pierheads,
30 wherein the empty space of the half joint has an access only from the direction transverse to the longitudinal axis of the span for the placement of bearing replacement device; comprising the steps of (a) Inserting one or more load lifting devices to the half joint area; (b) Transferring load to the one or more load lifting devices introduced in the step (a); (c) Replacing one or more bearings of the half

joint area and transferring loads to the newly installed one or more bearings; (d) Removing the one or more load lifting devices introduced in the step (a).

In a second aspect, it relates to a bearing replacement system for use in a half joint area of a viaduct comprising a plurality of axially arranged elongated spans, wherein the half joint area is a substantially rectangular empty space approximately located at at least one (or preferably located at each) longitudinal end of the elongated span, resulted from the elongated span being supported on the bearings which in turn are supported on at least one or two neighbouring pierheads, wherein the empty space of the half joint has an access only from the direction transverse to the longitudinal axis of the span for the placement of bearing replacement device, wherein the half joint area preferably has a restricted dimension defined by a bottommost transverse length (T) of the half joint area parallel to the elongated span, wherein the half joint area has an accessible empty space defined by a ratio of total bottommost transverse length of the half joint unoccupied by the bearing assembly: bottommost transverse length of the half joint occupied by the bearing assembly, wherein the ratio is less than 3:1, preferably less than 3:2; wherein the system comprises one or more load lifting devices for lifting loads, insertable to the accessible empty space of the half joint area, wherein the load lifting devices are preferably hydraulic jacks, pneumatic lifting devices, mechanical screw jacks, motorized screw jacks and/or magnetic lifters.

In one preferred embodiment, the method of replacing bearings in a half joint area of a viaduct comprising a plurality of axially arranged elongated spans according to the present invention, wherein each of the elongated span is supported on at least three or four bearings, forming supporting bases of the span, such that the centre of gravity and/or the resulting force of all actions on the span of the elongated span lies within an area inscribed by the supporting bases of the span; wherein the half joint area is a substantially rectangular empty space approximately located at at least one (or preferably located at each) longitudinal end of the elongated span, resulted from the span being supported on the bearings which in turn are supported on at least one or two neighbouring pierheads, wherein the empty space of the half joint has an access only from the direction transverse to the longitudinal axis of the span for the placement of

bearing replacement device, wherein the half joint area has a restricted dimension defined by a bottommost transverse length (T) of the half joint area, parallel to the elongated span; wherein the bearing together with a plurality of supporting plates and grout pads form a bearing assembly occupying a space of the half joint area, wherein the accessible or remaining empty space of the half joint area is defined by a ratio of total bottommost transverse length of the half joint unoccupied by the bearing assembly: bottommost transverse length of the half joint occupied by the bearing assembly, wherein the ratio is less than 3:1, preferably less than 3:2; comprising the steps of (a) Inserting one or more load lifting devices to the accessible or remaining empty space of the half joint area; (b) Transferring load to the one or more load lifting devices introduced in the step (a), thereby forming one or more temporarily new supporting bases of the span; (c) If the centre of gravity of the elongated span still lies within the area inscribed by the supporting bases of the span after the loads are transferred to the one or more load lifting devices introduced in the step (b), then replacing the one or more bearings on the half joint area which their loads are temporarily taken by the one or more load lifting devices introduced in the step (b); (d) If the centre of gravity of the span now lies outside of the area inscribed by the supporting bases of the span after the loads are transferred to the one or more load lifting devices introduced in the step (b), installing load stabilizing device to provide lateral supports for the stability of the span; (e) Then replacing one or more bearings on the half joint area which their loads are temporarily taken by the one or more load lifting devices introduced in the step (b), and transferring loads to the newly installed one or more bearings; (f) Removing the one or more load lifting devices introduced in the step (a).

It goes without saying that while replacing bearing of a viaduct, when an old bearing is removed and is temporarily supported by one or more load lifting devices and/or load carrying devices, it is preferably that the centre of gravity of the span lies within an area inscribed by those supporting bases. If the centre of gravity lies outside of the area inscribed by those supporting bases, then the one or more load stability device may be useful to keep the stability of the span (preventing the span from tilting e.g. from side to side). For instance, when a span comprises two supporting bases on each of its longitudinal end (of half joint areas), then the centre of gravity of the span lies well within a rectangular area

inscribed by the supporting bases of the span and will not require one or more load stability devices. However, if only three supporting bases (or bearings) are provided originally in the half joint areas of a span of a viaduct (two bearings on one half joint area while another bearing is provided on another half joint area of the span), when the only one bearing of the half joint area is being replaced, depending on the location where the load lifting devices and/or the load carrying devices are being provided to exert a temporary load lifting or carrying capability, load stability device may or may not be required (depending on the centre of gravity of the supporting bases of the span).

10 In other words, present invention according to claim 1 relates to a method of replacing bearings, wherein the one or more bearing replacement devices (e.g. load lifting device, load carrying device and/or stability device) are at least partially or completely positioned within the empty space of the half joint area.

15 In a preferred embodiment, it relates to a bearing replacement system for use in a half joint area of a viaduct comprising a plurality of axially arranged elongated spans, wherein the half joint area is a substantially rectangular (e.g. either horizontal or slightly sloping) empty space approximately located at at least one longitudinal end of the elongated span, resulted from the elongated span being supported on the bearings which in turn are supported on at least one or two neighbouring pierheads, wherein the half joint area has a restricted dimension defined by a bottommost transverse length of the half joint area, parallel to the elongated span, wherein the half joint area has a remaining or an accessible empty space defined by a ratio of total bottommost transverse length of the half joint unoccupied by the bearing assembly: bottommost transverse length of the half joint occupied by the bearing assembly, wherein the ratio is less than 3:1, preferably less than 3:2; wherein the system comprises one or more load lifting devices for lifting loads, insertable to the accessible empty space of the half joint area, wherein the load lifting devices are preferably hydraulic jacks.

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30 This embodiment is especially suitable when the half joint area of certain viaducts has particular dimension such that the load lifting devices can be inserted into the half joint area. For example, the half joint area may have a total bottommost transverse length (i.e. parallel to the direction of the longitudinal axis of the

elongated span) of about 1250 mm, if for instance the bearing assembly has a bottommost transverse length of 500 mm (e.g. the base support plate has a width of 500 mm), the accessible or remaining empty space (total bottommost transverse length unoccupied by bearing assembly) will be 750 mm. This
5 measuring technical can also be done through a 2D geometry measurement method, for instance by taking a picture of the half joint (having the bearings) from either the front or back entrance and subsequently measuring the ratio. This method is straightforward and easy for any person compared to 3D geometry measurement.

10 According to some preferred embodiments, the step (a) is carried out by inserting the one or more load lifting devices on both sides of the bearing, thereby flanking the bearing either longitudinally or transversally of a longitudinal axis of the elongated span. This has the advantage that the centre of gravity of the elongated span most likely lies within an area inscribed by the supporting
15 bases of the span, therefore the load stability devices may not be needed.

According to some embodiments, the step (a) is carried out by inserting the one or more load lifting devices in between two bearings of a half joint area. The system of the present invention allows the load lifting devices and/or load carrying devices to be inserted in the said location (between two
20 bearings in a half joint area), insertion of the load lifting devices in such a manner allows the bearing to be replaced can be removed easily as the path is not blocked by the devices which are temporarily inserted within the half joint area.

In some embodiments, the method of replacing bearings is carried out as follows: (a) Inserting one or more load carrying devices in between two
25 bearings located in a half joint area of an elongated span, wherein the load carrying devices are preferably mechanical jacks; (b) Inserting one or more load lifting devices to the half joint area of the elongated span, close to the peripheries of the half joint area (or close to the openings of the half joint area), wherein the load lifting devices are preferably hydraulic jacks; (c) Transferring load to the one
30 or more load lifting devices introduced in the step (b); (d) Transferring load to the one or more load carrying devices introduced in the step (a); (e) Removing the one or more load lifting devices introduced in the step (b); (f) Replacing one or

- more bearings on the half joint area of the elongated span; (g) Repeating step (b); (h) Transferring load to the one or more load lifting devices introduced in the step (g); (i) Transferring loads to the newly installed one or more bearings; (j) Removing the one or more load lifting devices introduced in the step (g); (k)
- 5 Removing the one or more load carrying devices introduced in step (a).

In some embodiments, the method of replacing bearings is carried out as follows: (a) Inserting one or more load lifting devices to a half joint area of the elongated span, close to the peripheries of the half joint area, wherein the load lifting devices are preferably hydraulic jacks; (b) Installing one or more load

10 stabilizing devices around the half joint area to provide lateral supports for the stability of the elongated span; (c) Transferring load to the one or more load lifting devices introduced in the step (a), or perform this step before the step (b); (d) Engaging the one or more load stabilizing devices introduced in the step (b) to the elongated span; (e) Removing the one or more load lifting devices introduced

15 in the step (a); (f) Replacing one or more bearings on the half joint area of the elongated span; (g) Repeating the step (a); (h) Transferring load to the one or more load lifting devices introduced in the step (g); (i) Replacing the remaining bearings on the half joint area of the elongated span; (j) Transferring load to newly installed bearings and removing the one or more load lifting jacks introduced in

20 step (a).

In some embodiments particularly according to claims 5 and 6, the method of replacing bearings is performed through a first half joint located around a longitudinal end of an elongated span, wherein a second half joint area comprising a single bearing located around another longitudinal end of the

25 elongated span, the single bearing is replaced as follows: (a) Inserting two or more load lifting devices to the second half joint area of the elongated span, close to the peripheries of the second half joint area, wherein the load lifting devices are preferably hydraulic jacks; (b) Installing one or more load stabilizing devices around the second half joint area to provide lateral supports for the stability of the

30 elongated span, or perform this step before the step (b); (c) Transferring load to the two or more load lifting devices introduced in the step (a); (d) Engaging the one or more load stabilizing devices introduced in the step (b) to the elongated span; (e) Removing one or more of the load lifting devices introduced in the step

(a); (f) Replacing the bearing on the half joint area of the elongated span; (g) Repeating the step (a); (h) Transferring load to the two or more load lifting devices introduced in the step (g); (i) Transferring load to the newly installed bearing; (j) Removing all the load lifting devices introduced in the step (g) and the load
5 stabilizing devices introduced in the step (b).

According to some other preferred embodiments, the system further comprises one or more load carrying devices for carrying load, wherein the load carrying devices are preferably mechanical jacks. Mechanical jacks has the advantage when uncontrolled lowering of hydraulic jacks due to leakage of
10 hydraulic fluid is of a main concern and when due to limited space new mechanical safety devices such as threaded rings can be used to mechanically secure the extended hydraulic piston.

In further embodiments, the system further comprises one or more load stabilizing devices to provide lateral support for the stability of the elongated
15 span. This allows the span to be supported and stable even if the centre of gravity of the span lies outside of the area inscribed by the supporting bases.

According to some embodiments, the one or more load lifting devices are a battery of lifting jacks comprising a plurality of chambers which are hydraulically linked.

20 In some preferred embodiments, each of the chambers is operable to apply a lifting capacity of at most 15 tonnes, preferably at most 10 tonnes. In some instances, it is preferably between 5 T and 15 T, between 7 T and 12 T, between 8 T and 10 T.

In yet some embodiments, the battery of lifting jacks has between 5 to
25 20 chambers, preferably 10 chambers. These chambers are predominantly cylindrical chambers or in some instances, other shapes of the chambers can be provided.

In some embodiments, the battery of lifting jacks has an elongated dimension, wherein the overall length is at least three times of its width, preferably at least 3.5 times, 4 times, 4.5 times, 5 times or between 3 times and 6 times.

5 In yet some embodiments, the load carrying device is a mechanical wedge system, preferably mechanical jacks, having an elongated dimension, where the overall length is at least three times of its width, preferably at least 3.5 times, 4 times, 4.5 times, 5 times or between 3 times and 6 times.

In some embodiments, the battery of lifting jacks has a combined lifting capacity of approximately 100 tonnes.

10 The terms "bearing" and "bearing assembly" as used herein are interchangeable, as a "bearing" typically requires number of additional components (e.g. supporting plates such as top plate, base plate or bottom plate, sliding plates, guide plates; elastomeric pads, pots, grout, fixation bolts, sliding surfaces, and etc.) to form a bearing assembly such that a functioning supporting
15 base can be provided. For example, the bearings provided in a half joint area serve as supporting bases for the elongated span.

The term "half joint area" refers to a space, usually an empty space having restricted dimension, created by two or more structural components of a construction that are closely aligned to each other. The half joint area may be a
20 rectangular or a substantially rectangular (e.g. slightly sloping) empty space. For instance, the half joint may be formed in a location between a pierhead and one longitudinal end of a span. The half joint area, typically but not always, comprises an upper nip half joint and a lower nip half joint, thus the empty space created in between these upper and lower nips are known as a half joint area. The half joint
25 according to the present invention comprises an access only from a direction transverse to the longitudinal axis of the elongated span, as the lateral sides of the half joint are obstructed from access by the aforementioned structural components. Due to this restricted access of the half joint area, the bearing replacement devices (e.g. load lifting devices, load carrying devices, load stability
30 devices) proposed herein are specially designed and/or arranged in order to allow sufficient accessibility (or empty space) is reserved for the removal and insertion

of the bearings (while using e.g. load lifting devices, load carrying devices for the temporary supports of the load). To the contrary, in other bearing set ups (e.g. a bridge deck resting on a bearing which in turn is support by a pierhead), there is no restriction to access to the bearing as at least three of the four sides and
5 corners of the bearing are free from any obstruction (cf. Figure 5). Hence, as bearings installed in this set up do not face accessibility difficulties as compared to bearings installed in a half joint area, thus those aforementioned bearings can be replaced easily.

Spatially relative terms, such as "beneath", "below", "lower", "above",
10 "upper", "front", "back", "lateral" and the like, may be used herein for ease of description to describe one element or feature's relationship to another element(s) or feature(s) as illustrated in the figures. It will be understood that the spatially relative terms are intended to encompass different orientations of the device in use or operation in addition to the orientation depicted in the figures.
15 For example, if the device or element in the figures is turned over, elements described as "front", other elements or features would then be oriented "back" of the other elements or features. Thus, the example term "front" can encompass both an orientation of front and back. The element may be otherwise oriented (rotated 90 degrees or at other orientations) and the spatially relative descriptors
20 used herein interpreted accordingly.

The term "bearing replacement device" refers to devices used to replace bearings. Such devices are typically load lifting device and load carrying device and in some instance stability device are included. Hydraulic jacks and mechanical jacks are typical examples of a load lifting device.

Brief description of the drawings

Figure 1 shows an example of a schematic overview of an MRT viaduct.

Figure 2 shows a first known prior art method of replacing bearings of
5 a viaduct.

Figure 3 shows a second known prior art method of replacing bearings of a viaduct.

Figure 4 shows a third known prior art method of replacing bearings of a viaduct.

10 Figure 5 shows an example of bearings serve as supporting bases for a bridge deck, wherein the bearings are not installed in half joint set-up.

Figure 6 shows an enlarged end view (through front or back) of a half joint area of a viaduct where a bearing/ bearing assembly can be seen.

Figure 7 shows a first example of a schematic representative top view
15 of an elongated span where the centre of gravity of the elongated span lies within an area inscribed by the supporting bases.

Figure 8 shows a second example of a schematic representative top view of an elongated span where the centre of gravity of the elongated span lies within an area inscribed by the supporting bases.

20 Figure 9 shows a third example of a schematic representative top view of an elongated span where the centre of gravity of the elongated span lies outside of an area inscribed by the supporting bases.

Figures 10a to 10f show an example of a load lifting device according to one embodiment of the present invention, wherein the load lifting device can
25 also be served as a load carrying device, wherein said device is a hydraulic jack.

Figures 11a to 11g show a first deployment method of one or more load lifting devices in a half joint area.

Figures 12a to 12d show a second deployment method of one or more load lifting devices in a half joint area.

5 Figures 13a to 13d show an example of a load carrying device according to an embodiment of the present invention, wherein the load carrying device is a mechanical jack.

Figures 14a to 14f show a first example of the method of replacing bearings according to the present invention.

10 Figures 15a to 15d show four examples of the installation methods of one or more load stability devices.

Figures 16a to 16d show a second example of the method of replacing bearings according to the present invention.

15 Figures 17a to 17h show a third example of the method of replacing bearings according to the present invention.

Figures 18a to 18g show a fourth example of the method of replacing bearings according to the present invention.

Figures 19a to 19c show three examples how the load lifting devices 300 can be positioned within a half joint area.

20 Figure 20 shows a schematic perspective end view of a half joint, indicating an example of measuring bottommost transverse length of the half joint that is parallel to the longitudinal axis of an elongated span.

Detailed description of the invention

Figure 1 shows a typical viaduct 150 of a Mass Rapid System (MRT) where a series of spans 160 are arranged longitudinally, forming a track, wherein each of the span 160 is supported through bearings which in turn are supported
5 on two neighbouring pierheads 170 where the pierheads are supported by a pier column / pile. In this example, the MRT viaduct comprises two rail tracks that are provided on two spans 160. In other words, each pierhead 170 comprises two spans 160 arranged parallel to each other.

As illustrated in the Figure 1, four half joint areas 180 are formed
10 between the pierhead 170 and the spans 160 (although only two half joints can be seen in the Figure 1). The half joint area 180 has a substantially elongated rectangular empty space, wherein the empty rectangular space has a limited dimension. Usually one or two bearings are provided in each of the half joint area 180. In some unusual settings, it may be possible to provide more than two
15 bearings in each half joint area 180.

A number of methods are used at present to replace the bearings. Figure 2 shows a first example of the bearing replacement method. One or more towers are usually built on a pilecap 140 and reaching the pierhead 170 and/or span 160. Subsequently, lifting means can be used by jacking up the span (not
20 shown) in order to replace the worn-out bearings 200 that are provided in a half joint area 180. In this method of bearing replacement, it requires a substantially large ground area for the mounting of towers on the pilecap 140.

A second bearings replacement method is demonstrated in Figure 3. Instead of building the towers, one or more hydraulic jacks tower, sometimes with
25 the assistance of a modified tractor, can be built on ground or on top of a pilecap 140 to jack up the span 160 and/or the pierhead 170.

A third bearing replacement method is illustrated in Figure 4 where a number of external columns are installed on top of pilecaps 140 located next to the vertical piles/ pier columns of the viaduct through which cross beams (or
30 known as temporary supporting structures 130) are horizontally connected

thereto with the external columns. These cross beams may serve as a platform for the positioning of jacks 138 for temporary lifting of the span 160 for the replacement of bearings. Although large jacks having high lifting capacity can be use in this example, nevertheless, this method is deemed not optimum as it
5 requires much investment, longer preparation time as well as more access for space to install the external columns, thereby causing longer and more serious disruption to traffics.

All the above-discussed methods are not optimal as not only traffic flows are disrupted; higher costs and longer setting up time of the towers are
10 needed. For these reasons, present invention provides some revolutionised solutions to overcome the problems.

Typically, one or two bearings 200 (or bearing assembly 200) are provided to a half joint area 180 to serve as supporting bases for the elongated span 160, wherein the half joint 180 is formed in a location between a pierhead
15 170 and one longitudinal end of a span 160.

Figure 5 shows a schematic cross section view of a bridge deck where a deck 195 rests on two bearings 200 which in turn are supported by a pierhead 170. In this type of bearing set-up, the empty space surrounding the bearings are not half joint area as the bearings 200 are sandwiched by the upper deck 195 to
20 the top and the lower pierhead 170 to the bottom. In other words, the all four sides and corners of the bearings are free from any obstructions. Contrary to a half joint area where the empty space of the half joint is accessible only from the direction transverse to the longitudinal axis of the span (i.e. front F and the back B) whereas the lateral sides are also free from any obstruction. For this reason, the
25 bearings as shown in the Figure 5 can be easily removed and replaced and the old bearings can be taken out from any of the four directions.

Figure 6 illustrates a closed-up end view of a half joint area 180 from a perspective, wherein the half joint 180 is seen from one entrance of a half joint (either front or back entrance). A bearing 200 (or also known as a bearing
30 assembly 200 in the present application) can be seen provided in the half joint area 180, serving as a supporting base for the span 160, which in turn is

supported on a pierhead 170. The half joint typically comprises an upper nip half joint 162 and a lower nip half joint 172, wherein an empty space created in between these upper and lower nips 162, 172 are known as a half joint area 180. In other words, the half joint area 180 has a very limited space delimited by the
5 space between a pierhead 170 and a span 160. The dimension of the half joint area 180 is usually substantially cuboid in shape where its length and width are usually substantially greater than the height.

The bearing assembly 200 shown in this example has a total height of approximately 150 mm for instance. Usually, the height of the half joint area is
10 ranging from 50 mm to 500 mm, more commonly 120 mm and 250 mm, or between 80 mm and 300 mm. To this end, the terms “bearing” and “bearing assembly” are used interchangeably as a “bearing” typically requires number of additional components (e.g. base plates, supporting plates, grouts and etc) to form a bearing assembly 200 such that a functioning supporting base can be
15 provided. The reference T shows the width of a half joint area (i.e. bottommost transverse length parallel to the elongated span, measurement in 2D geometry, which will be explained hereinafter).

As an example, the bearing/bearing assembly 200 according to this embodiment (Figure 7) comprises different components such as base plate 221,
20 supporting plates 222, 223 and a bearing 225. Grouts such as epoxy grout or cement grout are typically provided additionally to form a bearing assembly.

For the sake of an easy yet accurate calculation of the dimension of a half joint, in the present invention, the concept of “bottommost transverse length (of a cross section) of a half joint area parallel to the longitudinal axis of a span”
25 is used. This is represented by the reference “T” as shown in the Figure 6, which is a substantially flat surface of a pierhead where one or more bearing assembly 200 can be placed thereon. To this end, it is disclosed that the side (or corner) of the half joint may not be always flat but may be curved or chipped (reference “C”) or has a small gap as demonstrated in the Figure 6. Depending on the angle of
30 the curve, said surface may not be suitable to be considered as a bottommost transverse length “T” as used in the present invention. In the present application,

those chipped or curved corners are generally not being considered as part of a width of a half joint area.

A span is an elongated concrete structure which serves as a rail track base for trains to run from above. Each elongated span 160 may have a weight of approximately 360 Tons, though some within the range of 50 Tons and 2000 Tons, or between 50 Tons and 500 Tons. Each of the span 160 may be supported by three or four bearings 200 (or bearing assemblies 200) as supporting bases, which in turn are supported on pierheads 170.

Figure 7 shows an example of such a bearing arrangement. The span 160 may be provided with only three bearings 200 (two bearings located in a half joint 180' at one longitudinal end of the span 160 while another bearing is provided to another half joint 180'' which is located at another longitudinal end of the span 160). Although only three bearings are provided, the span 160 is perfectly stable mounted on the pierheads. This is due to the centre of gravity of the span (black dot, G) lies within an area (triangular area delimited by the dotted lines) inscribed by those supporting bases, the span 160 is therefore stable and does not require any external structures or devices to further stabilize the span 160.

When two bearings 200 are provided to each half joint area 180', 180'' of a span 160, the centre of gravity G of the span lies within an even larger area (a rectangular area, not shown) inscribed by those four supporting bases (Figure 8). During the bearing replacement process, one or more load lifting devices 300 maybe inserted in between the two bearings 200 located in a half joint area 180'', serving temporarily as a supporting base for said two bearings 200 while the two bearings 200 are being deactivated (represented by dotted bearings). In this case, due to the location of the insertion of the load lifting device 300, the centre of gravity of the span still lies within a triangular area (an area delimited by the triangular dotted lines) inscribed by the supporting bases, therefore the span is stable and does not require any external components or devices, which is similar to the situation as illustrated in the Figure 7.

To the contrary, as illustrated in the Figure 9, when two of the bearings 200 are being deactivated (represented by a dotted bearing with an "X") and replaced by a load lifting device 300 where the load lifting device 300 is placed at a longitudinal periphery of the span 160 (close to the entrance/opening of the half joint area 180"), the centre of gravity G of the span 160 now lies outside of an area (triangular area delimited by the dotted lines) inscribed by the three supporting bases. The span 160 is therefore not stable and requires some external assistance for stabilization. In the embodiment as illustrated by the Figure 9, four load stabilizing devices 500 are installed at four corners of the span 160 (or longitudinal sides close to the half joint areas) to provide lateral supports to the span 160 such that tilting of the span 160 can be prevented.

To this end, it is disclosed that the load lifting device 300 according to one embodiment of the present invention is disclosed as shown in Figures 10a to 10f. The load lifting device 300 comprises a substantially elongated but narrow body such that the load lifting device 300 can be inserted into a half joint area 180 that has a restricted space. Figure 10a shows a perspective overview of the load lifting device 300 that is substantially elongated with narrow body. The load lifting device 300 according to this embodiment is fabricated from one steel block with 10 chambers 310, each having nine tonnes (T) capacity. In other words, the device 300 has a total lifting capacity of 90 T. It can be foreseen that the load lifting device 300 according to the present invention has a lifting capacity of between 50 T and 200 T, preferably between 75 T and 150 T or between 80 T and 120 T.

Figure 10b and Figure 10e are schematic elevation views (from the side) of the load lifting device 300 of the present invention, wherein Figure 10b represents a retracted position having a minimum height as illustrated in the cross-sectional view as shown in the Figure 10c (dissected from the position of A-A of Figure 10b) whereas Figure 10d represents an extended position having a maximum height as illustrated in the cross-sectional view of the Figure 10e (dissected from the position of B-B of Figure 10d). Figure 10f shows a top view of the device 300, wherein the load lifting device 300 comprises 10 chambers.

According to this embodiment of the load lifting device 300 which is a hydraulic jack, all chambers 310 are hydraulically linked. The hydraulic jack is equipped with one or more return springs for self-retraction. Piston stroke is between 10 to 15 mm (Figures 10c and 10e show the chamber comprises an extension screw 330). For the sake of clarity, it is noted that the area between jack and span is usually fitted with one or more shims but there will be small space (of a couple of mm) until jack piston pushing shim and getting in contact with the span. Hence piston stroke is larger than the jack up height of the span e.g. 5 mm). The overall dimension of the load lifting device 300 can be for instance approximately 65 mm x 120 mm x 635 mm in size as shown in this example, and has an estimated weight of between 35 kg and 45 kg. To this end, it is disclosed that the load lifting device may have a tilt saddle to take up to 3.5 % tilting.

It is foreseeable that the load lifting device 300 may have a different dimension, number of chambers, weight and lifting capacity. Depending on the size or dimension of the half joint area, the load lifting device 300 may be customised for each half joint area of a viaduct. For example, the device may have between five and 25 chambers that are hydraulically linked. To this end, it is appreciated that a hydraulic jack is both a load lifting device and a load carrying device as it is capable of lifting a load as well as holding a lifted load.

Due to the small dimension of the load lifting device 300 according to the present invention, it is insertable to a half joint area 180. In order to position the load lifting device 300 in a desired location of a half joint area 180, the load lifting device 300 may be placed on a support tray 600 such that it can be brought in and be oriented through positioning the support tray 600. The support tray 600 may be foldable and extendable e.g. provided with a drawbridge concept to lower a side plate 605, as demonstrated in the Figures 11a and 11b. The support tray 600 may be equipped with gears such that the side plate 605 can be lowered before the device 300 is moved. This allows the load lifting device 300 to move (e.g. from front to back) on the lowered side plate 605 of the support tray. In other words, it is capable of transversal and longitudinal displacement and rotation about the devices own longitudinal axis. To this end, it is disclosed that the

supporting tray may also be used for other devices such as a load carrying device e.g. mechanical jack.

Figures 11c to 11g illustrate how the load lifting device 300 according to the present invention can be positioned and oriented in a half joint area 180.

5 Firstly, two load lifting devices 300 which are placed on a support tray 600, respectively, are placed flanking a bearing assembly 200 in a half joint area (see Figure 11c) through the gaps in the half joint (on the left and the right side of the bearing as seen on Figure 11c). Both the support trays 600 may be pushed until a central position of a half joint 180 i.e. between two bearing assemblies for

10 instance. Once the load lifting device 300 on a support tray 600 reaches the desired central position, the side plate 605 of the support tray 600 can be lowered down (see Figure 11d). Thereafter, the load lifting device 300 may move sideward (see the two arrowheads in Figure 11e) along the side plate 605 that is being lowered to reach the desired position.

15 Once the desired position is reached, shim plate 625 can be inserted, one by one, and placed on top of the load lifting device 300 (see Figure 11f). Then the shim plates 625 can be pushed (see arrowheads of Figure 11f) so that they rest on top of the load lifting devices 300 (see Figure 11g). Subsequently, the load lifting devices 300 can be jacked up (or lifted) to transfer load temporarily to

20 the load lifting device 300 from the bearing 200.

Alternatively, Figures 12a to 12d show a second deployment method of one or more load lifting devices in a half joint area, wherein an extension rod (or a long stick) may be used to push in the load lifting device to a desired location of the half joint area manually by a worker through the entrance of the half joint

25 area. Firstly, base shims can be inserted in a half joint area (see Figure 12a), followed by inserting one or more load lifting devices 300 (see Figure 12b). The load lifting device e.g. hydraulic jack can then be pushed by the extension rod (e.g. manually by a worker through the entrance of the half joint) so that it slides onto the base shims (Figure 12c, see arrowheads) before the hydraulic jack can

30 be engaged and jacked up (Figure 12d) to lift up the span.

Similar to the load lifting device 300, the load carrying device 400 according to the present invention also has a small dimension so that it is suitable to be placed in a half joint area. Figures 13a to 13d demonstrate a type of load carrying device 400 according to one embodiment of the present invention. A load
5 carrying device has a capability to hold a lifted load that has been lifted by a load lifting device, such as a hydraulic jack. The load carrying device 400 shown in this example is a mechanical jack. In some instances, mechanical jack is preferred over hydraulic jack when leakage of hydraulic jack is an issue. Mechanical jack not having a hydraulic system is therefore the preferred option.

10 The mechanical jack according to this embodiment is a double-wedge jack that is extendable using horizontal rod where the end nuts can be potentially turned with an electrical motor. The mechanical jack according to this embodiment may have a dimension of 75 mm x 100 mm x 750 mm with a weight of approximately 35 kg to 40 kg; can be extended to reach a height of e.g. 100-
15 160 mm or a maximum height of 160 mm; may have a capacity of 90 metric tonnes and may have a piston stroke of 60 mm.

The load lifting device 300 and the load carrying device 400 according to the present invention is relatively light weight, hence they are portable, have a simple control (e.g. by means of a hand lever) and require minimum maintenance.
20 The mechanical jack may have an integrated wedge concept: friction-free, smooth and parallel wedge movement to eliminate flange damage and spreading arm failure; may have a unique interlocking wedge design (e.g. no first step bending and risk of slipping out of joint), requires very small access gap (e.g. 6 mm), may have a stepped spreader arm design (each step can spread under full
25 load) and have few moving parts (hence high durability and low maintenance).

As explained previously, the prior art methods of jacking up from pilecap and/or pier are deemed not satisfactory as they require much investment, longer preparation time, more space for access and hence disruption to existing traffic below, and are more costly. For these reasons, followings methods are
30 proposed according to the gist of the present invention.

Figures 14a to 14f demonstrate a first example of the bearing replacement method. In this example, a total of four bearings 200 (two bearings 200 on each half joint) are provided to the two half joint areas 180', 180" which are present at the longitudinal end of the elongated span 160. The centre of gravity of the span lies well within an area (rectangular area) inscribed by the four supporting bases (not shown) (see Figure 14a).

Before replacing the old bearing 200 (in the half joint 180"), one or more load lifting device 300 may firstly be inserted in a location of a half joint area 180" between two bearings 200, through the method as explained above. The load lifting devices 300 in this example are hydraulic jacks. Once the hydraulic jack 300 is positioned (e.g. in between the two existing old bearings), the hydraulic jack can be activated so that the two old bearings 200 can be deactivated (mark "X" with dotted bearing represents "deactivated"), as illustrated in the Figure 14b. In other words, part of the span load is now transferred to the newly introduced load lifting device 300 (in the centre position).

In most instances, it may be sufficient to lift up the span by approximately 5 mm for the bearing replacement work to be carried out. At this stage, the span itself may still be stable as the centre of gravity lies within a triangular area inscribed by the supporting bases (two old bearings 200 located in half joint 180' and one temporary installed load lifting device 300 in another half joint 180"), similar as demonstrated in the Figure 8.

At this stage, additional load lifting devices in form of hydraulic jacks 300a, 300b may be introduced at the periphery location of the half joint area (i.e. a location close to the "front entrance F" and "back entrance B" (see arrowheads) of a half joint area as illustrated in the Figures 14c and 14d, to allow train to pass. In other words, these "periphery-located" hydraulic jacks) are provided to render additional supports to the span and therefore the rail track does not need to be closed for maintenance.

Moreover, bearing assembly 200 comprises a number of components including bearing, supporting plates, shim plates, grout, bolts, pads and etc. Hardening of epoxy grout may take more than one-night shift (e.g. 5 hours) and

in some instances, insertion of the periphery-located hydraulic jacks 300a, 300b may be blocking the accessibility of the bearing 200. For this reason, load stabilizing device 500 may be installed optionally so that the one or more periphery-located hydraulic jacks 300a, 300b may be removed to vacate the
 5 entrance of the half joint area ("front" or "back" entrances of the half joint 180) such that the old bearing can be reached for replacement. Furthermore, the load stabilizing device 500 is capable of serving as a back-up in case hydraulic jacks are faulty during injection and levelling of epoxy grout.

Once the newly installed one or both bearings are replaced and
 10 functioning (see Figure 14e where the checkered bearings 200 in half joint 180'' which represent new and functioning bearing/bearing assembly 200), the hydraulic jack 300 which is placed in the central position of the half joint area 180'' (Figure 14e) can then be deactivated and removed, thereby the two bearings 200 located in the half joint area 180'' are now replaced (Figure 14f). The other two
 15 bearings 200 located in another half joint 180' can be replaced with the same methods as described.

Of course, the method of replacing bearings through a half joint can also be realised in more than one-night shift. For instance:

First night (between 12 am and 6 am)

- 20
- | | |
|-----------|---|
| Step 1 | Preparation and Install jack with temporary bearing |
| Step 2 | Jacking ~ 7mm |
| Step 3 | Install shim block ~ 5mm |
| Step 4 | Temporary load transfer to shim block |
| 25 Step 5 | Remove existing bearing |
| Step 6 | Install jack with temporary bearing |
| Step 7 | Jacking ~ 7mm |

Second night (between 12 am and 6 am)

- 30
- | | |
|------------|--|
| Step 8 | Match drill new bearing |
| Step 9 | Jacking ~ 7mm |
| Step 10 | Install shim block ~ 5mm Bearing |
| Step 11 | Temporary load transfer to shim block |
| 35 Step 12 | Install new bearing and Epoxy grouting |
| Step 13 | Install jack with temporary bearing |

Step 14 Jacking ~ 7mm

Third night (between 12 am and 6 am)

- 5 Step 15 Remove shim block (after epoxy gain strength)
- Step 16 Load transfer to new bearing
- Step 17 Remove jack with temporary bearing
- Step 18 Allocation equipment to next location

10 To this end, it is reiterated that in order to introduce the one or more
load lifting devices 300 and/or load carrying devices 400 to their desired position
(e.g. different locations in a half joint area), those devices 300, 400 may be placed
and mounted on a support tray, which may be equipped with gears to lower side
plate 605 (e.g. Figure 11a) to translate the devices to forward or backward, as
aforementioned.

15 The load stabilizing device 500 can be installed to provide lateral
supports for the stability of the elongated span, against the pierhead and/or pier.
Figures 15a to 15d illustrate four examples how the methods of installation and
activation of the load stabilizing device 500 can be carried out. To this end, it is
disclosed that load lifting device 300 e.g. hydraulic jacks may also be attached
20 between the device 500 and the lateral faces of the span to ensure active
engagement of the device 500.

 The first method is a so-called “one level of bracket with chemset
bolts”. As can be seen in the Figure 15a (left), construction workers may first
reach the required position to install the load stabilizing device 500. As the name
25 implies, the stability bracket 500 is provided only at one level by securing slightly
below a half joint area 180 on a lateral side of a pierhead 170 with the stability
brackets 500. One longitudinal end of the stability bracket 500 can then be
secured with the neighbouring span 160 to form a “one support” S (as illustrated
in the Figure 15, middle), thereby the pierhead 170 and the span 160 are secured
30 to prevent translational movements. It can be foreseen that both lateral sides of
the viaduct can be installed with such stability bracket 500 to provide lateral
supports to the span 160.

Alternatively, this method of “one level of bracket with chemset bolts” may also be secured and supported with two supports S by securing the stability bracket 500 provided at a lateral side of a pierhead 170 to the both elongated spans 160 flanking the pierhead 170 (see two “S” in Figure 15a, right sketch).
5 This configuration further increases the stability of the span 160 to prevent translational movement (e.g. tilting from side to side). Thanks to the stability bracket 500, the spans 160 and pierhead 170 are provided with additional lateral support to maintain the stability of those structures.

In this first method, the concrete structure is assumed to have a
10 concrete strength of C40/50. The stability bracket with chemset bolts may have a jacking force of for instance 300 kN. The bolts required for this method are for instance 2x5 M24 with embedment depth of 220 mm.

A second variant of the method of installing the load stabilizing device 500 is shown in the Figure 15b. In this example, the “one level of bracket with
15 stressbars” is demonstrated. As can be seen in the first and second sketch (from the left), vertically set-up stressbars are firstly provided on each lateral side of the viaduct, subsequently “one level of bracket” which is similar to the first example as explained above is provided.

In this second variant, a pre-compression may be provided with 350
20 kN using two stressbars of unequal size: top stressbar (A) has a diameter of 18 mm while the bottom stressbar (B) has a diameter of 26 mm. The utilisation of stressbar is about 42 % GUTS. In addition, the top stressbar having diameter of 18 mm is located within the 50 mm chamfer region.

A third example of installing the load stabilizing device 500 is shown in
25 the Figure 15c which is known as a “one level of bracket with U-frame” method. This third variant is the most preferred method as no stressbars or chemset bolts are required. The reference “C” in the Figure 15c shows the section at U-frame. The reference “S” shows that one support is provided in this example (secured to the neighbouring structure).

A fourth example of installing the load stabilizing device 500 can be realised with a method known as "two levels of brackets with U-frame". As the name implies, the stability brackets 500 are provided at two levels on the pierhead 170 and its neighbouring spans 160, where the stability of the spans is secured
5 through the lateral supports of the stability brackets. The reference "C" in the Figure 15d shows a section at U-frame. The reference "S" shows that two supports are provided as illustrated in the Figure 15d.

To this end, it is reiterated that depending on the condition (e.g. stability of the span; centre of gravity of the span; degree of safety), the load
10 stabilizing device 500 may or may not be required in a bearing replacement method.

A second bearing replacement method is illustrated in Figures 16a to 16d. In this method, it does not require a load stability device 500 but through a load carrying device 400. In this particular example, a mechanical jack 401 is
15 used as a load carrying device 400 in the bearing replacement process. In some instances, mechanical jack is preferred over hydraulic jack due to safety concerns of hydraulic jack leakage.

Figure 16a shows a typical elongated span 160 which comprises two half joints 180', 180'' located approximately at each longitudinal end of the span
20 160. Two bearings 200 are installed on each of the half joints 180', 180''.

A load carrying device 400 e.g. a mechanical jack 401 is firstly inserted in between two bearings 200. The method of bring in the mechanical jack can be referred to the previous deployment methods (e.g. Figures 11 and 12). Once the mechanical jack 401 is inserted in the desired position (but not being load
25 transferred, mark "X" represents not yet activated), two additional load lifting devices i.e. hydraulic jacks 300a, 300b are placed at the periphery of the half joint area (i.e. close to the "front" and "back" entrances/openings of the half joint 180'') (see Figure 16b) such that load are transferred to these positions through these two hydraulic jacks 300a, 300b. Once the span 160 is being lifted e.g. around 5
30 mm, the mechanical jack 401 which was inserted in between the bearings 200

can then be extended for 5 mm so that the load can be transferred from the two hydraulic jacks 300a, 300b to the mechanical jack 401.

Once the mechanical jack 401 serves as a functioning supporting base for the span, the hydraulic jacks 300a and 300b can be removed in order to vacate the entrance of the half joint area 180". This step may be needed because in order to replace the bearings, the entrance of the half joint should not be blocked.

During the bearing replacement process, new bearing assembly 200 installation may require more than one shift (e.g. 8 hours) as the epoxy or cement grout requires some time to be hardened (see Figure 16c, checkered bearing represents new bearing 200, "X" represents not yet activated). In order to increase the safety of the span and allow train to pass, the two hydraulic jacks 300a, 300b are re-inserted back to the same position as described earlier (see Figure 16c) to provide additional supports.

Once the new bearing assembly 200 are ready to function (e.g. epoxy grout is hardened), the load can be transferred to the newly installed bearings. The two hydraulic jacks 300a, 300b that are located at the periphery of the half joint (or close to the openings of the half joint) can then be removed, followed by the removal of the mechanical jack 401 (Figure 16d).

Similar steps can be repeated on another half joint area 180' (located on the left on the sketch).

A third method of bearing replacement is illustrated in Figures 17a to 17h. In this example, load stabilizing devices 500 are employed without involving load lifting devices 300 such as hydraulic jacks in the centre of a half joint (e.g. between two bearings).

Figure 17a shows that two bearing assemblies 200 are provided on each of the half joint area 180', 180". Load stabilizing devices 500 i.e. stability brackets are installed at each longitudinal sides of the span 160, between a span 160 and a pierhead 170 (see Figure 17b) to provide lateral supports to the span in order to increase its stability.

Once the stability brackets 500 are installed (but not yet activated), two hydraulic jacks 300a, 300b are inserted to the periphery of the half joint area (close to the opening/entrance of the half joint 180", as shown in the Figure 17b). The span 160 is then lifted up about 5 mm through the two newly introduced
5 hydraulic jacks 300a, 300b. Subsequently, ring nuts of the stability brackets can be secured and followed by the activation 505 of the stability brackets by engaging the stability brackets to the span 160, against the pierhead 170 (see Figure 17c) or pier.

Thereafter, the two old bearings 200 can then be deactivated
10 (represented with dotted bearing with an "X", see Figure 17d) and replaced. In order to reach to the old bearing 200, the hydraulic jack 300b may need to be removed in order to vacate for the accessibility of the half joint so to reach one of the two old bearings 200. Once the old bearing 200 is replaced (but not yet activated, see checkered bearing but with an "X" in the Figure 17e), the hydraulic
15 jack 300b which was removed earlier can then be re-inserted back to the same position and activated (see Figure 17f). Similar process can be repeated on another old bearing 200 in the half joint area 180" (see Figure 17f). At this stage, the span load (of the half joint 180") is supported through the two hydraulic jacks 300a, 300b and the stability brackets 500 installed at the half joint area 180" as
20 the newly installed bearings are not yet activated. The newly installed bearings 200 may need 24 hours or 48 hours as the epoxy grout requires some time to be hardened. Therefore, by providing the additional hydraulic jacks 300a, 300b and the stability brackets 500, trains are allowed to pass the span 160.

Once the newly installed bearings 200 are activated (checkered
25 bearing without "X" mark, see Figure 17g), the temporary installed hydraulic jacks 300a, 300b can be removed and the stability brackets 500 can be deactivated (see Figure 17h). Similar procedure can be repeated on another half joint area e.g. on half joint 180'.

A fourth example of a bearing replacement method is illustrated in
30 Figures 18a to 18g. In this example, the elongated span 160 comprises three bearings 200 which form the three supporting bases of the span 160 (see Figure 18a). The method of replacing bearing in this example focuses on the half joint

area 180' which comprises only one bearing 200 (left half joint area as shown in the Figure 18a). The other half joint area 180'' comprising two bearings 200, the bearings 200 can be replaced with any of the three previously explained methods.

As shown in the Figure 18b, two load lifting devices e.g. in form of hydraulic jacks 300a, 300b are placed (but not yet activated; "X" represents not yet activated) flanking the bearing 200 in a half joint area 180'. Thereafter, load stabilizing device 500 i.e. stability brackets are installed (but not yet activated/engaged; without the reference 505) at the longitudinal sides of the span near to the two half joint areas 180', 180'' of the span 160. Thereafter, both the hydraulic jacks 300a, 300b are activated by jacking up approximately 5 mm so that part of the load is transferred from the bearing 200 (in half joint area 180') to the both hydraulic jacks 300a, 300b (see Figure 18c).

Once both the hydraulic jacks 300a, 300b are activated, the old bearing 200 in the half joint 180' can be deactivated (represented by the dotted bearing with an "X") (see Figure 18d). One of the hydraulic jacks e.g. hydraulic jack 300b may need to be deactivated and removed so that it frees up the entrance of the half joint for the accessibility to reach the old bearing 200. Before this step, the installed stability brackets 500 may be activated 505 so that lateral supports can be provided to the span (see Figure 18e).

As soon as the old bearing is replaced with a new bearing (represented with checkered bearing), however the newly installed bearing is not yet activated (represented by an "X", see Figure 18f). The hydraulic jack 300b which was removed earlier can now be placed back to the similar position, re-activated and lifted so that part of the load is transferred to the hydraulic jacks (see Figure 18f).

The introduction of the both hydraulic jacks 300a, 300b and the four stability brackets 500 allows the span to function as if in normal condition e.g. allow train to pass although the newly installed bearing 200 is not yet activated, as the bearing assembly 200 comprising epoxy grout requires at least an overnight e.g. 8 hours to be hardened.

Once the grout is hardened, the bearing assembly 200 can be activated to serve as a supporting base for the span 160 (represented by a “checkered” bearing without an “X”). Subsequently, the two hydraulic jacks 300a, 300b and the four load stabilizing devices 500 can be deactivated and removed,
5 wherein the one bearing on the half joint 180’ is being replaced (see Figure 18g).

As explained above, the one or more load lifting devices 300 and/or the load carrying device 400 may be first placed on a supporting tray such that the load lifting device 300 and/or the load carrying device 400 can be carried into the limited space of a half joint area 180 and be arranged in a desired position
10 before exerting lifting or holding force. These devices 300, 400 may be arranged and positioned in different configuration in a half joint area 180 in order to carry out the bearing replacement task.

As shown in the Figure 19a which is a first example of the arrangement, the load lifting device 300 according to the present invention
15 comprises a plurality of chambers which are hydraulically connected. The load lifting device 300 may be placed in between two bearings (bearing assemblies) 200 e.g. in a central position of the half joint area. The lifting force exerted by the load lifting device 300 would allow the two neighbouring bearings 200 to be released temporarily from their duty and therefore can be replaced with the new
20 bearing assemblies. The load lifting device 300 according to this example may be arranged in 4 x 3 chamber configuration (total of 12 chambers) having for instance a total of 108 T load lifting force.

In a second configuration as illustrated in the Figure 19b, the smaller lifting capacity of the load lifting device 300 may be used. For instance, in
25 between the two existing bearings 200’, 200’’, four smaller load lifting devices 300 each having a total lifting capacity of 60 T are provided in the central location. In some configurations, the 60 T lifting capacity device may be even shared by two even smaller lifting devices, each having 30 T lifting capacity. This allows a smaller dimension of load lifting device 300 to be placed and positioned in a half
30 joint area which have a very limited space. At the periphery of the half joint (or the “front” and the “back” entrance/opening of the half joint 180), two load lifting devices 300 each having 75 T lifting capacity may be placed at each of the

entrances. These load lifting devices 300, when activated, load can be transferred from the bearings 200', 200'' to these load lifting devices 300 so that the old bearings can be replaced.

Alternative to the Figure 19b, in the central position of the half joint area (in between two existing bearings 200', 200''), two load lifting devices 300 each having 120 T lifting capacity (wherein each of the load lifting device 300 comprises four chambers each having 30 T lifting capacity) are placed parallel to each other in the central position between two existing bearings 200', 200'' (see Figure 19c). Similar to the Figure 19b, two load lifting devices 300 each having lifting capacity of 75 T are placed at the "front entrance F" and "back entrance B" (see horizontal arrowheads) of the half joint 180. Together, these load lifting devices 300, when activated, load can be transferred from the bearings 200', 200'' to these load lifting devices 300 so that the old bearings can be replaced.

It is noted that the central position of the half joint area usually has a very limited empty space. For instance, as shown in the Figure 19c, the bottommost transverse length (of a cross section) of the half joint area parallel to the elongated span is represented by "T" which has a transverse length of $150+500+150 = 800$ mm. The bearing assembly 200', 200'' usually has a square surface area of (500 mm x 500 mm) 250,000 mm² whereas the half joint 180 has a total rectangular surface area of approximately $[(100+180+500+500) \times 2] \times (150+500+150) = 2,560 \times 800 = 2,048,000$ mm². Deducting the space occupied by the two existing bearings $[2 \times (500 \times 500)]$, the accessible or remaining empty space of a half joint area is estimated to be approximately 1,548,000 mm² (obtained from 2,048,000 mm² minus 250,000).

To this end, it is emphasized that the dimension of a half joint area may be defined using different methods or parameters. For instance, the total space of the half joint area is usually delimited by the space between pierhead and span (regardless whether bearings are being provided). Nevertheless, the geometry of the components of the viaduct may not be always symmetrical e.g. its surface may not be even or may not have sharp edges. This causes difficulty in calculating or estimating the space or dimension of the half joint, if not impossible. Thus, such 3D geometrical measurement of space is extremely

difficult. For this reason, the presently proposed method of calculating or estimating the half joint dimension by the concept of "bottommost transverse length (of a cross section) of a half joint" gives the best (and easiest) solution is henceforth proposed, as measuring a 2D geometry would be much straight-
5 forward and direct than by measuring a 3D geometry. A skilled person in the art can easily understand and capable to measure the length of the bottommost (or almost bottommost) transverse length (T) of the half joint area, wherein the bottommost transverse length of the half joint is parallel to the longitudinal direction of the elongated span. This bottommost (or almost bottommost)
10 transverse length is visually ascertainable and can be directly measured at the entrance/opening of the half joint area, hence it is sufficiently clear and straight-forward to any person.

In this connection, it is disclosed that the half joint area which is suitable for the present invention has a restricted dimension as defined
15 hereinbefore or hereinafter, wherein the measurement of "bottommost transverse length of a half joint parallel to the direction of the elongated span" is espoused. A half joint that is suitable for the present invention is where the half joint has an accessible or remaining empty space defined by having a ratio of less than 3:1, preferably less than 3:2 of total bottommost transverse length of the half joint
20 unoccupied by a bearing assembly: bottommost transverse length of the half joint occupied by a bearing assembly, or preferably defined by having a ratio in between 2:3 and 3:2, or in between 1:2 and 1:1. Generally, it is well within the range ratio of 2:1 and 1:2.

Turning the ratio into exemplary value (using the ratio of less than 3:2
25 as an example), it can be better understood that for instance if the bottommost transverse length of a half joint parallel to the elongated span has a total length of 1000 mm (c.f. reference number T in Figure 20), and when the bottommost transverse length occupied by a bearing assembly has a length of 400 mm (c.f. reference number O in Figure 20), in other words, 600 mm will be the bottommost
30 transverse length of the half joint unoccupied by a bearing assembly (i.e. free empty space to allow the insertion or the withdrawal of devices into the desired location of a half joint), as illustrated in the Figure 20. In this connection, it is disclosed herein that the 600 mm of space may be equally divided on both sides

of the bearing assembly (i.e. 300 mm empty space on each side of the bearing assembly) or it may be divided unequally, for instance 200 mm on one side and 400 mm of free space on another side of the bearing assembly 200, or in other positions which could serve to support the loads.

5 To this end, it is reiterated that the bearing assembly 200 comprises a number of components which have different dimension or length. Hence, it can be understood easily by a skilled person that the component having the largest dimension usually is the deciding factor of the dimension of a bearing assembly. A general rule of thumb is that those components of the bearing assembly 200
10 arranged beyond the height of the load lifting device and/or load carrying device are not considered as the deciding factor of the dimension (reference "O" of Figure 20) of the bearing assembly 200, as these components do not hinder or block the insertion of the load lifting device and/or load carrying devices in the half joint area. For instance, usually components arranged at the bottom half of
15 the bearing assembly 200 (e.g. bearing support plate and/or base plate) are the deciding factor when determining the length or dimension of the bearing assembly 200.

In other words, using Figure 20 as an example, the ratio of total bottommost transverse length of the half joint unoccupied by a bearing assembly:
20 bottommost transverse length of the half joint occupied by a bearing assembly can be represented by the reference numbers (R1+R2) which is the reference number "O". When the half joint has an accessible or remaining empty space defined by having a ratio of less than 3:2 of (R1+R2): O, if for instance the bearing assembly has a bottommost transverse length of 400 mm, the bottommost
25 transverse length of R1+R2 would be 600 mm at most.

To this end, it is reiterated that the load lifting device, the load carrying device and optionally at least partially the load stability device are inserted within the half joint area, arranged in such a way that the path to withdraw the bearing to be replaced is not obstructed by the aforementioned devices.

30 The method and system of replacing bearings through a half joint area of a viaduct espoused in the present invention is suitable for different types of

bearings and not only one specific type of bearing, for instance also suitable for fixed bearings, rocker bearings, elastomeric bearings, sliding bearings, curve bearings or spherical bearings.

Claims

1. A method of replacing bearings through a half joint area of a viaduct comprising a plurality of axially arranged elongated spans,
- 5 wherein each of the elongated span is supported on at least three or four bearings, forming supporting bases of the span, such that the centre of gravity of the elongated span lies within an area inscribed by the supporting bases of the span;
- 10 wherein the half joint area is a substantially rectangular empty space approximately located at at least one longitudinal end of the elongated span, resulted from the span being supported on the bearings which in turn are supported on at least one or two neighbouring pierheads, wherein the empty space of the half joint has an access only from the direction transverse to the longitudinal axis of the span for the
- 15 placement of bearing replacement device;
- comprising the steps of
- a. Inserting one or more load lifting devices to the half joint area;
 - b. Transferring load to the one or more load lifting devices introduced in the step (a);
 - 20 c. Replacing one or more bearings of the half joint area and transferring loads to the newly installed one or more bearings;
 - d. Removing the one or more load lifting devices introduced in the step (a).

2. The method of replacing bearings in a half joint area of a viaduct comprising a plurality of axially arranged elongated spans according to claim 1,

5 wherein each of the elongated span is supported on at least three or four bearings, forming supporting bases of the span, such that the centre of gravity of the elongated span lies within an area inscribed by the supporting bases of the span;

10 wherein the half joint area is a substantially rectangular empty space approximately located at at least one longitudinal end of the elongated span, resulted from the span being supported on the bearings which in turn are supported on at least one or two neighbouring pierheads, wherein the empty space of the half joint has an access only from the direction transverse to the longitudinal axis of the span for the placement of bearing replacement device, wherein the half joint area
15 has a restricted dimension defined by a bottommost transverse length (T) of the half joint area, parallel to the elongated span;

20 wherein the bearing together with a plurality of supporting plates and grout pads form a bearing assembly occupying a space of the half joint area, wherein an accessible empty space of the half joint area is defined by a ratio of total bottommost transverse length of the half joint unoccupied by the bearing assembly: bottommost transverse length of the half joint occupied by the bearing assembly, wherein the ratio is less than 3:1, preferably less than 3:2;

comprising the steps of

- 25 a. Inserting one or more load lifting devices to the accessible empty space of the half joint area,

- b. Transferring load to the one or more load lifting devices introduced in the step (a), thereby forming one or more temporarily new supporting bases of the span;
- c. If the centre of gravity of the elongated span still lies within the area inscribed by the supporting bases of the span after the loads are transferred to the one or more load lifting devices introduced in the step (b), then replacing the one or more bearings on the half joint area which their loads are temporarily taken by the one or more load lifting devices introduced in the step (b);
- d. If the centre of gravity of the span now lies outside of the area inscribed by the supporting bases of the span after the loads are transferred to the one or more load lifting devices introduced in the step (b), installing load stabilizing device to provide lateral supports for the stability of the elongated span;
- e. Then replacing one or more bearings on the half joint area which their loads are temporarily taken by the one or more load lifting devices introduced in the step (b), and transferring loads to the newly installed one or more bearings;
- f. Removing the one or more load lifting devices introduced in the step (a).
3. The method of replacing bearings according to claim 1 or claim 2, wherein the step (a) is carried out by inserting the one or more load lifting devices on both sides of the bearing, thereby flanking the bearing either longitudinally or transversally of a longitudinal axis of the elongated span.
4. The method of replacing bearings according to claim 1 or claim 2, wherein the step (a) is carried out by inserting the one or more load lifting devices in between two bearings of a half joint area.
5. The method of replacing bearings according to any one of the preceding claims, wherein the method is carried out as follows:
- a. Inserting one or more load carrying devices in between two bearings located in a half joint area of an elongated span.

wherein the load carrying devices are preferably mechanical jacks;

- 5 b. Inserting one or more load lifting devices to the half joint area of the elongated span, close to the peripheries of the half joint area, wherein the load lifting devices are preferably hydraulic jacks;
- c. Transferring load to the one or more load lifting devices introduced in the step (b);
- 10 d. Transferring load to the one or more load carrying devices introduced in the step (a);
- e. Removing the one or more load lifting devices introduced in the step (b);
- f. Replacing one or more bearings on the half joint area of the elongated span;
- 15 g. Repeating step (b);
- h. Transferring load to the one or more load lifting devices introduced in the step (g);
- i. Transferring loads to the newly installed one or more bearings;
- 20 j. Removing the one or more load lifting devices introduced in the step (g);
- k. Removing the one or more load carrying devices introduced in step (a).

6. The method of replacing bearings according to any one of the preceding claims 1 to 4, wherein the method is carried out as follows:

- 25 a. Inserting one or more load lifting devices to a half joint area of the elongated span, close to the peripheries of the half joint area, wherein the load lifting devices are preferably hydraulic jacks;

- b. Installing one or more load stabilizing devices around the half joint area to provide lateral supports for the stability of the elongated span;
- 5 c. Transferring load to the one or more load lifting devices introduced in the step (a), or perform this step before the step (b);
- d. Engaging the one or more load stabilizing devices introduced in the step (b) to the elongated span;
- 10 e. Removing the one or more load lifting devices introduced in the step (a);
- f. Replacing one or more bearings on the half joint area of the elongated span;
- g. Repeating the step (a);
- 15 h. Transferring load to the one or more load lifting devices introduced in the step (g);
- i. Replacing the remaining bearings on the half joint area of the elongated span;
- j. Transferring load to newly installed bearings and removing the one or more load lifting jacks introduced in step (a).
- 20 7. The method of replacing bearings according to the preceding claims 5 or 6 performed through a first half joint located around a longitudinal end of an elongated span, wherein a second half joint area comprising a single bearing located around another longitudinal end of the elongated span, the single bearing is replaced as follows:
- 25 a. Inserting two or more load lifting devices to the second half joint area of the elongated span, close to the peripheries of the second half joint area, wherein the load lifting devices are preferably hydraulic jacks;

- b. Installing one or more load stabilizing devices around the second half joint area to provide lateral supports for the stability of the elongated span;
 - 5 c. Transferring load to the two or more load lifting devices introduced in the step (a), or perform this step before the step (b);
 - d. Engaging the one or more load stabilizing devices introduced in the step (b) to the elongated span;
 - 10 e. Removing one or more of the load lifting devices introduced in the step (a);
 - f. Replacing the bearing on the half joint area of the elongated span;
 - g. Repeating the step (a);
 - 15 h. Transferring load to the two or more load lifting devices introduced in the step (g);
 - i. Transferring load to the newly installed bearing;
 - j. Removing all the load lifting devices introduced in the step (g) and the load stabilizing devices introduced in the step (b).
- 20 8. A bearing replacement system for use in a half joint area of a viaduct comprising a plurality of axially arranged elongated spans, wherein the half joint area is a substantially rectangular empty space approximately located at at least one longitudinal end of the elongated span, resulted from the elongated span being supported on the bearings which in turn are supported on at least one or two neighbouring pierheads, wherein
- 25 the empty space of the half joint has an access only from the direction transverse to the longitudinal axis of the span for the placement of bearing replacement device,
- 30 wherein the half joint area preferably has a restricted dimension defined by a bottommost transverse length (T) of the half joint area parallel to the elongated span, wherein the half joint area has an accessible empty space defined by a ratio of total bottommost transverse length of the half joint unoccupied by the bearing assembly:

bottommost transverse length of the half joint occupied by the bearing assembly, wherein the ratio is less than 3:1, preferably less than 3:2;

5 wherein the system comprises one or more load lifting devices for lifting loads, insertable to the remaining empty space of the half joint area, wherein the load lifting devices are preferably hydraulic jacks.

9. The system according to claim 8, further comprising one or more load carrying devices for carrying load, wherein the load carrying devices are preferably mechanical jacks.
10. The system according to claim 8 or claim 9, further comprising one or more load stabilizing devices to provide lateral support for the stability of the elongated span.
11. The system according to any one of claims 8 to 10, wherein the one or more load lifting devices are a battery of lifting jacks comprising a plurality of chambers which are hydraulically linked.
- 15 12. The system according to claim 11, wherein each of the chambers is operable to apply a lifting capacity of at most 15 tonnes, preferably at most 10 tonnes.
- 20 13. The system according to any one of claims 11 or 12, wherein the battery of lifting jacks has between 5 to 20 chambers, preferably 10 chambers.
14. The system according to any one of claims 13 to 16, wherein the battery of lifting jacks has an elongated dimension, wherein the overall length is at least three times of its width.
- 25 15. The system according to any one of the preceding claims 9 to 14, wherein the load carrying device is a mechanical wedge system, preferably mechanical jacks, having an elongated dimension, where the overall length is at least three times of its width.