HEAVY MOVABLE STRUCTURES, INC.

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"New Bascule Bridge Center Locks"

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MOVABLE BRIDGE CENTER LOCK

by

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Movable bridges have been used for centuries to provide land vehicle or personnel passage across a body of water while allowing vessels to navigate on the waterway past the location of the bridge. The most common types of movable bridges include the bascule bridge, the swing bridge, and the vertical lift bridge. The swing bridge rotates about a vertical axis to remove its obstruction from the waterway. The vertical lift bridge has a span over the waterway that can be lifted up sufficiently to clear a vessel navigating the waterway. The bascule bridge rotates about a horizontal axis at a right angle to the bridge or parallel to the waterway, swinging up and away from the navigation channel to clear it for vessels.

Some movable bridges consist of two leaves, which are cantilevered toward each other over the navigation channel. These movable bridges, which are usually bascule types but in a few instances are swing bridges, have generally been stabilized by the use of locking devices. A double leaf swing bridge or bascule bridge has a pair of movable bridge sections, or leaves, which meet at or near the center of a navigation channel. The bridge forms a removable roadway crossing over the channel, one leaf projecting from one side of the navigation channel, and the other leaf projecting from the other side of the channel. The bridge leaves open by rotating about axes which are usually at right angles to the bridge. Each leaf of the double leaf bascule rotates in a vertical arc, while each leaf of a double leaf swing bridge rotates in a horizontal arc. The double leaf bridge usually has a mating pair of center lock devices rigidly attached to each of the bridge trusses or girders on each leaf. These devices, when the bridge is in the lowered position, engage to form a shear connection between the two leaves.

There have been some double leaf bascule bridges which form a simple truss when closed and carrying traffic. At least one of this type is still in existence. There are a few double leaf bascules which form a 3-hinged arch when carrying traffic. Other cantilevered double leaf bascules have attempted to support one leaf on the other. There has been at least one double leaf bascule bridge, if you call it that, that has been constructed as ½ cable stay and ½ simple span. These are all special case double leaf bridges which are shown as exceptions to the rule, and are not the topic of this paper.

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The double leaf bascule type of bridge is frequently used due to its economy of construction, ease and rapidity of operation, and minimal obstruction of the navigation channel. Most modern double leaf bascule bridges consist of two cantilever spans on opposite sides of a navigable waterway. These spans are arranged so that the spans rotate downward when closing, driven by operating machinery, bringing their tips, or toe ends, to near proximity at the center of the channel to provide a passageway for vehicular traffic. A few double leaf swing bridges have been built which have features similar to double leaf bascule bridges, but which rotate about a vertical axis instead of a horizontal one to open the waterway for navigation and to reposition the bridge for carrying land highway traffic. This type has been around for along time, possibly longer than the conventional double leaf bascule. An example was in use in Cleveland OH in the 1870's

The dead load of the extended leaves of the double leaf bridge and the live load upon the leaves is usually carried back to the piers in cantilever fashion Center locks are deployed to link the tips of the two leaves together when closed, so that live load at the midportion of the span is shared by the leaves. In this way both leaf tips deflect approximately the same when the bridge is carrying live load and reacting to the possibly uneven effects of temperature changes. This minimizes the discontinuity at the roadway surfaces at the meeting point of the two leaves, reducing or eliminating the bump experienced by a vehicle passing from one leaf to the other.

Previous devices for forming this shear lock function have been limited in utility because of the tendency of the mating components of the center locks to wear. This wear is largely due to contamination of the surfaces which slide while under live load and other forces. Typical center locks for a double leaf movable bridge are of one of three types:

1) A bolt that is thrust by mechanical means, from the end of each girder or truss on one leaf into a socket rigidly attached to the end of the corresponding truss or girder on the other leaf

2) A pincer type mechanism, which may consist of male or female movable jaws on one leaf, which reach out and grasp an extension on the other leaf

3) Mating rigid male - female jaws mounted on the projecting ends of the bridge girders or trusses of each bridge leaf which interlock as the bridge is closed.

The center lock components of these devices suffer from impact and wear forces, resulting largely from deflection when under the influence of live loads. The typical configuration of traditional center locks places high bearing pressure on components that move relative to each other when the bridge is carrying traffic and are exposed to contamination by dirt, dust in the air, rain water and other contaminants. The result of the combination of high bearing pressure and contamination is rapid wear of the components. As wear occurs, clearances increase, adding impact loads to the forces on the lock components, causing further increases in the rate of deterioration. This eventually allows substantial misalignment of the two leaves at their meeting point. After a time, due to this deterioration, other bridge components, such as the span operating machinery and live load shoes, suffer degradation because of the worn-out condition of the center locks. Various schemes have rearranged the components of center locks, such as rotating them so that the lock bars are at right angles to the main bridge girders or trusses, without eliminating the problem of wear of components exposed to contamination.

A brief discussion of several patented of types of center locks follows (patent number, inventor, and date are given in the headings):

511,713 Scherzer, Wm (1893)

This is the first Scherzer bascule bridge patent, and apparently the original center lock type devised for the Scherzer rolling lift bridge. It is a complicated mechanical arrangement as opposed to the later simple tongue and jaw type (see below). This arrangement allows the two leaves to open and close independently. . ***n.b.*** This patent also calls for the bridge to be span heavy when open, and counterweight heavy when closed. It also calls for optional hydraulic piston operation, in 1893.

554,390 Jennings (1896)

This bridge lock design forms a bowstring tied arch out of two cantilevered bascule leaves by connecting the lower chords of the main bridge members by means of laterally acting cylindrical lock bars. A couple of alternative activating mechanisms are shown, a crank and a rack pinion arrangement.

617,606 Sampson (1899)

This center lock is for a retractile bridge. The locks act vertically, connecting the upper chords and the bottom chords.

632,985 Brayton (1899)

This center lock device acts to form an arch bridge, by butting the top chords of the bascule trusses together, which probably would have been sufficient to hold the bridge up, but also adds a connection at the lower chords which could allow them to become tension members, by using a wormgear and screw arrangement to engage a pair of link plates to laterally mounted pins at the ends of the lower chords of the bascule bridge.

685,768 Keller (1901)

This patent is for a pin type center shear lock oriented with the axis of the pin horizontal, but at a right angle to the axis of the bridge. I never heard of any bridge being built with this type of center lock.

689,856 Cummings (1901)

This center lock is a laterally oriented cylindrical pin arrangement, with a secondary pin and mechanism to tension the "lower chord" after the main pin has been engaged.

780,193 Joyce (1905)

This bascule bridge center lock consists of rollers and tongues, so that the longitudinal expansion and contraction of the leaves can be accommodated easily and freely, while still carrying the shear loads across the center of the bridge. The leaves must be opened and closed simultaneously, to engage and disengage the rollers and tongues.

968,988 Scherzer, Albert (1910)

This is a clear representation of the jaw type center lock commonly used on Scherzer type rolling lift double leaf bascule bridges. It requires synchronized opening and closing of the leaves.

1,157,449. Strauss (1915)

This center lock device attempts to form a true simple truss span out of two cantilevered bascule leaves. The top chords butt against each other, and a complicated heavy locking device ties the lower chords together in tension. One leaf is fixed, and the other is on rollers, so that the simple truss bridge, when connected, can expand and contract and deflect in the longitudinal direction like any other simple span could.

1,542,972 Straus (1925)

This center lock arrangement was patented by Joseph Straus, one of the more prolifically creative bridge engineers of the early 20th century. This is the invert of # 1,646,340 (below)

1,646,340 Ash (1927)

This center lock has a mechanical jaw arrangement on one leaf that "bites" onto a projecting tongue on the other leaf. This arrangement has been successfully applied to several bascule bridges, including a new double leaf bascule in Washington State in 1994. It has the advantage of a fairly easy readjustment to accommodate wear in the jaw-tongue contact area, more so than # 1,542,972 (above). It has the disadvantage of having many moving parts.

2,610,341 Gilbert (1949)

This center lock design calls for a laterally mounted lockbar engaging a rotating socket. It requires all longitudinal displacement to be taken up in relative motion between the bar and the socket. There appears to be no control or limitation of the rotation of the socket. I have never heard of a bridge being built with this type of center lock.

5,327,605 Cragg (1995)

This center lock is a variation of the Earle Gear lock bar and drive, with sets of belleville washers added to make the bar & socket connection flexible, allowing rotation and flexure of the bascule leaves in a vertical plane without pinching the lockbar between the socket shoes. This arrangement has bee used on several bascule bridges, but the improvement has not yet had sufficient time in service to show how much it increases the durability of this type of center lock.

Koglin (2000)

This center lock calls for a non-circular lockbar on one leaf that firmly engages a socket on the other, the socket being free to move to accommodate all extraneous motions of the bridge leaves while engaged, while still supporting and transferring the necessary vertical shear loads.

By separating the components that move under live load conditions from the components that are exposed to contamination, double leaf movable bridges can be provided with center locks that are much more durable than those heretofore employed. This principle can be applied equally as well to double leaf bascule bridges of the simple trunnion type, rolling lift type, heel trunnion type, most other variations of double leaf bascule bridges. It can also be applied to those bascule bridges which incorporate multiple parallel sets of leaves, with the bascule leaves on the same side of the navigation channel either connected or unconnected. It can also be applied to other types of movable bridges, such as double swing bridges, rolling retractile bridge, or pontoon retractile bridges, which have two separate leaves which meet over the navigation channel.

The improved center lock system consists of a set of center locks engaging parallel to the axes of rotation of the movable bridge, driven by thrusting mechanisms at each mating pair of main bridge support members. This system separately accommodates engagement and deflection of the bridge leaf sections.

DETAILED DESCRIPTION

The proposed center locks affect the shear connection of the two mating leaves. This is done by making and breaking between the lockbar and the rotating socket, a rigid connection which is provided that does not directly accommodate deflections due to live load and thermal stresses. These center locks provide a permanent center lock bearing with rotating bearing surfaces at the rotating socket which is never disengaged from the internal bearing surface of the associated sliding block. The external sliding bearing surfaces at either of the sliding blocks are never disengaged from the bearing surfaces of the respective guides, which directly accommodate deflections due to live load and thermal strains.

The most appropriate material for each component is determined by the particular application, as the ability to resist the loads encountered in service is the primary criterion. Typically when all components consist of steel, the assembly will operate satisfactorily. Lubrication is important, and must be applied as a regular maintenance procedure to all moving parts. Substitution of other materials, such as bronze, teflon, or other modern materials, may reduce the need for regular maintenance of the proposed center locks in service.

OPERATION

When the movable bridge is in position blocking the navigation channel, carrying traffic crossing over the bridge, the center locks are in the engaged position, forming a shear connection at each mating pair of girders at the bridge leaves. Each lock bar mates intimately with all its associated guides and rotating socket. As the bridge deflects due to the application of live load such as a motor vehicle, rotational deflection of the ends of the two bridge leaves is accommodated by the lock device described. This occurs by means of rotation of the rotating socket within the associated sliding block. The socket rotates with the lock bar and the end of the near leaf to which the lock bar is attached. The sliding block rotates with end of the far leaf, to which the sliding block is attached, via the guides. The amount of relative rotation between the lockbar and the sliding block is equal to the absolute sum of the degree of angular deflection of the ends of the two leaves under the live load. The rotating socket rotates within the sliding block, the rotation of the socket being equal to that of the lockbar. In addition to rotational deflections, the tips of the two leaves come closer together and farther apart as the live loads are applied and released and as temperature increases and decreases. The relative longitudinal motion is taken up by the movement of the associated sliding block within its guides on the bridge girder upon which it is mounted. The total amount of this movement is determined by the geometry and rigidity of the leaves of the movable bridge, by the amount of live load applied, and by the amount of temperature change causing thermal expansion or contraction of the bridge components. Temperature changes can also cause angular deflection of the tips of the leaves, with results similar to those experienced because of live load deflection.

The construction of each double leaf movable bridge and the conditions upon which it operates and carries traffic will allow the center lock proportions and material properties required for the particular application to be determined. This is done by application of standard engineering practice and references, such as those published by the American Association of State Highway and Transportation Officials for highway bridges, and the American Railway Engineering and Maintenance of Way Association for railway bridges. The amount of free longitudinal movement of the sliding blocks along the guides, and free rotational movement of the rotating sockets within the sliding blocks, should be the minimums necessary for the application.

The leading end of the lock bar has a rectilinear cross section and is fitted with tapered sides so that the lock bar can be driven into the mating hole in the rotating socket without initial interference. The pressure of the advancing tapered sides of the leading end of the lockbar against the contacting sides of the hole in the rotating sockets produces torsional moments on the rotating socket. This forces the alignment of the hole in the rotating socket with the lockbar by causing rotation of the socket within the sliding block. In this manner lateral forces are developed against the leading edge of the lockbar as it continues to enter the hole in the rotating socket. This forces movement of the sliding block, via the rotating socket, along the guides so that axial alignment of the lockbar and the rotating socket is attained, regardless of the initial position or orientation of the rotating socket within the sliding block. This is also true regardless of the position of the sliding block within the guides. In other words, after the leading edge of the lock bar has entered the hole in the rotating socket, further extension of the lock bar causes the rotating socket to align itself with the lock bar, by rotating the socket within the sliding block, and causes the combination of rotating socket and sliding block to translate longitudinally along the guide and come into alignment with the lock bar. When the lock bar is fully driven, the hole in the rotating socket is fully in contact with the prismatic section of the lockbar. There is no freedom of rotational, longitudinal or vertical movement between the lock bar and rotating socket. All the required freedom of movement between mating bridge leaves is obtained by the rotation of the socket within the sliding block, and the translation of the sliding block within the guides. Only sufficient clearances are desired between the lockbar and the socket to allow easy entry and withdrawal of the lockbar into and out of the socket.

To allow the bridge to be opened for marine traffic, the lock bars are withdrawn by means of the thrusting mechanism or mechanisms, to the position relative to rotating socket and sliding block, and the bridge can be opened. After the bridge has opened and the marine vessel has passed, the leaves of the bridge are returned to the closed position, the thrusting mechanisms are actuated for extending the lock bars to full engagement with the associated rotating sockets. After any additional safety devices not directly a part of the proposed center locks are placed in their active positions, the bridge is ready to carry traffic.