Paper No. 25

Structural Elements

Energy Absorbing Live Load Shoes and Anchorages for Bascule Bridges

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“Energy Absorbing Live Load Shoes and Anchorages for Bascule Bridges”

Although a bascule bridge must be designed so that it can quickly and reliability change its orientation to alternately permit the passage of land and waterway traffic as required, it should, desirably, be just as rigid and immovable in the closed position as a fixed span. The system that secures the leaf when closed is called the “ Static Stabilizing System” and can include several components - typically; span locks, live load shoes, anchorages and machinery brakes; some leafs also have tail locks.

Let’s take a quick look at representative systems on bascule leafs.

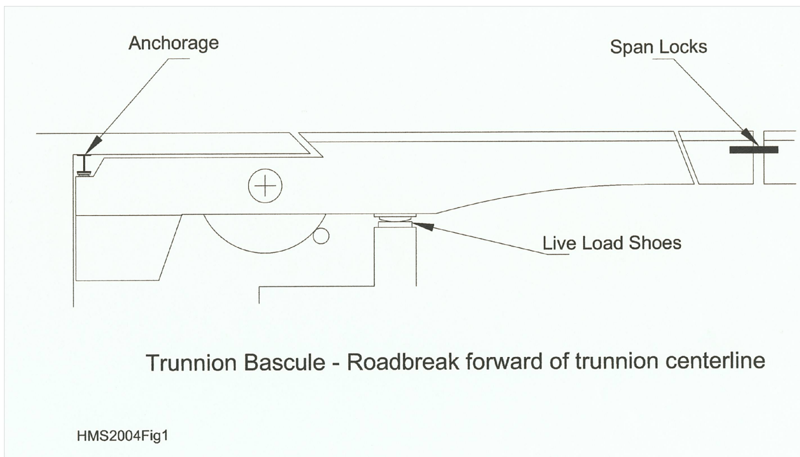
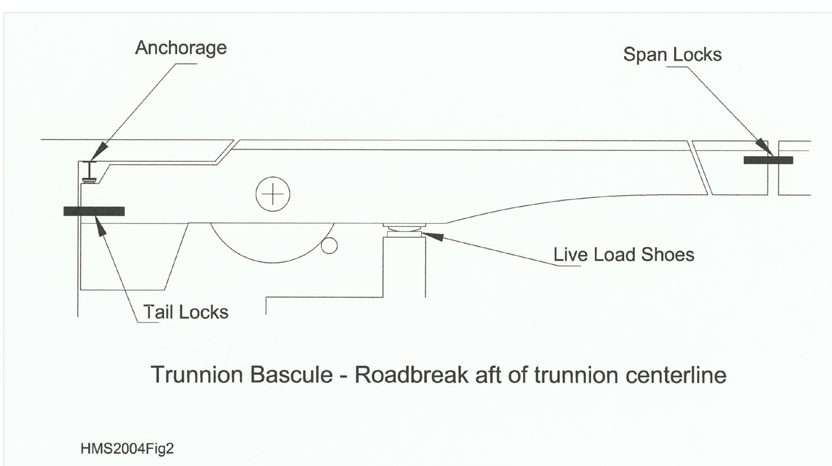
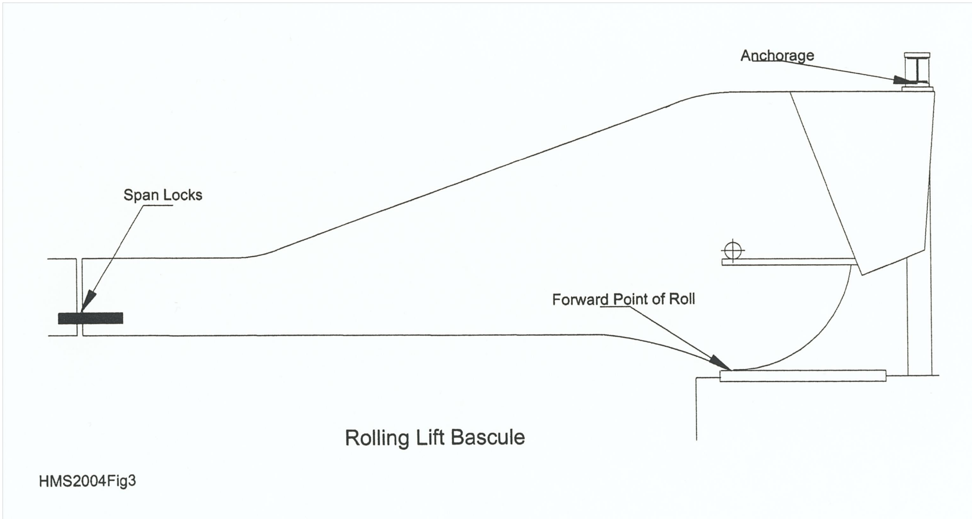


Fig 1 illustrates one leaf of a two leaf trunnion type bridge and includes span locks, live load shoes and anchorages. Notice the road break is forward of the trunnion centerline and there are no tail locks - since, with proper balance, no forces would occur that tend to open the leaf when closed. On a leaf that has the road break to the rear of the trunnion centerline tail locks are essential because reverse moments will occur frequently during the passage of vehicular traffic, Fig 2. It should be noted here that some bascule leafs of this design do not have live load shoes forward of the trunnions.



Rolling lift bridges must have span locks and anchorages but no not require live load shoes forward of the center of roll as all the dead and live loads are transferred directly to the piers through the curved and flat track plates, Fig 3.



Machinery brakes are included in all the operating machinery systems and are set whenever the machinery is not energized - their purpose is to prohibit any rotation of the machinery while the bridge is not moving - that is; closed, open or at some intermediate location.

It is seen that although the components of the systems are simple devices they must be properly set and maintained so they act in concert with one another - for instance; with no live load present the live load shoes should be adjusted to be in firm contact with their seats after the span locks are driven; on most trunnion bascules the anchorages should have a small clearance when the leaf is closed but on a rolling lift it is desirable to have the anchorages seated with the leaf closed, and so on.

While it appears a routine request to maintain the components so they are properly adjusted fulfillment of that request can be a time consuming, labor intensive headache that gobbles up a lot of dollars from an already strained maintenance budget. The problems are many since the parts wear, experience corrosive deterioration, are cumbersome and often difficult to access. Also; correct adjustment requires closing the span to vehicular traffic with the attendant inconvenience to the traveling public and thermal variations can result in structural distortions so that what was correctly set at midnight is out of kilter at noon the following day.

Some of the adjustment and maintenance problems and expense have been reduced by the use of zero clearance, energy absorbing guides and receivers in the span lock systems. Yet there is still need to address the difficulties associated with live load shoes and anchorages.

Many serious structural problems as well as distress and failures of machinery components are directly related to poorly adjusted and maintained static stabilizing components. Here are some we’ve come across:

A. Live load seat support column cracking, Fig 4.
Two conditions probably contributed to this failure:
1. Frequent high shock loads caused by slamming the leaf hard onto the seat during closing.
2. Absence of firm live load shoe contact with the leafs closed and the locks engaged permitting repetitive shock loads during the passage of vehicular traffic.

B. Rack tooth breakage, Fig 5.
The weld repaired tooth seen here is the one engaged with the pinion when the leaf is closed. Rotation of the pinion cannot occur as the machinery brakes have been set. Thus, any motion of the leaf as vehicular traffic passes causes cyclic shock loads on both faces of the rack tooth which eventually resulted in fracture of the tooth. Investigations at the site revealed that poorly adjusted live load shoes as well as excessive clearance in the span locks were the major culprits. Additionally, the tail locks had been removed so that a bad situation was made worse.

C. Trunnion bearing failure, Fig 6.
On this leaf not only were the live load shoes out of contact by about 1/4 in. and the span locks well worn, but also, the anchorages were in hard contact with the leaf closed. Live loads on the leaf caused extremely high loads and repetitive shocks on the trunnion bearings. The one we see here finally fractured across its full width.

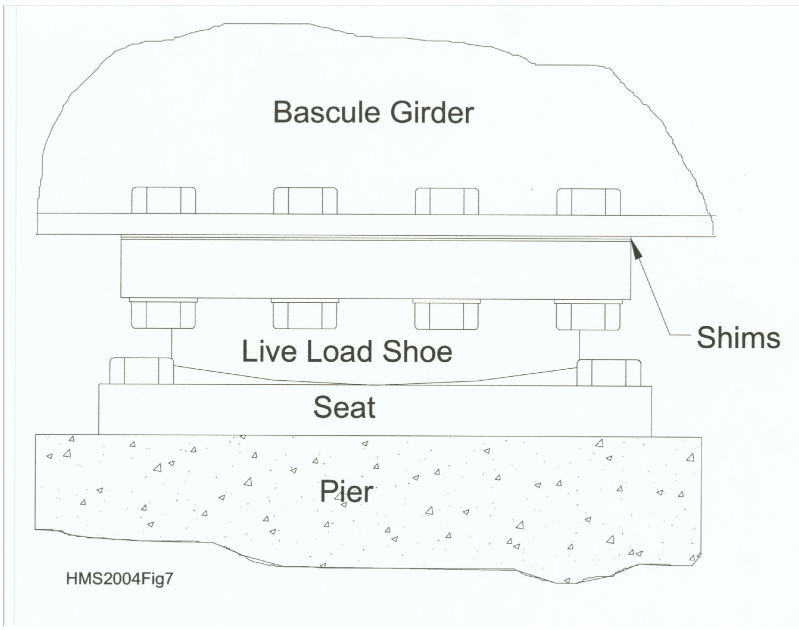
While service interruptions and repair costs for the first two of these failures were modest, replacing the trunnion bushings in the third case was very costly both in inconvenience to bridge users as well in dollars to restore the span to operating condition.

Two common threads are present in all of these failures:

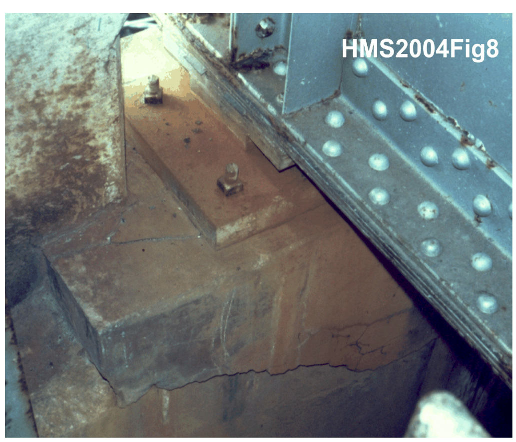
» Repetitive, high shock loads

» Faulty adjustment of the individual components as well as the overall system

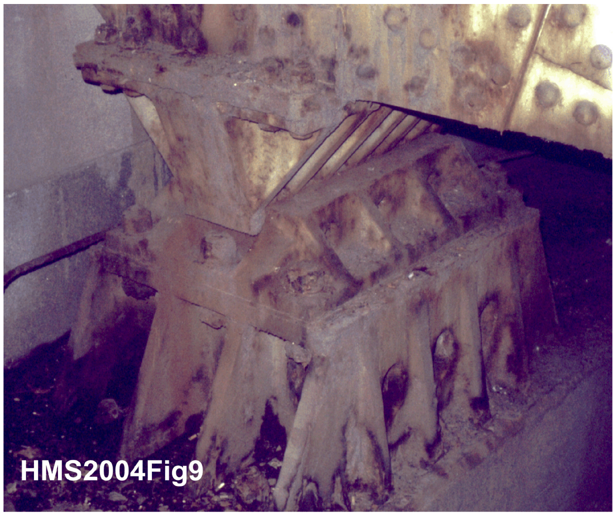
Live load shoes are elementary devices which consist of a shoe, usually attached to the moving structure on the lower surface of the bascule girder, and a seat situated on the fixed structure or pier, Fig 7.



This sketch is typical of shoes on many trunnion bascules, such as those over the ICW throughout Florida and other states. Their purpose is too transfer load from the girder to the pier when the leaf is closed. To do this they must be adjusted so that with the leafs closed, locks engaged and no live load on the span the shoe is in firm contact with the seat. Adjustment is accomplished by shimming between the shoe and the bascule girder, Fig 8.



The shoes and seats are either fabricated or cast steel and must be securely attached to the girder and pier. Of course, the particular design depends upon the structure size, magnitude of loads and configuration of the leafs and piers. For instance, large bascules, like those in the heart of Chicago, will have massive shoes and seats as seen in Fig 9.



Anchorages are similar to live load shoes, consisting of a shoe and seat, but are adjusted differently for various type bascule leaves. On trunnion bascules having live load shoes it is desirable to have a slight clearance between the shoe and seat with the leaf closed, Fig 10.

Hool and Kinne in their book *"Movable and Long Span Bridges"* suggest the whole idea here is to have the leaf act under load as a cantilever span, supported at the live load shoes and secured at the anchorages. Now, by adjusting the live load shoe shims the leaf may be made to come to bearing at the live load shoes before the anchorages seat, thus allowing the trunnions to lift slightly under live load by removing the dead load deflection from the trunnion bearing supports. Usual no load clearance at the anchorages is about 1/16 to 3/16 inches. Trunnion bascules without live load shoes and rolling lifts should have firm contact at the anchorages with the leaf closed, locks engaged and no live load on the span.

Although adjusting live load shoes and anchorages is not a complicated task it is difficult, tedious and time consuming due to the bulk of the shoes and accuracy to which they should be shimmed. Add to this the fact that vehicular traffic has increased greatly, making service interruptions undesirable, and bridge owners are faced with a constant and costly nuisance. Alternatives to properly adjusting live load shoes and anchorages is to use other means - such as; shimming atop the seat, Fig 11, which is a sure loser, or do noting at all. Both courses are invitations to future problems.

Yes, it's possible to ignore poorly adjusted live load shoes but surely not prudent. The potential costs to repair resultant damage and probable inconvenience to users of the bridge dictate that they be properly maintained.

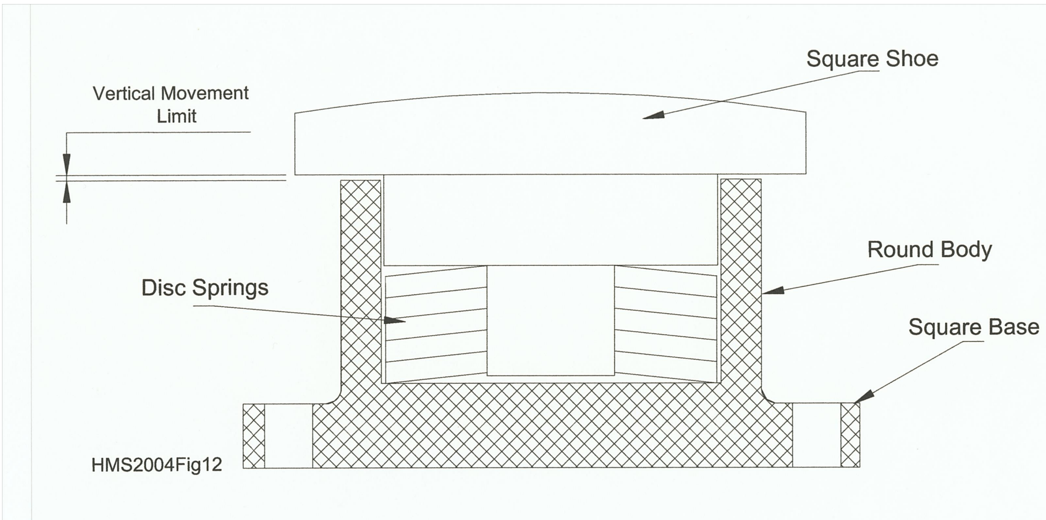
Generally shock loads on live load shoes are caused by:

1. Slamming the leaf down during closing.
2. Leaf bounce as vehicular traffic crosses the span.

Fine tuning the controls and making certain the buffer cylinders are in working order will ease the shocks during closing; and, correct shimming of the load shoes will reduce but not completely eliminate bounce. Another approach is to provide shoes that will reduce the bounce and absorb the shocks as they occur. Shock absorbing mounts for heavy machinery surely are not unique nor a novel idea for stationary machinery, they have been used for many years. But the demands imposed by bascule bridges require the shock absorbers to be effective while the leaf is closed, by damping the continuous bouncing, as well as cushion the leaf during closing.

The constraints in vertical movement of the closed leaf under a wide range of dead loading, the need for infinite life of the shock absorbing medium and the requirement to soften the impact of the leaf during closing requires the use of stiff springs in the energy absorbing system. Prior successful experience with disc springs in span lock systems suggested their use in live load shoes and anchorages.

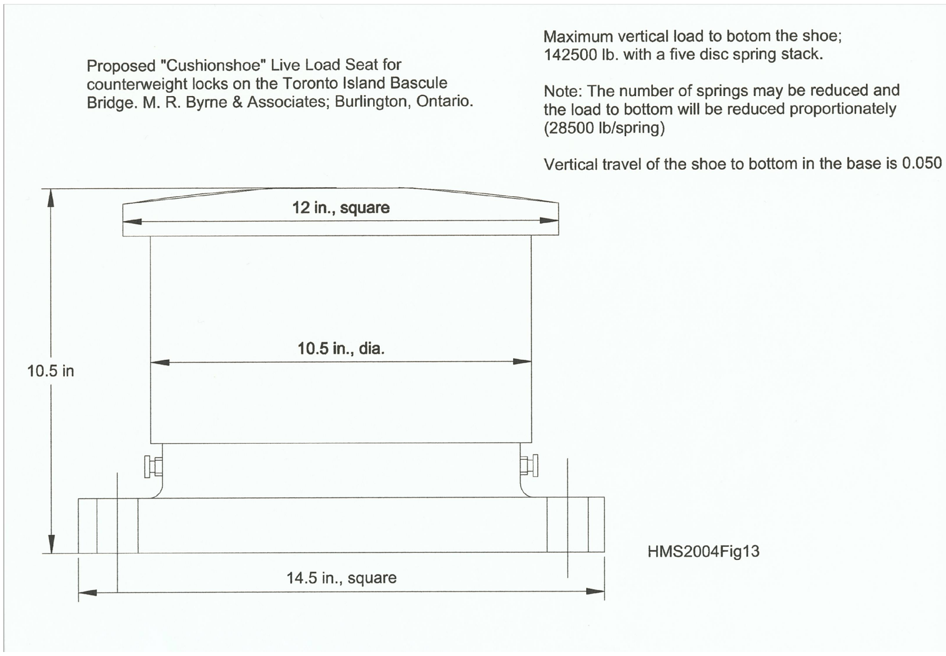
Conceptually these are straightforward applications as the dynamic motions are vertical, although sufficient support is required to resist horizontal loads resulting from thermal variations. Fig 12 illustrates such a device.



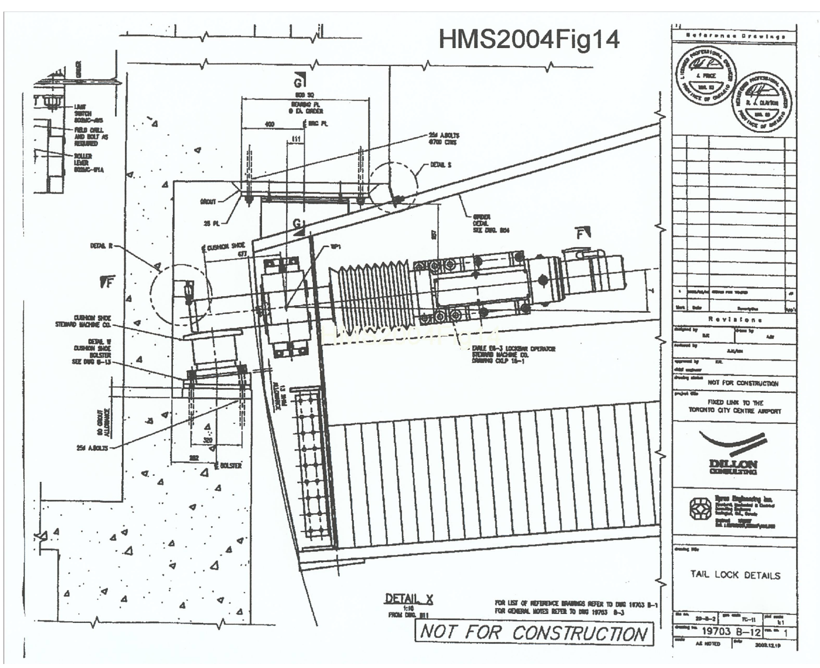
The basic unit consists of a base which can be secured to the pier or girder, the circular interior houses the spring assembly and provides radial stability to the shoe that is supported by the springs. Vertical movement of the shoe is limited to a pre-determined amount since its lower surface will seat on the base before the disc springs are flattened. This distance is limited in order to assure infinite fatigue life of the springs by controlling the maximum stresses occurring as the springs are depressed. Usually the maximum vertical movement is about 0.065 inches.

This sketch represents a concept and requires several other features to make it suitable for use on a bascule leaf. First off, the assembly must be capable for use as shown or upside down - thus the shoe has to be made captive in the housing; provision is necessary to seal off the spring chamber against the entry of water and foreign material; means are required to relubricate the springs and flush out the chamber and the alignment of the square shoe with the bascule girder must be assured.

Fig 13 depicts an assembled unit that incorporates all the requirements. Maximum vertical movement of the shoe is 0.060 inches. The shoe is supported by five disc springs and the vertical load required to seat the shoe on the housing is about 132,000 lbs. If desired the number of springs can be reduced and the load to bottom will go down proportionately - 26,400 lb/spring.



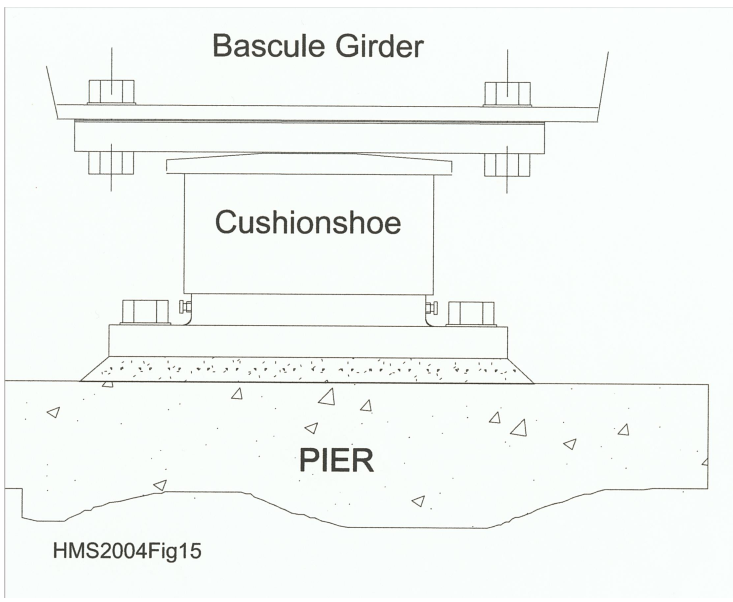
This unit has been proposed for use on the Toronto Island Bridge; a four girder, double leaf bascule, designed by Byrne Engineering Inc., Burlington, Ontario, Canada. As the bridge has no live load shoes forward of the trunnion centerline and the road break is aft of the trunnion centerline, the "Cushionshoes" are used in the tail lock system in conjunction with the anchorages. Fig 14 shows the installation.



The loads from intentional, span heavy imbalance and live loads forward of the trunnion centerline are resisted by the anchorages. Loads that result from any condition that would tend to introduce reverse rotation to the leaf when closed are resisted by the tail lock system.

While this is somewhat similar to a span lock system, it is different in that the receiver has only one spring loaded shoe. With the lock bar extended any loads acting to cause the leaf to open are supported by the “Cushionshoe”. The setting of the extended bar and the shoe , with no live load on the leaf, is intended to be line to line and the tolerance range from 0.010 clearance to 0.010 preload At this condition about 1.1 HP is required to move the bar. Properly functioning tail locks prevent leafs from accidentally popping open. In addition, this system absorbs the shock loads from vehicular traffic, compensates for wear of the sliding surfaces and helps maintain firm contact at the anchorage, even when the leaf is improperly balanced.

The same type shoe can be used on trunnion bascules that have live load shoes forward of the trunnion centerline to even greater advantage, Fig 15.



- » Smoother, more controlled closings are possible as the springs will absorb the shock loads rather than constantly pounding the piers.
- » Firm contact between the shoe and seat will be present with the desired, slightly span heavy condition of the closed leaf.
- » Total downward movement of the leaf will be limited by the “Cushionshoe”.
- » Shock loads from vehicular traffic will be greatly reduced.
- » Maintenance costs will be reduced.
- » The “Cushionshoe” can be mounted either on the pier or bascule girder.

When using “Cushionshoes” as live load shoes it is desirable to make them so they can be easily adjusted after original installation without having to shim the shoe or seat. This capability can be accommodated conveniently by having the spring and shoe assembly mounted in a carrier that is threaded into the housing. In this way a one inch total vertical adjustment range of the shoe is provided without loss of load carrying capacity, Fig 16. With this design the shoe can be adjusted vertically in increments of approximately 0.032 inches.

Additionally, the adjustment can be done quickly, without any special tools or skills and without lengthy interruptions in traffic flow or inconvenience to users of the bridge.