End Lift Machinery For Swing Bridges
(There’s More Then One Way To Lift A Span)

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END LIFT MACHINERY FOR SWING BRIDGES
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I. INTRODUCTION

There are an estimated 1,573 swing bridges in North America alone\(^1\). These include Rim Bearing, Center Bearing, and Combined (Rim and Center) Bearing Types with either equal span arrangement or Bobtail (asymmetrical & counterweighted type). Framing consists of Though Trusses, Deck Trusses, Through Girders, Multi-Stringers and even Segmental Concrete Boxes. In almost all cases these swings spans have some form of end lift system.

II. WHY DO WE NEED END LIFTS ON SWING BRIDGES.

Swing bridges of all types are multi-span structures. Looking at the influence line for end reactions for a continuous 2 span beam (see Figure1), it can be noted that a load in the span 2 will provide a negative reaction at support 1. Since the end lift doesn’t provide any restraint against upward movement, the cantilever end of span 1 will lift off of the bearing due to a load applied in span 2. The way in which AASHTO addresses this issue is to lift the cantilever ends of both spans sufficiently to prevent uplift due to live load. However, if you look past the wording of the AASHTO specification and understand the intent these provisions end lift could be eliminated if the bearing provided at the cantilevered end of the swing span were to prevent uplift.
1. The number of swing spans is taken from "Movable Bridge Engineering" by Terry L. Koglin

### III. IMPACT OF END LIFTS ON STRUCTURAL ELEMENTS

Lifting forces applied to the end of a swing span induce stresses in the main structural members. The main structural members are designed as cantilevers under dead load. The stresses due to lifting are typically opposite to the dead load stresses. The relative magnitude of the dead load and lifting load stresses is dependent on span geometry and the stiffness of the main members. For some members the magnitude of the stress due to lifting can be greater than the stress due to dead load. This condition is typically true for top and bottom chord members near the end of the span. This can be seen by reviewing the stress table for the 145th Street Swing Span over the Harlem River in New York City provided in the appendix. Live load stresses can be either the same or opposite in sign to the dead load stresses depending on which span is loaded. While lifting the end of the swing span typically reduces the stress in main members, there is no economic advantage because AASHTO requires that we consider the load combination of dead load without the wedges driven combined with live load and impact loading on one span. This requirement is to account for the event of end lifts being inoperable.

An additional affect that is typically neglected in the design of structural elements is the horizontal forces generated when lifting the bridge. With a well maintained bearing these forces are very small compared with the dead loads. However if
the lubrication in a wedge is hardened or frozen these forces can be significant and should be considered in the design.

IV. ALTERNATIVES AND HOW THEY WORK

A. END WEDGES: The inclined plane is one of the first simple machines used by man. The inclined plane was also used in many of the first end lifts. The end wedges work by forcing mating inclined surfaces to slide against each other. These mating surfaces are lubricated to reduce the coefficient of sliding friction. End wedges can be pulled and driven in a variety of different ways, using different types of drive mechanisms.

1. CENTRAL MOTOR WITH LINKS

This particular mechanism uses a central power source and speed reduction through gears to transfer the power to pull and drive the wedges. The central gearing rotates drive shafts that are perpendicular to the roadway. The shafts articulate an arrangement of levers that pull and drive the wedges. Additionally, a brake is provided prior to the gear reduction to prevent the system from reversing once the wedges are driven and a live load is present on the span. A schematic for the end wedge system for Columbus Drive in Hillsborough County, FL. Has been included as an example and is included in the appendix. Here the east and west wedges are controlled by two separate motors and enclosed reducer drive sets. Another example of a smaller scale wedge system is the Rancocas Creek Bridge, in Burlington County, NJ. This bridge has a similar setup with gearing, shafts, and levers to actuate the wedges. The Rancocas Creek Bridge is operated by turning roadway mounted hand cranks to power the wedge machinery and the main drive machinery.

2. LINEAR ACTUATORS
Electric linear actuators can be mounted horizontally to drive and pull the end wedges. Each of the lift points on the span has its own individual actuator that pulls the wedge by turning a threaded rod that retracts a piston connected to the wedge. The process is reversed when the wedges are driven. Each of the linear actuators also has its own brake to secure the actuator and driven wedge. Linear actuators are limited by the magnitude of the load. This means that their use is limited to smaller bridges. An example of linear actuator driven wedges is provided in the appendix.

B. HYDRAULICS: Hydraulics can be used in a number of ways for end lifts. End wedges can be driven by hydraulic cylinders or cylinders can be mounted vertically to lift the span. A central pump can be used to power each of the pistons. Typically if a hydraulic operating system is provided for the swing span then the same pump can be used to operate the end lifts. Check valves should be used to reduce head loss due to live load pumping.

C. END WHEELS AND INCLINED PLANE: Another less common application of the inclined plane is to place wheels at the end of the span mounted tangentially. The bridge seat is inclined at the ends so that as the bridge is closed the wheels ride up the inclined plane and raise the bridge the desired amount. In this case there is no need for additional end lift machinery to be mounted near the end of the span. The main drive machinery performs the work of lifting the end of the span. The system has to be sized such that it is able to overcome the additional resistance load applied to the cantilevered end of the swing span as it comes into contact with the inclined bridge seat. This “end Lift Load” is in addition to worst-case loading conditions such as wind loading and ice loading. Therefore, such systems are usually used in smaller spans, since the power required would not be a substantial increase to the main drive machinery. An example of the end wheels and incline plane is the Smithville / Port Republic Swing Bridge in Atlantic County, NJ. A simple layout of this system is shown below.
D. SCREW JACKS: Another simple machine used in end lifts is the screw. Motors along with gear reduction are used to turn a vertically mounted acme threaded rod with a horizontal bearing plate on the end. The gearing allows the high speed of the motor to be translated into the low speed, high torque force used to raise the end of the span. In addition to a motor brake, the type of thread helps prevents the machinery from reversing when the live load is applied to the span when the ends are lifted. This type of end lift is used on the Kingsland Avenue Bridge in Bergen County, NJ to lift the ends of the span, one in each corner of the span. A schematic of the end lift arrangement is provided in the appendix.
E. ECCENTRIC ROLLERS: The eccentric rollers work by mounting a wheel on a shaft such that and the center of the wheel is offset from the center of the shaft. This offset distance from the shaft’s center of rotation to roller’s center of rotation allows the mechanism to provide lift to the end of the span when the drive shaft is rotated less than a half rotation. Overall this particular mechanism has the potential to raise or lower the end of the span by twice the distance of the center to center offset, which is usually more than required. A motor and gear reduction is provided at each end lift point to rotate the eccentric shafts and rollers. This design also includes a motor mounted brake to prevent the roller from reversing. In addition this type of mechanism, due to the geometry of the roller, does not see much machinery load due to live loading of the span. The eccentric roller system is used on numerous swing span bridges over the Harlem River in New York City. The arrangement of the eccentric roller system for the 145th Street Bridge over the Harlem River designed by Bergmann Associates for the New York City DOT is shown in the Appendix.

F. CENTER JACKS: While a center jack is not technically an end lift it can be used to achieve the same results. By lifting the swing span at the center of pivot the load can be relieved from the cantilevered ends of the swing span. Likewise by lowering the jacks at the center of pivot a load can be induced at the end of the span sufficient to overcome thermal loads plus 1.5 times the maximum uplift due to live load and impact. In this way AASHTO requirements are satisfied without the use of end lifts. We know of no example of this application for center jacks. The West Seattle Swing Bridge which was presented at the 4th HMS Biennial Symposium in Ft. Lauderdale by Andrzej Studenny and Worm Lund does use a center jacking cylinder to lift the bridge off of the service pads along the perimeter of the pivot pier. A section through the pivot pier from their paper is
included in the Appendix. This bridge uses span locks to transmit live load between spans therefore this center cylinder is not intended to develop positive reactions at the cantilevered end of the swing span. The center cylinder could be used to develop the required positive reactions specified by AASHTO.

G. SPAN LOCKS: A lock bar can be used and driven into a receiver at the rest piers. The lock bar would restrain movement in both directions at the ends of the swing span. Therefore the lock bar would be designed to carry live load plus impact, wind loads and seismic loads. Since the lock bar restrains the span from uplift it is necessary to lift the end of the swing span. The end of the lock bar would be tapered in order to accommodate any vertical and horizontal misalignment of the span. Special care must be taken when designing swing span trusses to minimize deflections at the cantilevered ends due to thermal stresses.

V. DESIGN APPROACH

A. STRUCTURAL DESIGN: End lifts should be designed for two separate conditions. The first condition is the dynamic or lifting condition. This condition is used to size the end lift machinery. The second condition is the static condition. In this case the end lift is already driven and the end lift acts as a bearing to transmit live load and impact from the bridge superstructure to the bridge substructure units. Additional consideration should be given in the static condition to ensure that the end lifts remain stable under the application of live load. Brakes should be engaged before the application of live load to prevent end lifts from disengaging.

Section 2.2.1 of the Standard Specifications for Movable Highway Bridges provides the design loading conditions for Swing Span Bridges. Section 2.2.1 states the following:

“The stresses in the main girders or trusses of swing spans, continuous on three or four supports, shall be calculated for the following conditions:

Case I. Dead Load: Bridge open, or closed with the end wedges not driven.

Case II. Dead Load: Bridge closed, with the ends lifted to give positive reaction, equal to the reaction due to temperature plus 1.5 times the maximum negative reaction of live load and impact, or the force required to lift the span one inch (25.4 mm), whichever is greater.

Case III. Live Load Plus Impact: Bridge closed with one arm closed but with wedges not driven.
Case IV. Live Load Plus Impact. Bridge closed and considered as a continuous structure.”

Section 2.2.2 of the Standard Specifications for Movable Highway Bridges provides the bridge load combinations that a swing span should be designed for in addition to the group loadings provided in the Standard Specifications for Highway Bridges. Section 2.2.2 of the Standard Specifications for Movable Highway Bridges states the following:

“The following load combinations of the case shall be used for determining the maximum and minimum stresses:

Case I alone plus 20 percent
Case I with Case III
Case II with Case IV

The stress computations shall show the stresses in the different members for each of the foregoing cases, together with the combinations which give the greatest maximum and minimum stresses in each member. Wind loads shall be as specified in Article 2.1.13”

Therefore the first thing that needs to be determined is how much the end of the lift span needs to be lifted. In order to determine the lift the suggested approach is to assume the end lifts to be pinned bearings. Live loads and thermal loads can be applied to the model and the maximum uplift at the bearing can be determined. If the end bearings are removed from the swing span model the load required to lift the span one inch can be determined. This can be done by inducing a 1 inch deflection at each end or by applying a unit load at each end and determining the deflection at the cantilever ends of the span. Since there is a linear relationship between the load and the deflection at the end of the span, the load required to produce a one inch deflection can be easily determined. The lifting force is determined by comparing the force caused by thermal stresses plus 1.5 times the maximum uplift due to live load plus impact and comparing this to the force required to lift the span 1 inch. The lifting force should be the greater of these two cases. If the inch lift produces the greater force which is typically the case for a stiffer span, then the height off the lift is one inch. If the force due to thermal stress plus 1.5 times the maximum uplift due to live load plus impact then the distance the end of the span has to be lifted can be determined by applying this load to the cantilevered ends of the swing span.

Once you have the required lifting force and the required lifting distance you have enough information to design the end lift for the lifting case. In order to design the end lift as a bearing for the static case you need to determine the maximum load that the bearing would support including live load and impact. For this the maximum positive live load and impact would be added to the lifting load
previously determined. Please note that for simplicity this discussion hasn’t included forces due to seismic, wind or other design loadings that must typically be included in bridge design.

B. MACHINERY DESIGN: As stated earlier, the end lift machinery is sized for the dynamic or lifting condition. This load is determined by the “worst case” conditions that the machinery sees when it is operating. According to The American Association of State Highway and Transportation Officials (AASHTO), section 2.7.7, the loads are identified are defined as follows:

1. The end wedges, or equivalent devices, shall lift the ends of the swing bridge an amount sufficient to produce a positive reaction at that end due to live load and impact.

2. The end lift machinery shall be proportioned to exert a lifting force equal to the greater of:

   a) The lifting force specified in (1) above plus the reaction due to temperature difference..., or,

   b) The lifting force required to raise the span one inch.

Determining the loads for both condition a) and b) were discussed earlier, it is just a matter of using the greater load in the sizing of the end lift drive machinery. The loads seen by the end lift machinery usually depend on the size of the swing span. Normally, the end lifts are located at the cantilevered ends of the main load carrying members although end lifts could be located below the end floorbeams. Primarily, the magnitude of the load seen at each of the lift points, and speed at which the end of the span will be lifted are what determine the power requirements for the end lift machinery. Additional factors such as machinery component efficiency and frictional losses also have an impact on the power requirements of the end lift machinery. It should also be noted that physical clearance constraints, cost, and ease of maintenance are also factors to consider in the sizing, and type selection for end lift machinery.

The power source provided to actuate the end lift machinery is usually independent from the swing span’s main drive machinery. The most common source of power is an electric motor, although some systems utilize hydraulic pumps, or even manpower in some smaller scale cases. Machinery design examples for wedge and eccentric motor type end lifts are provided in the appendix.

VI. ADVANTAGES AND DISADVANTAGES

Each type of end lift has advantages and disadvantages. There is no single end lift that is right for all applications and clients. The following is a quick summary
of some of the advantages and disadvantages to the various end lifts discussed in section II;

A. WEDGES

1. Central Motor: This is a simple mechanical system. It is the most common system used. The disadvantage is that there many moving parts that require lubrication and other maintenance. Many of these parts aren’t easily accessible and therefore they are often not maintained properly. The sliding surfaces must be well lubricated in order to minimize the frictional forces. This lubricant is exposed to the elements and therefore becomes quickly contaminated. It therefore requires constant attention.

2. Linear Actuators: These systems are compact, less expensive, and require less maintenance. The wedges still require constant lubrication due to the elements and contamination.

B. HYDRAULIC SYSTEMS: Hydraulic systems typically require less maintenance unless there are leaks. Long lines provide for potential pressure losses so good check valves are important. If the hydraulics are used to drive wedges then the wedge maintenance is still a problem. If the cylinders are used to provide the lift then significant live load pumping is present in the cylinders.

C. END WHEELS: The big advantage to this type of lift is that there are no additional mechanical systems required to drive the end lift. The system is powered by the bridge operating system. The disadvantage is that horizontal forces are applied to the ends of the swing span near the fascias at the furthest distance from the center of rotation. Therefore a significant amount of addition torque is required for large spans which would require much larger operating systems.

D. SCREW JACKS: The big disadvantage to screw jacks is the time of operation required to lift the bridge because of the number of revolutions that are required to achieve the desired lift. The big advantage is that less power and less gear reduction is required therefore the system is lighter takes up less room and provides greater clearance. These systems also require less maintenance.

E. ECCENTRIC ROLLERS: These systems are expensive, big and heavy at the very end of the cantilever so the loading impacts the structural systems significantly. The rollers have a quick time of operation since the shaft need only turn a fraction of a revolution. This system has the capacity to provide for large lifting loads. The eccentric rollers require less maintenance then wedge systems. In order to remove the weight from the span the eccentric rollers,
motors reducers and shafts can be mounted on the rest piers. This approach was taken on the 3rd Avenue Bridge over the Harlem River in New York City. Since the end lift system has to be controlled by the bridge control system putting the end lifts on the fixed span requires additional submarine cable conductors or wireless communication systems that add to the cost.

F. CENTER JACK: This is a singular centrally located system that is easy to maintain. It eliminates the need for any machinery or wiring on the span. It provides a much cleaner design. The magnitude of the lifting loads is greater. More engineering required to design drive systems that can accommodate the alignment changes resulting from the lift of the span prior to operation. Also the center pivot must be designed to carry lateral and overturning forces.

G. LOCK BARS: This is a clean simple system that is relatively inexpensive and low maintenance. The lock bar must be designed for live load and impact as well as seismic and wind loads. The lock bar also helps to center the bridge. The lock bar has a minimal tolerance for misalignment therefore the bridge controls need to provide a higher level of accuracy. It is also important to provide a structural design that minimizes vertical misalignment due to changes in temperature.

VII. SELECTION CRITERIA

There are no set selection criteria to help in the selection of end lifts for a new bridge. A life cycle cost analysis that takes into account the affect the end lifts have on structural, mechanical, and electrical systems as well as the initial cost and maintenance costs for the end lift systems is a good starting point. Ease of maintenance should also be considered. Esthetics can be factored into the equation. Ultimately client preference has a big impact on the selection process. If there are several similar bridges that need to be maintained then it is beneficial if they each use a similar design.
APPENDIX
KINGSLAND AVENUE BRIDGE
SCREW JACKS

Movement
of span end

End of Span

Movement
of span end

Motor

Reducer

Drive Gear

Screw Jack

Bearing Plate

NOT TO SCALE
WEST SEATTLE SWING BRIDGE
CENTER JACK

Rotation of span during opening and closing

Movement of span and center lift cylinder
**Calculate Theoretical Power Requirement**

\( d = \text{Lift to take up clearance between the lifting device and the span plus the 1" lift of the span, the clearance is assumed to be 1.5 inches to accommodate normal clearance plus misalignment.} \)

\[
d = 1.5 + 1 = 2.5 \text{ inches}
\]

The original design time to accomplish this lifting is 10 seconds; the vertical velocity of the lifting device is:

\[
V = \frac{d}{t}
\]

\[
V = \frac{2.5}{10} = 0.25 \text{ in/sec or } 0.0208 \text{ ft/sec}
\]

The power to lift a load a distance within a period of time is defined as Horsepower and expressed as:

\[
HP = \frac{F \cdot V}{550}
\]

Where
- \( F = \text{Force in lbs} \)
- \( V = \text{Velocity in ft/sec} \)

The force that each end lift must work against is either:

- Case A) Thermal load plus 1.5 live load and impact.
- Case B) Force required to lift 1 inch.

Whichever is larger (AASHTO 2.7.7.2B)

For 145th Street Bridge Case B, the load to lift 1 inch is the greater load (123 kips vs. 77.72 kips). These loads were provided by the structural designers.
The horsepower to perform the lifting of the end lift without friction can be calculated as:

\[ HP = \frac{123,000 \text{ lbs} \times 0.0208}{550} = 4.65 \text{ HP} \]

This horsepower is the ideal case where machinery is ideal and no friction occurs. Friction is a major loss in the system. For the 145th Street endlifts, friction comes from the operation of the eccentric shaft within the roller. Friction is calculated as:

\[ f = k \times N \]

Where

- \( k = 0.18 \) (AASHTO 2.5.5) for trunnions
- \( N = \text{Normal force (lbs)} \)

\[ f = 0.18 \times 123 \text{ kips} = 22.14 \text{ kips} \]

The horsepower to overcome friction is calculated as:

\[ HP = \frac{22,140 \text{ lbs} \times 0.0208}{550} = 0.837 \text{ HP} \]

The total horsepower becomes:

\[ HP_{\text{Total}} = 4.65 + 0.837 = 5.487 \text{ HP} \]

The machinery has losses. These losses are the sum of the individual losses.

**Machinery Efficiency**

System Efficiency \((\eta) = \eta_{\text{Component Efficiencies}}\)

\[ \eta = \eta_{\text{Other}} \times \eta_{\text{Roller}} \times \eta_{\text{Brg}} \times \eta_{\text{Reducer}} \]

\[ \eta = 86\% \]

The system efficiency is 86%.

The minimum horsepower which must be delivered is:

\[ \frac{5.487}{0.86} = 6.38 \text{ HP} \]
Weight of HS-20 = 72000 lb
East Span Length = 106.5 ft
West Span Length = 57.89 ft

Longitudinal numbers
Front Wheel (A) = 4000 lb
Back Wheel (B1, B2) = 16000 lb
Ratio of spans = 1.84

Total length of span = 164.39 ft
Assume 160 ft length span

Longitudinal Distribution

Since only the east wedge is being replaced size wedges for reactions at east bearing

Two trucks on 1 end of span, find the uplift reaction

\[
\text{C.G.} = \frac{(Ya_3 \times A_3) + (Yb_2 \times B_2)}{(A_3 + b_2)}
\]

\[
\text{C.G.} = 8.4 \text{ ft away from } B_1
\]

\[
\text{Reaction at R3} = \% R3 \times B_2
\]

Case 1 - B1

From the table:
For the Load at 0.5 in span one,
% R3 = -0.0408 from table
Reaction at R3 = -652.8 lb

Case 2 - B2

From the table:
For the Load at 0.7 in span one,
% R3 = -0.0389 from table
Reaction at R3 = % R3 \times B_2
Reaction at R3 = -622.4 lb

Case 3 - A3

From the table:
For the Load at 0.2 in span one,
% R3 = -0.0209 from table
Reaction at R3 = % R3 \times B_2
Reaction at R3 = -83.6 lb
Total reactions at R3 = Case1 + Case 2 + Case 3
Total reactions at R3 = -1358.8 lb  \textit{Negative number denotes upward direction}

Transverse Distribution
Two trucks on one side of roadway, find the bearing reaction

Consider 4 individual loads with the general formula

\[ R_1 = \frac{C_1 d_1}{L} \]

\begin{align*}
\text{Case 1} & : & C_1 &= -1358.8 \text{ lb} \\
& & d_1 &= 38 \text{ ft} \\
& & L &= 40 \text{ ft} \\
& & R_1 &= -1290.86 \text{ lb}
\end{align*}

\begin{align*}
\text{Case 3} & : & C_3 &= -1358.8 \text{ lb} \\
& & d_3 &= 28 \text{ ft} \\
& & L &= 40 \text{ ft} \\
& & R_3 &= -951.16 \text{ lb}
\end{align*}

\begin{align*}
\text{Case 2} & : & C_2 &= -1358.8 \text{ lb} \\
& & d_2 &= 32 \text{ ft} \\
& & L &= 40 \text{ ft} \\
& & R_2 &= -1087.04 \text{ lb}
\end{align*}

\begin{align*}
\text{Case 4} & : & C_4 &= -1358.8 \text{ lb} \\
& & d_4 &= 22 \text{ ft} \\
& & L &= 40 \text{ ft} \\
& & R_4 &= -747.34 \text{ lb}
\end{align*}

Total Reaction for 2 trucks
\[ R_{total} = R_1 + R_2 + R_3 + R_4 \]
\[ R_{total} = -4,076 \text{ lb} \]
\[ R_{total} = -4.0764 \text{ kips} \]

Transverse Distribution - Total Reaction for 3 trucks
\[ R_3 \text{ trucks} = (R_{total} + \text{additional truck}) \times 0.9 \text{ reduction factor} \]
\[ R_{total} = -4,892 \text{ lb} \]
\[ R_{total} = -4.891905 \text{ kips} \]

Transverse Distribution - Total Reaction for 4 trucks
\[ R_3 \text{ trucks} = (R_{total} + 2 \text{additional trucks}) \times 0.75 \text{ reduction factor} \]
\[ R_{total} = -5,418 \text{ lb} \]
\[ R_{total} = -5.42 \text{ kips} \]

This is the worst case scenario

Compare to force required to lift span 1"
\[ R_{Lift} = 83658 \text{ kips} \]
\[ \text{Controls} \]
### TRUSS FORCE TABLE

#### MOVABLE BRIDGE CRITERIA

<table>
<thead>
<tr>
<th>LOAD CONDITIONS</th>
<th>LOAD COMBINATIONS</th>
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</thead>
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<td><strong>CASE I - DEAD LOAD FOR OPEN BRIDGE WITH END LIFTS NOT BRONED</strong></td>
<td><strong>CASE II - LIVE LOAD + IMPACT FOR BRIDGE CLOSED, WITH ONE ARM LOADED AND CONSIDERED AS A SIMPLE SPAN, BUT WITH END LIFTS NOT BRONED</strong></td>
</tr>
<tr>
<td><strong>CASE III - LIVE LOAD + IMPACT FOR BRIDGE CLOSED, WITH BOTH ARMS LOADED AND CONSIDERED AS A SIMPLE SPAN WITH END LIFTS NOT BRONED</strong></td>
<td><strong>CASE IV - LIVE LOAD + IMPACT FOR BRIDGE CLOSED AND CONSIDERED AS A CONTINUOUS STRUCTURE</strong></td>
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<tr>
<td><strong>CASE V - WHO LOAD FOR BRIDGE OPEN LOADED WITH WIND OF 1.5 m/s (30 PSI) ON ONE CHORD OF THE TRUSSES. ARMS AND 1.0 m/s (20 PSI) ON THE OTHER ARM</strong></td>
<td><strong>CASE VI - TRUSS FORCE TABLE (MOVABLE BRIDGE CRITERIA)</strong></td>
</tr>
</tbody>
</table>

#### REFERENCES

FOR MEMBER SECTION TYPE SEE DMS-SP-1

#### NOTES

LOAD CONDITIONS AND LOAD COMBINATIONS ARE IN ACCORDANCE WITH AASHTO STANDARD SPECIFICATIONS FOR MOVABLE BRIDGES DATED 1986.

LOADING CONDITIONS

CASE I - DEAD LOAD FOR OPEN BRIDGE WITH END LIFTS NOT BRONED

CASE II - DEAD LOAD FOR MAXIMUM OF:

- BRIDGE CLOSE WITH ENDS LIFTED TO GIVE POSITIVE END REACTION EQUAL TO 1.5 MAXIMUM NEGATIVE REACTION FROM LIAM PLUS END REACTION DUE TO TEMPERATURE DIFFERENCE OF 17°C (30°F) BETWEEN TOP AND BOTTOM CHORDS OF THE BRIDGE
- BRIDGE CLOSE WITH 1 INCH DISPLACEMENT AT THE END LIFTS.

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LOADING CONDITIONS

CASE I - DEAD LOAD FOR OPEN BRIDGE WITH END LIFTS NOT BRONED

CASE II - DEAD LOAD FOR MAXIMUM OF:

- BRIDGE CLOSE WITH ENDS LIFTED TO GIVE POSITIVE END REACTION EQUAL TO 1.5 MAXIMUM NEGATIVE REACTION FROM LIAM PLUS END REACTION DUE TO TEMPERATURE DIFFERENCE OF 17°C (30°F) BETWEEN TOP AND BOTTOM CHORDS OF THE BRIDGE
- BRIDGE CLOSE WITH 1 INCH DISPLACEMENT AT THE END LIFTS.

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**TRUSS FORCE TABLE (MOVABLE BRIDGE CRITERIA)**

**REFERENCES**

FOR MEMBER SECTION TYPE SEE DMS-SP-1

**NOTES**

LOAD CONDITIONS AND LOAD COMBINATIONS ARE IN ACCORDANCE WITH AASHTO STANDARD SPECIFICATIONS FOR MOVABLE BRIDGES DATED 1986.

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