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Machinery/Mechanics

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

(THERE'S MORE THEN ONE WAY TO LIFT A SPAN)

By:

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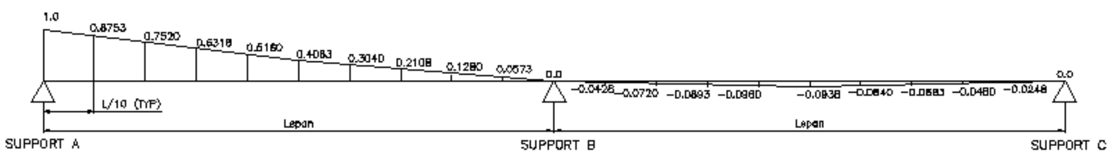
I. INTRODUCTION

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.



INFLUENCE LINE COEFFICIENT
FOR REACTIONS AT SUPPORT 'A'
(FIGURE 1)

REACTION = COEFFICIENT X Lspan X LOAD

1. The number of swing spans is taken from "Movable Bridge Engineering" by Terry L. Koglin

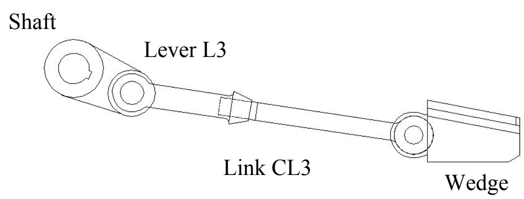
III. IMPACT OF END LIFTS ON STRUCTURAL ELEMENTS

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 then 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.

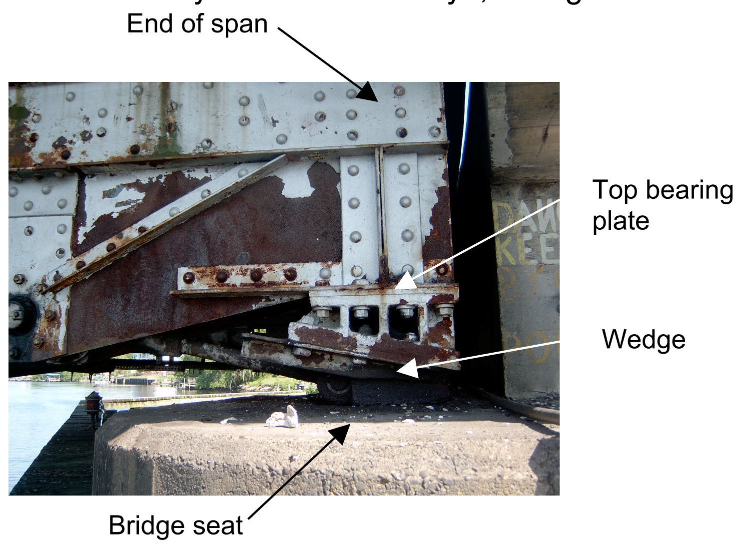
An additional affect that is typically neglected in the design of structural elements is the horizontal forces generated when lifting the bridge. With a well maintained bearing these forces are very small compared with the dead loads. However if the lubrication in a wedge is hardened or frozen these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



Example of a typical wedge setup.



1. CENTRAL MOTOR WITH LINKS

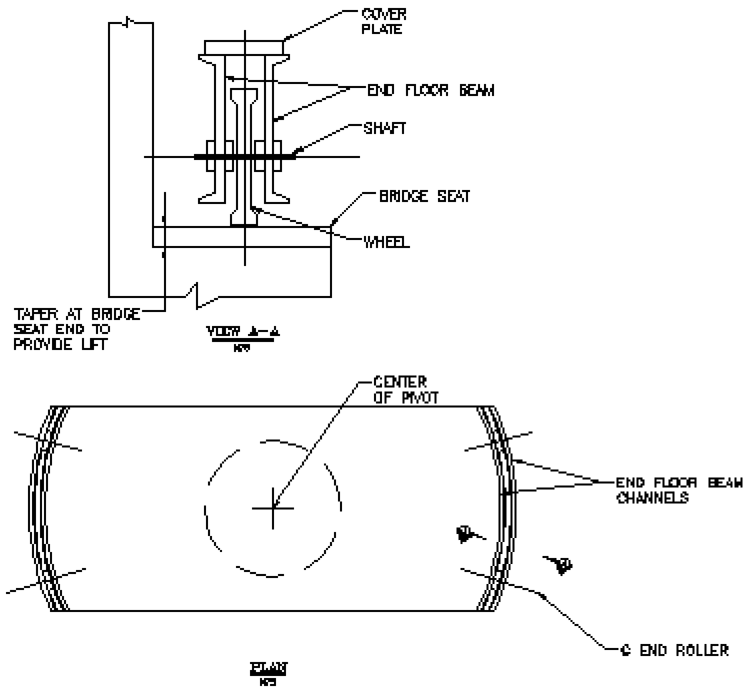
This particular mechanism uses a central power source and speed reduction through gears to transfer the power to pull and drive the wedges. The central gearing rotates drive shafts that are perpendicular to the roadway. The shafts articulate an arrangement of levers that pull and drive the wedges. Additionally, 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

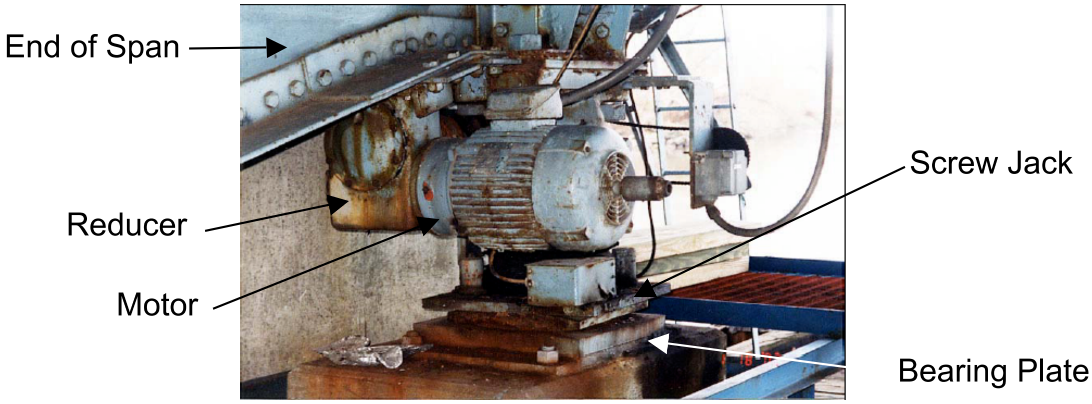
Electric linear actuators can be mounted horizontally to drive and pull the end wedges. Each of the lift points on the span has its own individual actuator that pulls the wedge by turning a threaded rod that retracts a piston connected to the wedge. The process is reversed when the wedges are driven. 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 there 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.



Example of screw jack end lift

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 with out 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 most 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 plus1.5 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 most be designed to carry lateral and overturning forces.

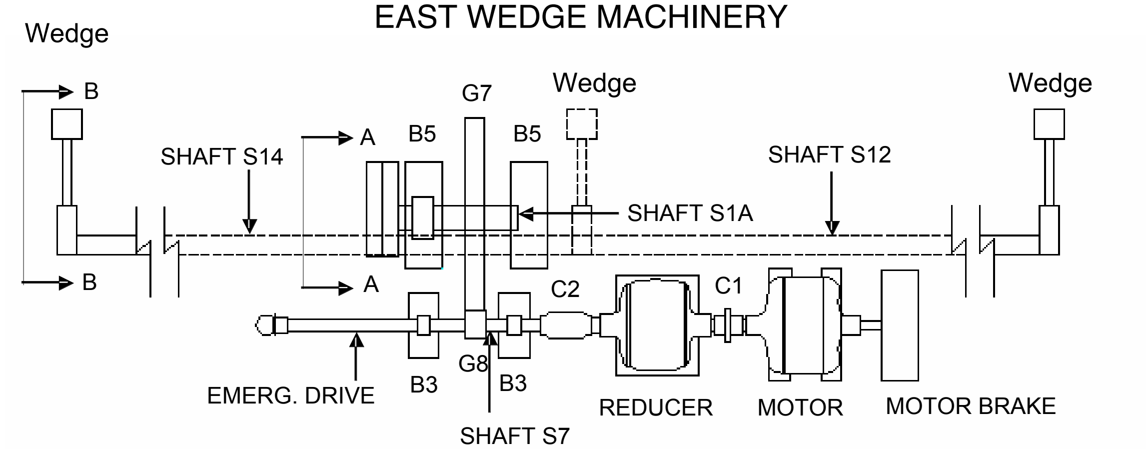
G. LOCK BARS: This is a clean simple system that is relatively inexpensive and low maintenance. The lock bar must be designed for live load and impact as well as seismic and wind loads. The lock bar also helps to center the bridge. The lock bar has a minimal tolerance for misalignment therefore the bridge 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

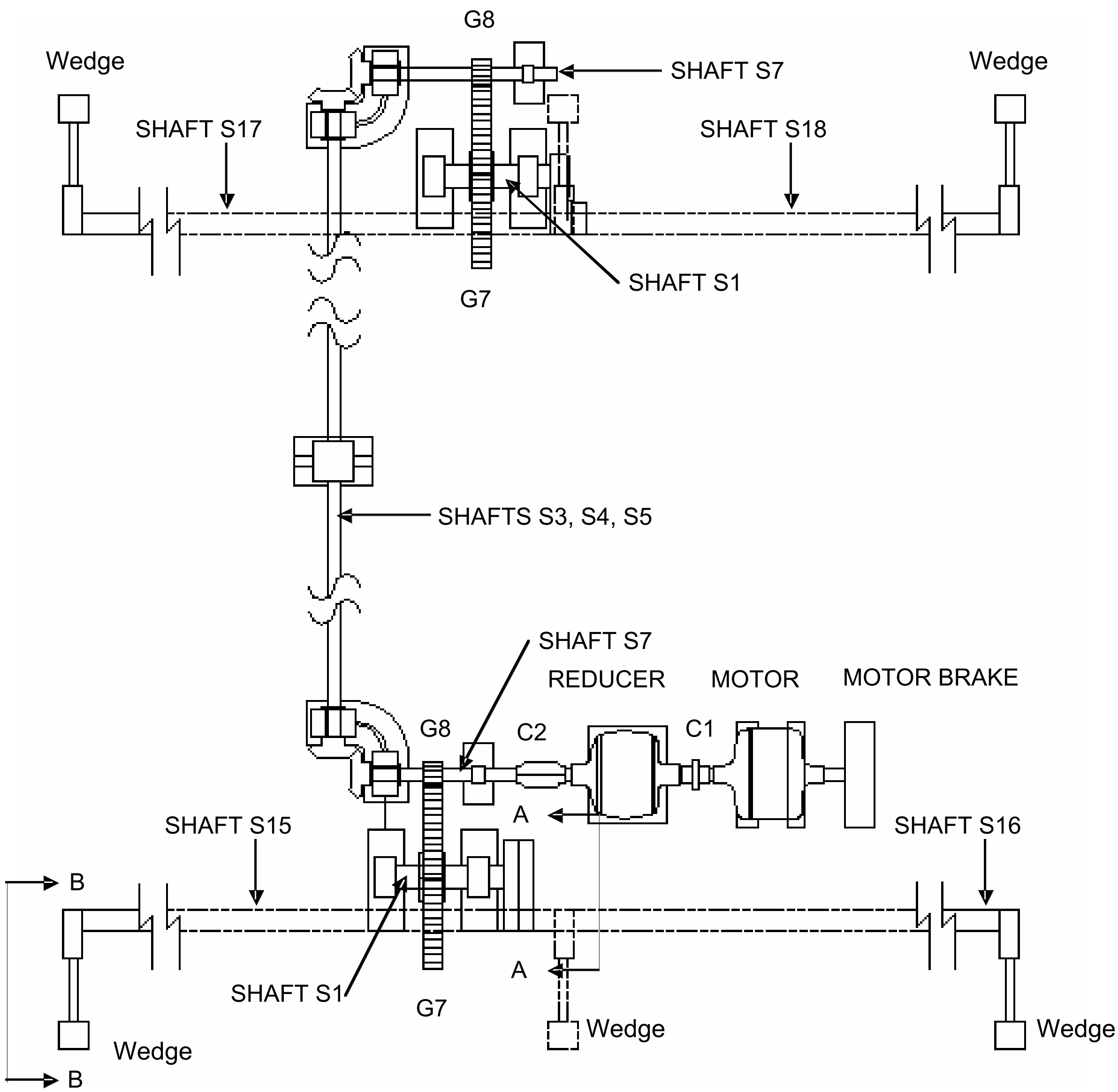
There are no set selection criteria to help in the selection of end lifts for a new bridge. A life cycle cost analysis that takes into account the affect the end lifts have on structural, mechanical, and electrical systems as well as the initial cost and maintenance costs for the end lift systems is 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

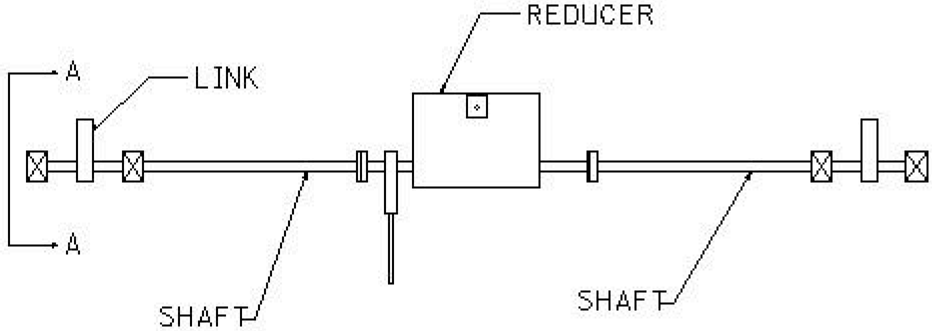
COLUMBUS DRIVE WEDGE MACHINERY
EAST WEDGE MACHINERY



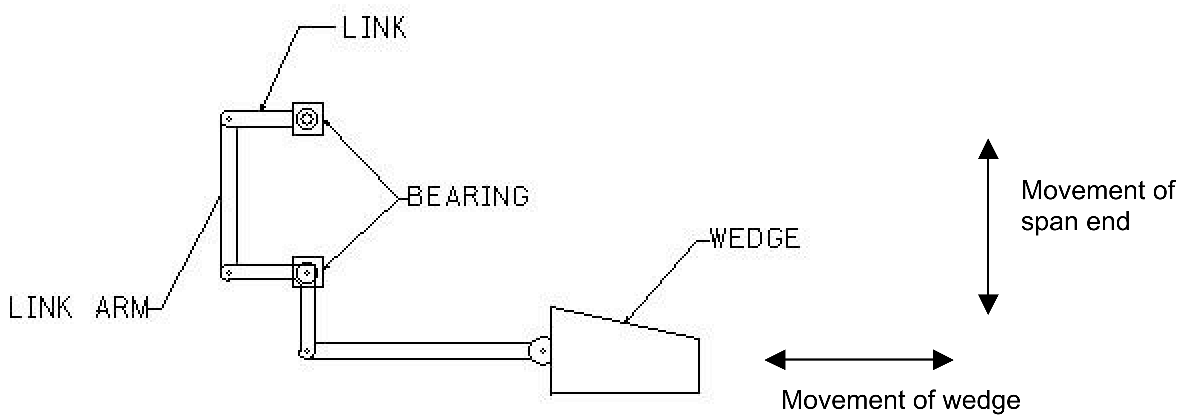
WEST WEDGE MACHINERY



RANCOCAS CREEK WEDGE MACHINERY

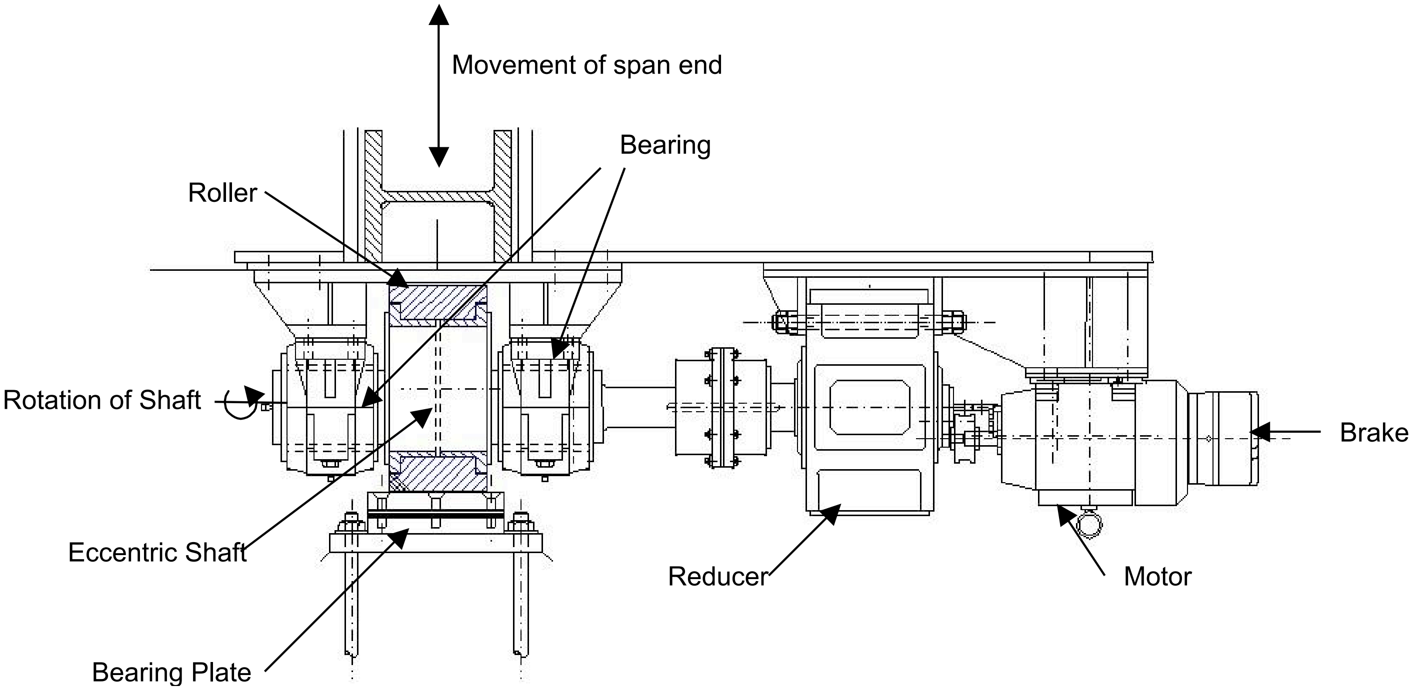


WEDGE MACHINERY
PLAN

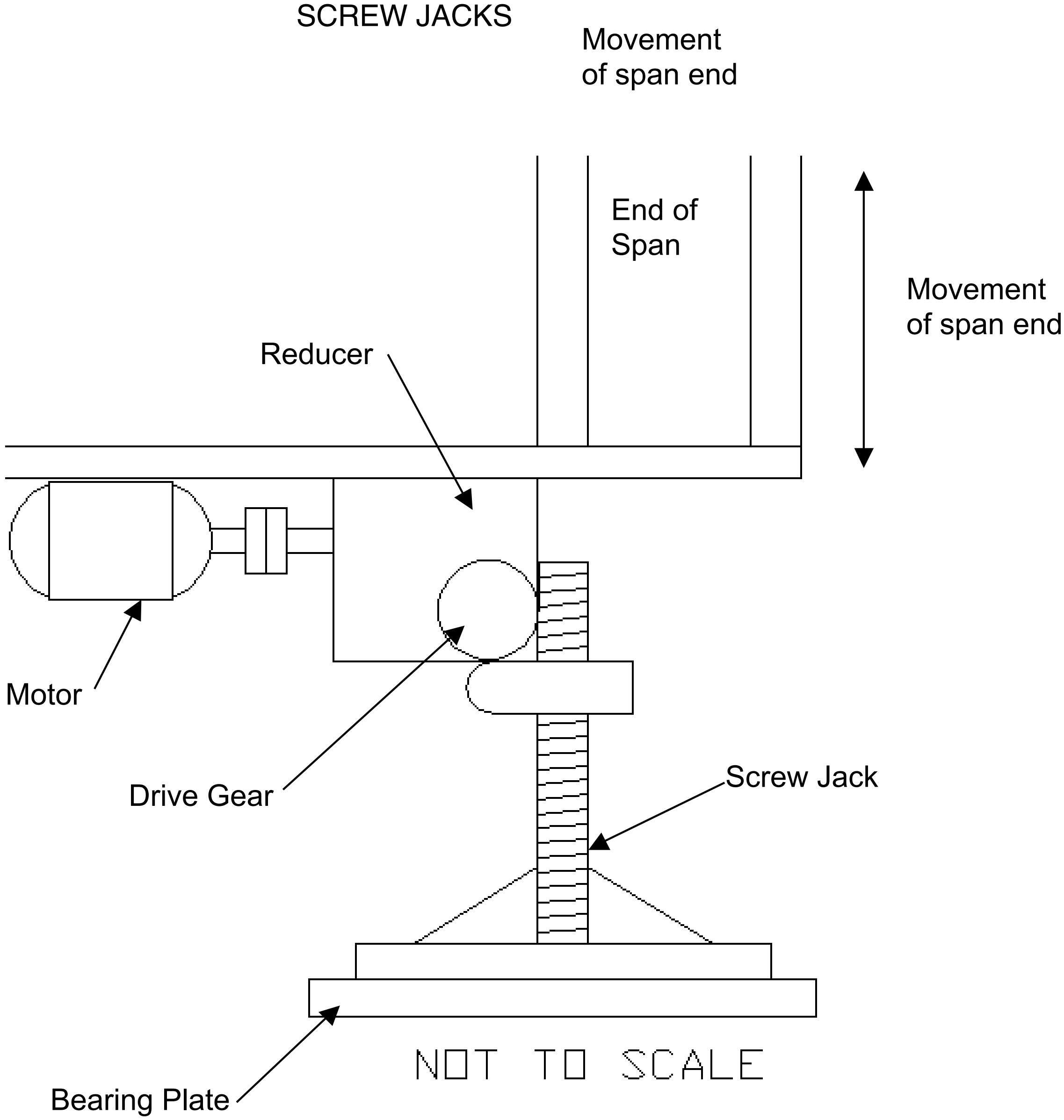


SECTION A-A

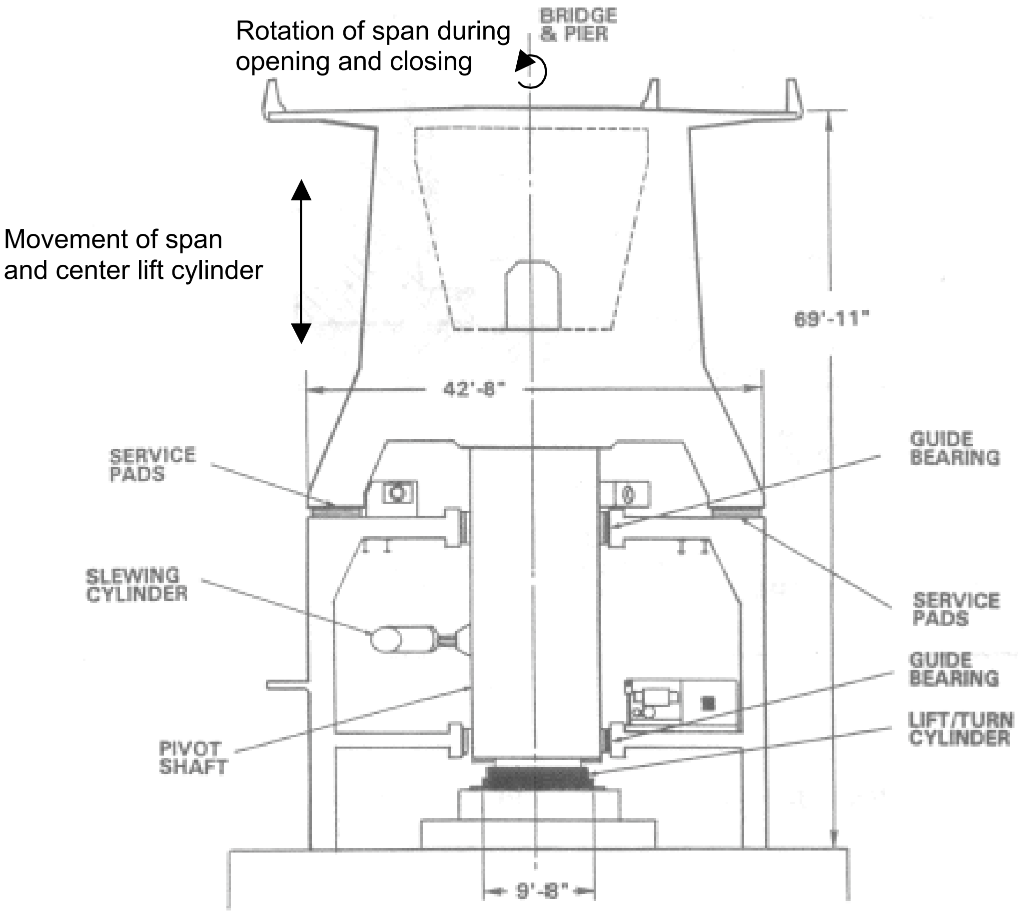
145TH STREET END LIFT
ECCENTRIC ROLLERS



KINGSLAND AVENUE BRIDGE
SCREW JACKS



WEST SEATTLE SWING BRIDGE
CENTER JACK



SECTION THROUGH A
PIVOT PIER SHOWING
THE LOCATION OF THE
LIFT/TURN CYLINDER

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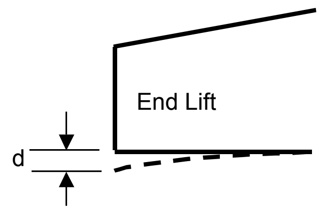
	Associates	Checked by		Date		Sheet No.	
For	145TH ST	Back checked by		Date			

Calculate Theoritcal Power Requirement

d = 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 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 = 2.5/10

V = 0.25 in/sec or 0.0208 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 = Force in lbs
V = 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 .
or
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.

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For	145TH ST	Back checked by		Date			

The horsepower to perform the lifting of the end lift without friction can be calculated as:

$$HP \ ? \ \frac{123{,}000\,lbs \ ? \ 0.0208}{550} \ ? \ 4.65\,HP$$

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:

$$f \ ? \ ?_k N$$

Where _$_k$ = Friction factor
_$_k$ = 0.18 (AASHTO 2.5.5) for trunnions
N = Normal force (lbs)

f = 0.18 x 123 kips
f = 22.14 kips

The horsepower to overcome friction is calculated as:

$$HP \ ? \ \frac{22{,}140\,lbs \ ? \ 0.0208}{550} \ ? \ 0.837\,HP$$

The total horsepower becomes:

HP_{Total} = 4.65 + 0.837 = 5.487 HP

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

Machinery Efficiency

System Efficiency (_) = _ Component Efficiencies
_ = $\_{Other}$ x $\_{Roller}$ x $\_{Brg}$ x $\_{Reducer}$
_ = 86%

Item	Efficiency
$\_{Reducer}$	97%
$\_{Brg}$	95%
$\_{Roller}$	96%
$\_{Other}$	97%

The system efficiency is 86%.

The minimum horsepower which must be delivered is:

$$\frac{5.487}{.86} \ ? \ 6.38\,HP$$

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		Checked by	HFP	Date	12/15/03	Sheet No.	
For	Columbus Drive	Back checked by		Date			

Weight of HS-20 = 72000 lb

Longitudinal numbers

Front Wheel (A) = 4000 lb

Back Wheel (B1,B2) = 16000 lb

East Span Length = 106.5 ft

West Span Length = 57.89 ft

Ratio of spans = 1.84

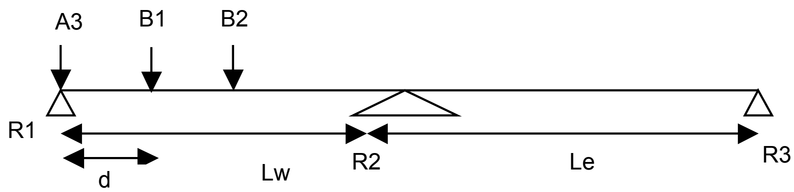
Total length of span = 164.39 ft

Assume 160 ft legnth 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



Le = 106.5 ft
Lw = 57.89 ft
d = 14 ft

center of gravity for truck:

C.G. =[(Ya3 x A3) + (Yb2 x B2)]/(A3 + b2)
C.G. = 8.4 *ft away from B1*

From Moment and shear reactions-AISC
The only reaction we are cocerned with is the reaction at R3
Assume center of gravity is at .6 of span length

Case1 -B1

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

Case2 -B2

From the table:
For the Load at 0.7 in span one,
% R3 = -0.0389 *from table*
Reaction at R3 = % R3 x B2
Reaction at R3 = -622.4 lb

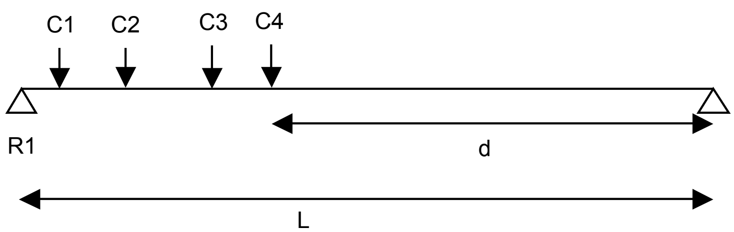
Case3-A3

From the table:
For the Load at 0.2 in span one,
% R3 = -0.0209 *from table*
Reaction at R3 = % R3 x B2
Reaction at R3 = -83.6 lb

Total reactions at R3 = Case1 + Case 2 + Case 3

Total reactions at R3 = -1358.8 lb *Negative number denotes upward direction*

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



L = dist from curb to curb = 40'

Consider 4 individual loads with the general formula

R1 = (Cd)/L

Case 1

C1 =	-1358.8	lb
d1 =	38	ft
L =	40	ft
R1 =	-1290.86	lb

Case 2

C2 =	-1358.8	lb
d2 =	32	ft
L =	40	ft
R2 =	-1087.04	lb

Case 3

C3 =	-1358.8	lb
d3 =	28	ft
L =	40	ft
R3 =	-951.16	lb

Case 4

C4 =	-1358.8	lb
d4 =	22	ft
L =	40	ft
R4 =	-747.34	lb

Total Reaction for 2 trucks

Rtotal = R1 + R2 + R3 + R4

Rtotal = -4,076 lb
-4.0764 kips

Transverse Distribution - Total Reaction for 3 trucks

R3 trucks = (Rtotal + additional truck)*.9 reduction factor

Rtotal = -4,892 lb
-4.891905 kips

Transverse Distribution - Total Reaction for4 trucks

R3 trucks = (Rtotal + 2 additional trucks)*.75 reduction factor

Rtotal = -5,418 lb *This is the worst case scenario*
-5.42 kips

Compare to force required to lift span 1"

R Lift <u>**83658**</u> kips **Controls**

FED. RD. REG. NO.	STATE	FEDERAL AID PROJECT NO.	SHEET NO.	TOTAL SHEETS
	NEW YORK	Q23.X757.059	310	556

RECONSTRUCTION OF 145TH STREET BRIDGE OVER HARLEM RIVER

PIN X757.59.121 | BOROUGHS OF MANHATTAN & BRONX | B.I.N. 2-24008-9

TRUSS FORCE TABLE (MOVABLE BRIDGE CRITERIA)

		LOAD CONDITIONS																			
		CASE I				CASE II				CASE III				CASE IV				CASE V			
MEMBER		FORCES		MOMENTS		FORCES		MOMENTS		FORCES		MOMENTS		FORCES		MOMENTS		FORCES		MOMENTS	
		C kN	T kN	My kNm	Mz kNm	C kN	T kN	My kNm	Mz kNm	C kN	T kN	My kNm	Mz kNm	C kN	T kN	My kNm	Mz kNm	C kN	T kN	My kNm	Mz kNm
LOWER CHORD	L0–L1	279	0	4	31	0	300	6	6	0	460	7	99	22	448	7	102	9	5	12	37
	L1–L2	537	0	14	39	0	459	9	7	0	640	5	99	35	596	10	98	18	29	17	47
	L2–L3	1052	0	28	42	0	600	13	9	0	653	7	79	49	577	12	80	28	79	24	51
	L3–L4	1757	0	45	63	0	721	15	17	0	541	7	83	69	460	11	82	41	155	30	76
	L4–L5	2770	0	39	62	0	842	14	18	0	341	6	86	95	275	12	81	56	260	38	75
	L5–L6	4211	0	78	360	0	1006	21	78	13	53	5	141	157	53	12	200	77	411	59	431
	L6–L7	3625	0	101	232	0	904	16	6	0	0	0	0	137	28	7	58	18	253	16	279
UPPER CHORD	L0–U1	0	613	7	18	627	0	2	12	844	0	15	14	819	44	21	14	7	2	95	21
	U1–U2	0	298	1	15	330	0	1	12	473	0	1	21	459	25	2	21	7	0	3	18
	U2–U3	0	783	1	3	544	0	1	5	632	0	1	23	594	44	1	23	14	0	3	4
	U3–U4	0	1475	0	3	721	0	0	2	627	0	1	22	567	63	1	21	30	0	2	4
	U4–U5	0	2324	1	3	868	0	0	4	516	0	1	24	450	82	1	26	51	0	3	4
	U5–U6	0	3347	1	98	1002	0	0	8	307	0	1	17	268	102	1	27	84	0	3	118
	U6–U7	0	4485	0	98	1100	0	0	8	0	0	0	0	34	176	1	37	127	1	2	118
VERTICAL POSTS	L1–U1	510	0	0	0	0	448	0	0	0	619	0	0	33	584	0	0	2	9	0	0
	L2–U2	982	0	3	0	0	394	1	0	125	410	14	0	132	385	31	0	2	26	114	0
	L3–U3	1440	0	3	0	0	354	1	0	301	262	20	0	318	240	39	0	3	43	112	0
	L4–U4	1853	0	3	0	0	317	1	0	445	143	17	0	466	135	35	0	4	60	111	0
	L5–U5	2317	0	4	0	0	293	1	0	580	48	13	0	592	61	38	0	4	96	195	0
	L6–M6	3457	0	10	5	0	427	2	0	677	0	29	2	515	57	17	4	0	160	194	6
	M6–U6	3460	0	10	5	0	465	2	0	662	0	29	2	600	32	17	4	0	118	194	6
DIAGONAL MEMBERS	L1–U2	0	1179	0	0	518	0	0	0	534	171	0	0	500	181	0	0	12	3	0	0
	L2–U3	0	1709	0	0	452	0	0	0	329	384	0	0	299	406	0	0	31	3	0	0
	L3–U4	0	2164	0	0	392	0	0	0	171	553	0	0	159	581	0	0	50	4	0	0
	L4–U5	0	2637	0	0	353	0	0	0	50	697	0	0	60	721	0	0	69	4	0	0
	L5–U6	0	2964	0	0	296	0	0	0	0	815	0	0	12	818	0	0	100	9	0	0
	L6–LM67	404	0	0	0	0	67	0	0	0	0	0	0	89	58	0	0	2	65	0	0
	LM67–M6	393	0	0	0	0	66	0	0	0	0	0	0	89	59	0	0	64	32	0	0
	UM67–U6	38	0	0	0	15	0	0	0	0	0	0	0	83	59	0	0	41	17	0	0
	M6–UM67	46	0	0	0	15	0	0	0	0	0	0	0	83	59	0	0	14	43	0	0
	M6–M7	0	293	0	0	34	0	0	0	0	0	0	0	0	53	0	0	13	2	0	0

		LOAD COMBINATIONS															
		CASE I + 20%				CASE I + III				CASE II + IV				CASE (I + 20%) + V			
MEMBER		FORCES		MOMENTS		FORCES		MOMENTS		FORCES		MOMENTS		FORCES		MOMENTS	
		C kN	T kN	My kNm	Mz kNm	C kN	T kN	My kNm	Mz kNm	C kN	T kN	My kNm	Mz kNm	C kN	T kN	My kNm	Mz kNm
LOWER CHORD	L0–L1	335	0	5	37	279	460	12	130	22	722	13	108	341	5	15	49
	L1–L2	644	0	17	47	537	640	19	138	35	1019	18	105	660	29	34	61
	L2–L3	1262	0	34	51	1052	653	35	122	49	1148	25	85	1288	79	57	70
	L3–L4	2108	0	54	76	1757	541	51	133	69	1170	25	89	2145	155	84	99
	L4–L5	3323	0	47	75	2770	341	45	148	95	1117	26	99	3379	260	85	97
	L5–L6	5054	0	94	431	4222	53	84	482	157	1052	33	279	5130	411	151	475
	L6–L7	4350	0	121	279	3626	0	101	232	137	932	23	64	4369	253	138	286
UPPER CHORD	L0–U1	0	736	8	21	844	613	22	31	1446	44	23	25	7	736	104	24
	U1–U2	0	358	2	18	473	298	3	36	790	25	2	32	7	358	5	21
	U2–U3	0	939	2	4	632	783	3	26	1137	44	2	28	14	939	5	4
	U3–U4	0	1771	0	4	627	1475	1	25	1288	63	1	23	30	1771	3	4
	U4–U5	0	2788	1	4	516	2324	2	27	1319	82	1	31	51	2788	4	5
	U5–U6	0	4017	1	118	307	3347	2	115	1270	102	2	36	84	4017	4	122
	U6–U7	0	5382	0	118	0	4486	0	98	1134	176	2	45	127	5383	2	122
VERTICAL POSTS	L1–U1	612	0	0	0	510	619	0	0	33	1032	0	0	614	9	0	0
	L2–U2	1178	0	3	0	1107	410	16	0	132	779	32	0	1180	26	117	4
	L3–U3	1728	0	3	0	1741	262	23	0	318	594	40	0	1731	43	115	6
	L4–U4	2223	0	3	0	2298	143	20	0	466	451	36	0	2227	60	114	7
	L5–U5	2780	0	5	0	2897	48	17	0	592	354	39	0	2784	96	200	8
	L6–M6	4149	0	12	6	4134	0	39	7	515	484	19	4	4149	160	206	7
	M6–U6	4152	0	12	6	4121	0	39	7	600	497	19	4	4152	118	206	9
DIAGONAL MEMBERS	L1–U2	0	1415	0	0	534	1350	0	0	1017	181	0	0	12	1418	0	0
	L2–U3	0	2050	0	0	329	2092	0	0	751	406	0	0	31	2054	0	0
	L3–U4	0	2597	0	0	171	2718	0	0	551	581	0	0	50	2601	0	0
	L4–U5	0	3165	0	0	50	3335	0	0	413	721	0	0	69	3169	0	0
	L5–U6	0	3556	0	0	0	3778	0	0	307	818	0	0	100	3566	0	0
	L6–LM67	484	0	0	0	404	0	0	0	89	125	0	0	486	65	0	0
	LM67–M6	471	0	0	0	393	0	0	0	89	125	0	0	536	32	0	0
	UM67–U6	46	0	0	0	38	0	0	0	98	59	0	0	87	17	0	0
	M6–UM67	55	0	0	0	46	0	0	0	98	59	0	0	69	43	0	0
	M6–M7	0	352	0	0	0	293	0	0	35	53	0	0	13	354	0	0

NOTES:

LOAD CONDITIONS AND LOAD COMBINATIONS ARE IN ACCORDANCE WITH AASHTO STANDARD SPECIFICATIONS FOR MOVABLE HIGHWAY BRIDGES DATED 1988.

LOADING CONDITIONS:

CASE I – DEAD LOAD FOR OPEN BRIDGE WITH END LIFTS NOT DRIVEN.

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 LL+I PLUS END REACTION DUE TO TEMPERATURE DIFFERENTION OF 11°C (20°F) BETWEEN TOP AND BOTTOM CHORD OF THE TRUSSES.
- BRIDGE CLOSE WITH 1" DISPLACEMENT AT THE END LIFTS.

CASE III – LIVE LOAD + IMPACT FOR BRIDGE CLOSED, WITH ONE ARM LOADED AND CONSIDERED AS A SIMPLE SPAN, BUT WITH END LIFTS NOT DRIVEN.

CASE IV – LIVE LOAD + IMPACT FOR BRIDGE CLOSED AND CONSIDERED AS A CONTINUOUS STRUCTURE.

CASE V – WIND LOAD FOR BRIDGE OPEN LOADED WITH WIND OF 1.5 Pa (30 PSF) ON ONE ARM AND 1.0 Pa (20 PSF) ON THE OTHER ARM.

REFERENCES:

FOR MEMBER SECTION TYPE SEE DWG.------SP-1

CITY OF NEW YORK
DEPARTMENT OF TRANSPORTATION
DIVISION OF BRIDGES

CONTRACT NO. HBX1029

RECONSTRUCTION OF 145TH STREET BRIDGE OVER HARLEM RIVER
BOROUGHS OF MANHATTAN AND BRONX B.I.N.2-24008-9

TRUSS FORCE TABLE (MOVABLE BRIDGE CRITERIA)

DWG. NO.	SCALE	DATE	SHEET
SP-3	NONE	AUG., 2003	310

NEW YORK CITY DOT — DIVISION OF BRIDGES IN-HOUSE DESIGN, 2 RECTOR ST., NEW YORK, N.Y. 10006

0 10 20 30 40 50 60 70 80 90 100 ORIGINAL SIZE IN mm

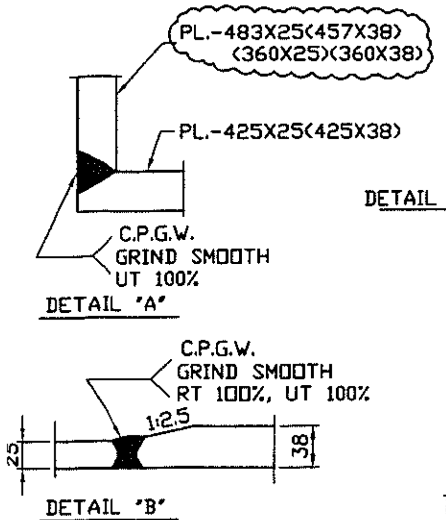
PREPARED BY IN CHARGE A. VYAS DRAFTER I. KHANANOV
DESIGNER E. JEAMGOCIAN CHECKER M. FRIDMAN

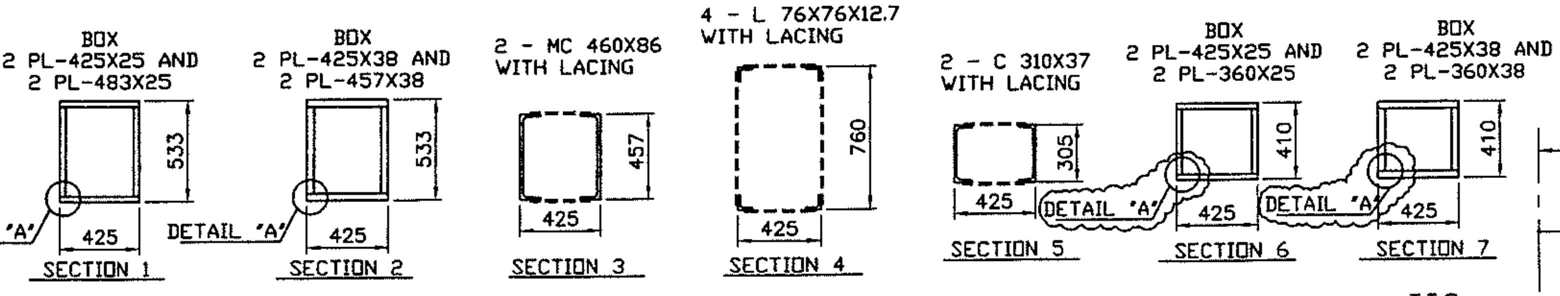
N. Y. C. D. O. T. MICROFILM IDENTIFICATION NUMBER
BIN 2-24008-9 ROLL J04 FRAME 310

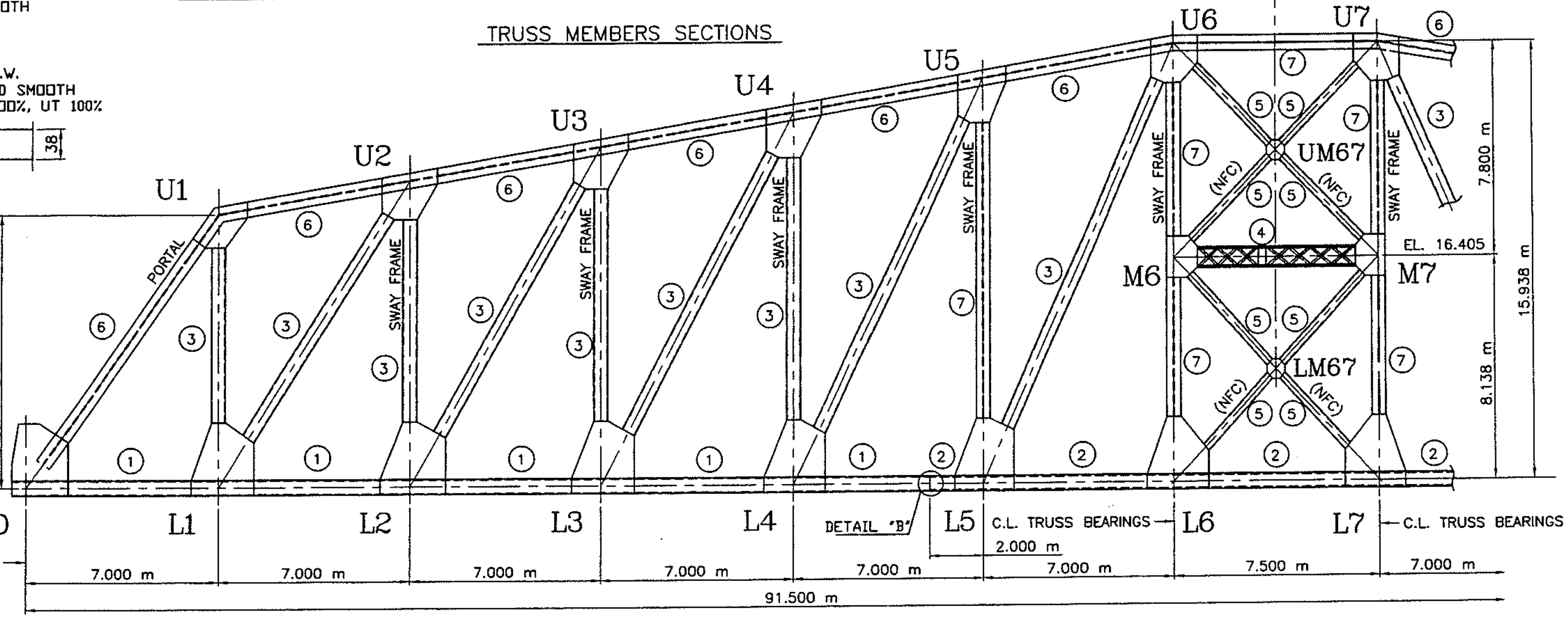
FED. RD. REG. NO.	STATE	FEDERAL AID PROJECT NO.	SHEET NO.	TOTAL SHEETS
	NEW YORK	Q23.X757.059	308R	556

RECONSTRUCTION OF 145TH STREET BRIDGE OVER HARLEM RIVER

PIN X757.59.121 | BOROUGHS OF MANHATTAN & BRONX | B.I.N. 2-24008-9







SWING SPAN TRUSS ELEVATION

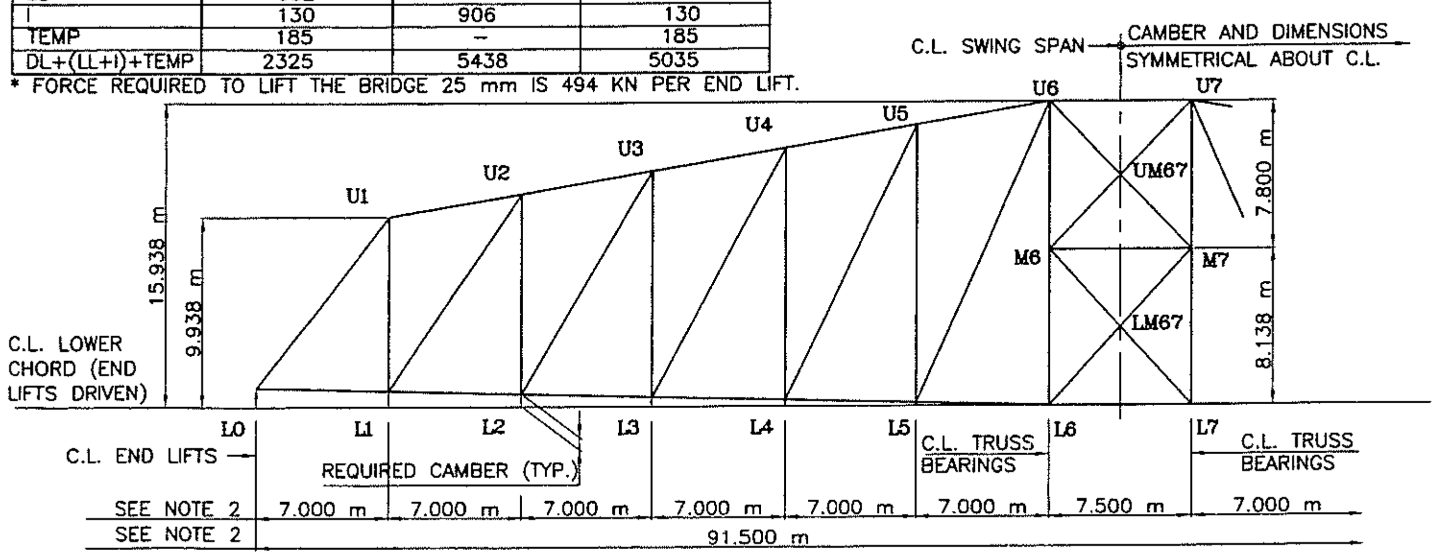
(JOINTS L0–L6 AND U1–U6 SHOWN
JOINTS L7–L13, U7–U12 MIRROR IMAGE)

1:100

SUPPORT REACTIONS

	AT END LIFT / PER END LIFT (KN)	AT CENTER PIER / PER DISTRIBUTION GIRDER SUPPORT (KN)	
		BRIDGE OPEN	BRIDGE CLOSED
DL	1328	4532	4038
LL	682	–	682
I	130	906	130
TEMP	185	–	185
DL+(LL+I)+TEMP	2325	5438	5035

* FORCE REQUIRED TO LIFT THE BRIDGE 25 mm IS 494 KN PER END LIFT.



CAMBER DIAGRAM

SWING SPAN TRUSS CAMBER TABLE (mm)

TRUSS CHORD	PANEL POINT	SELF WEIGHT OF TRUSSES, AND FLOOR BEAMS	DEAD LOAD	END LIFT DUE TO 25 mm LIFTUP	NET TOTAL
LOWER	L0	36	57	−25	68
	L1	34	53	−21	66
	L2	30	47	−15	62
	L3	25	38	−11	52
	L4	18	27	−6	39
	L5	11	16	−3	24
	L6	3	5	−1	7
UPPER	U1	34	54	−22	66
	U2	31	48	−16	53
	U3	26	40	−12	54
	U4	20	30	−7	43
	U5	12	18	−4	26
	U6	5	8	−2	11

NOTE:

1. THE TRUSS DIMENSIONS SHOWN REPRESENT THE THEORETICAL DIMENSIONS OF THE TRUSS UNDER FULL DEAD LOAD WITH THE END LIFTS ENGAGED.
2. ALL MAIN TRUSS MEMBERS WITH GUSSET PLATES AND SPLICE MATERIAL, PORTALS AND SWAY FRAMES WITH DIAGONALS, FLOOR BEAMS AND SIDEWALK BRACKETS ARE FRACTURE CRITICAL MEMBERS AND SHALL COMPLY WITH THE REQUIREMENTS FOR FRACTURE CRITICAL MEMBERS CRITERIA INCLUDING MATERIAL V-NOTCH IMPACT TOUGHNESS. ALL FRACTURE CRITICAL MEMBERS SHALL BE FABRICATED IN ACCORDANCE WITH SECTION 9 OF THE NYS STEEL CONSTRUCTION MANUAL.
3. ALL SWING SPAN STRUCTURAL STEEL SHALL BE PAID UNDER ITEM 564.5102 M.
4. FOR GENERAL NOTES SEE DWGS. NOS. GEN-10 THRU GEN-13.
5. MAIN TRUSS MEMBERS ARE THOSE INCLUDED IN THE STRESS TABLE ON DWG. SP-2.
6. ALL THE WELDS IN FRACTURE CRITICAL MEMBERS SHALL BE DONE AND TESTED IN ACCORDANCE WITH SECTION 9 OF THE NYS STEEL CONSTRUCTION MANUAL.

CAMBER NOTES:

1. THE TOTAL CAMBER SHOWN IS ASSUMED TO BE MEASURED VERTICALLY FROM A STRAIGHT LINE DRAWN THROUGH THE CENTER LINE OF THE LOWER CHORD WITH THE END LIFTS ENGAGED.
2. THE DIMENSIONS SHOWN ON THE CONTRACT PLANS ARE THE THEORETICAL DIMENSIONS OF THE TRUSS UNDER FULL DEAD LOAD WITH THE END LIFTS ENGAGED.
3. ALL CAMBERS GIVEN IN THE CAMBER TABLE ARE IN mm.
4. CAMBERS LISTED AS POSITIVE IN THE TABLE ARE UPWARD CAMBERS. CAMBERS LISTED AS NEGATIVE IN THE TABLE ARE DOWNWARD CAMBERS.
5. THE TRUSS MUST BE CAMBERED SYMMETRICALLY ABOUT ITS CENTER LINE.

RECORD

PART 2 OF 2

ADDENDUM NO. 4
THIS DRAWING SUPERSEDES
DWG. SP-1
AD-29

CITY OF NEW YORK
DEPARTMENT OF TRANSPORTATION
DIVISION OF BRIDGES

CONTRACT NO. HBX1029

RECONSTRUCTION OF 145TH STREET BRIDGE OVER HARLEM RIVER
BOROUGHS OF MANHATTAN AND BRONX B.I.N.2-24008-9

TRUSS ELEVATION
CAMBER DIAGRAM AND TABLE
END LIFT REACTIONS

NEW YORK CITY DOT

DIVISION OF BRIDGES
IN-HOUSE DESIGN
2 RECTOR ST., NEW YORK, N.Y. 10006

0 10 20 30 40 50 60 70 80 90 100
ORIGINAL SIZE IN mm

PREPARED BY
IN CHARGE A. VYAS DRAFTER M. FRIDMAN
DESIGNER M. FRIDMAN CHECKER E. JEAMGOCIAN

N. Y. C. D. O. T. MICROFILM IDENTIFICATION NUMBER
BIN 2-24008-9 ROLL J04 FRAME 308R

DWG. NO.	SCALE	DATE	SHEET
SP-1R	AS NOTED	AUG., 2003	308R