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Balancing and Synchronizing a Twin Leaf Bascule bridge Composed of Six Leaves

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HEAVY MOVABLE STRUCTURES, INC.

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Balancing and Synchronizing a Twin Leaf Bascule Bridge Composed of Six Leaves

By:

Peter Davis, P.E. Bergmann Associates
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Abstract

The Beades Bridge is located in Boston Massachusetts and spans Dorchester Bay. The bridge was originally constructed as two twin leaf rolling lift bridges which were tied together to act as a single twin leaf bridge. Each leaf has its own machinery. Synchronization between adjacent leaves was not considered in the design. The structural connection between the adjoining leaves was used to maintain synchronization. In 1955 two additional leaves were added to the bridge to accommodate widening of Morrisey Boulevard. To accommodate the widened roadway, the existing south sidewalk was removed and attached to the new leaves. Two new sets of drive machinery were installed and the leaves were structurally connected to the existing spans.

In 2001, the Metropolitan District Commission (MDC) embarked upon a rehabilitation of the structure. One of the objectives was to synchronize the six drive motors since their current draws ranged from 0 amps to overload condition.

This paper will discuss the construction staging and balance adjustments performed as the multiple leaves were disconnected from one another and then reassembled. A complicating factor in the project was that the original as built drawings of the structure were significantly different from the existing field conditions. The requirement for three axis balancing of each leaf and multiple leaf combinations will be discussed as well as the impact on interleaf connection loads. The use of balance adjustment to minimize the interleaf connection loads and the design considerations used will be discussed. The technique utilized to improve synchronization between the leaves will be discussed and the resulting bridge performance will be presented.

Introduction

The MDC expressed a need to improve the synchronization between the six drive systems. The reason for this desire was due to the disparate ampere readings between drive motors. The bridge was also out of balance as indicated by the operator. None of the bridge indication systems were working, so that all operation was manual. The operators would use visual clues to operate the bridge. The skill level of individual operators had a significant impact on the bridge opening and closing sequences particularly since the brakes were not functioning well. It was presumed at the outset of the project that synchronization could be achieved by balance and motor speed adjustments of the individual leaves. Another concern was the interconnections between the individual leaves. These connections were deteriorated and it was planned during the structural rehabilitation to modify these connections. Figure 1 provides a simplified plan view of the leaves as they exist today.

During construction it was discovered that the new 1955 counter-weight was not as shown on the as-built drawings. Another complication to the entire project was the reality that the contractor hired by the agency had never performed movable bridge rehabilitation. Balance and synchronization were achieved by balancing each leaf individually and then adjusting each motor to similar current draws.

The Problem

As mentioned previously, the client desired that at the conclusion of the rehabilitation that the amperage readings between the six drive motors (3 per side) would be synchronized and that a proper balance condition would be achieved. The operating machinery for each leaf is shown in figures 2 and 3. The 1927 operating machinery is a typical open gear arrangement with a single drive motor. No differential gear sets are included in the machinery. The 1955 machinery utilized the same overall gear ratios however and enclosed speed reducer with intermediate open gearing. The 1927 machinery had the expected level of wear given its age while the 1955 machinery has experienced severe wear, particularly at the pinion bearings. During the design, the leaf interconnections were to be rehabilitated. Since there are three sets of operating machinery per combined leaf, the machinery could potentially have an impact on the loads seen by these connections. Figure 4 shows the section view of the geometry of the three leaves making up each combined leaf. The bridge was originally constructed as a four leaf bridge with sidewalks located outboard of each leaf. In 1955 the third leaves were added, with the sidewalk being relocated outboard of span 3. Span 3 has different section geometry from the two original spans as shown in figure 4. The original amperage readings taken during the inspection work in advance of design indicated differences. As below, the amperage readings during raising of the span varied considerably.

Near #1	25 amps	Far #1	27 amps
Near #2	30 amps	Far #2	34 amps
Near #3	10 amps	Far #3	8 amps

As shown by the readings, the span two motors had the greatest current draw. The most troubling data was that the span three motors had such small current draws.

Construction Staging

The contractor began work by removing spans 1 near and far. The connections between spans 2 and 3 remained and were operated during the span 1 reconstruction. Once span 1 structural was completed, the leaves were installed, made operable and balanced. Each span was balanced individually prior to their reconnection. The span 2 leaves were then removed for rehabilitation. Once span 2 leaf reconstruction was completed, the leaves were installed, made operable and balanced. The span 3 leaves were removed. Spans 1 and 2 were then connected and balanced. Upon completion of the span 3 rehabilitation work the leaves were installed and ultimately connected to spans 1 and 2. The issue of balance began with the connection of spans 1 and 2. Note that span 1 has an eccentric load due to the facial girder and the sidewalk whereas span two is symmetrical about its centerline. The question of torsion loads through the structure and their ultimate impact on bridge operation was considered.

The Solution

It was decided that in order to minimize leaf interconnection loads and to assure proper span balance at the conclusion of construction, that each leaf should be balanced prior to interconnection. In order to synchronize each drive motor it was essential that each leaf be properly balanced.

Span 1 Balancing

Span 1 was installed and balance measurements taken using the strain gauge method. In addition the torsional load on the structure was calculated. Since each leaf has a different loading condition (since they are dimensionally different), the goal in balancing was to achieve a static condition where the loads through the flat tracks were the same. Calculations were performed to estimate the amount of balance adjustment required (see appendix 1). By treating the span transversely as a simple beam it is clear that the sidewalk imbalance has an impact on the loads seen at each flat track as well as by the interleaf connection. While this imbalance load is not necessarily significant from a structural viewpoint, it will impact the tendency of the machinery to drive the span in a transverse direction. It has been calculated that these transverse loads can increase pinion tooth loading by up to 1 kip. Since the loads that the pinions see are different, over time uneven wear on the machinery components can occur. Note that to counterbalance the torsion effect of the sidewalk and facia girder, the interconnection load is 13 kips. The span was found to be counterweight heavy, thereby offering the opportunity to reduce the torsion effect by judicious placement of the counterweight blocks on the span. As shown on the balance calculation (appendix 2) balance blocks were placed along the east girder to counteract the sidewalk loads. The net result was that the span was balanced such that interleaf connection loads were minimized.

Span 2 Balancing

Span 2 was both the most complex and simplest to balance. The leaf is of symmetrical design such that there are no eccentric loads (other than external loads). This leaf however is connected to leaf 1 to act as a combined leaf and then connected to span 3. Upon installation of the rehabilitated span 2 leaves, it was discovered that the span 3 counterweight was not constructed per the as built plans and resulted in the leaves being very counterweight heavy. Prior to recognizing this field condition, the loading of span 2 due to the torsion in span 1 was calculated, indicating a very small interleaf load betweens span 2 and 3 (3.6 kips). It was therefore decided that span 2 would be balanced without adjustments for torsion. The initial calculations for span 2 indicated a severely counterweight heavy condition. Simple addition of weight at the toe (approximately 19,600 lbs) resulted in an undesireable phi angle. The high phi angle was due to the location of both the span and counterweight centers of mass. In order to bring the phi angle into the desired range (0 to 32 degrees), the additional weight needed to be placed such that the span center of mass for the span was raised as far as possible. The roadway open grid deck was filled with concrete for the full width of the span for a length of 10 feet. An additional 2000 pounds of weight were added to the end floor-beam to provide for future adjustment.

Span 3 balancing

As span 3 was being removed, a counterweight sizing discrepancy was discovered. The counterweight as constructed was not per the as-built drawings resulting in an undersized counterweight. The balance calculations are presented in appendix 2. The counterweights were approximately 34,000 pounds undersized. As with span #2 merely adding weight resulted in a phi angle problem. The weight needed to be added to the counterweights at and below the center of roll (see figures appendix 2). The amount of weight which could be added to the counterweight was limited by available clearances. It was decided that a full Z axis (torsion balance) could not be performed. Approximately 1200 pounds of weight was installed at the west (inboard girders) of the span 3 leaves for Z axis balance.

Leaf synchronization

Upon completion of construction, the combined leaves were balance tested and synchronized. The balance condition was found to be adequate and required no further adjustment. The motor current readings while improved, still did not meet the overall goals for the project. The measured values during raising of the leaves were:

Near #1	33 amps	Far #1	27 amps
Near #2	35 amps	Far #2	35 amps
Near #3	17 amps	Far #3	18 amps

Note that the span 3 motors are drawing less amperage than spans 1 and 2. The current draw on span 3 is greater than prior to rehabilitation, but significantly different. To assure that the span #3 motors were not just being dragged along, the test was re-run with the span#2 motors disabled. The current readings from these tests were:

Near #1	35 amps	Far #1	32 amps
Near #2	N/A	Far #2	N/A
Near #3	21 amps	Far #3	25 amps

The conclusions drawn from these second tests indicated that the span #3 motors were driving, however the system was not as well synchronized as desired.

Adjustment to the resistor banks was performed to adjust motor currents under opening and closing operations. All drive motors are operated through a single drum controller. An inherent problem with the drive system design is that the speed torque characteristics between the span #1 and #2 motors are different from the span #3 motors. Because of this reality, perfect synchronization is not attainable. The result of the resistor bank adjustments allows for an improvement in the synchronization. The values of amperage after adjustments were made are as follows:

Near #1	32 amps	Far #1	26 amps
Near #2	35 amps	Far #2	33 amps
Near #3	18 amps	Far #3	16 amps

When the span #2 motors were disabled, the readings were:

Near #1	33 amps	Far #1	27 amps
Near #2	N/A	Far #2	N/A
Near #3	27 amps	Far #3	24 amps

The maximum variation between current readings with span #2 motors disabled are now +/- 10% for the near spans and +/- 6% for the far spans.

The Results

Upon completion of the synchronization and balance adjustments, the net result is a bridge which operates smoothly and is much easier for the operators to control. The electrical control systems for the bridge were not rehabilitated during this project. The question of the necessity of adjusting the balance condition of each leaf to counteract the eccentric loads is a matter of individual preference. The magnitude of the loads should be considered. For the Beades Bridge it was felt that since there are three sets of operating machinery per combined leaf, the most prudent approach would be to balance each leaf in all three axes. The adjustment to the resistor banks resulted in a more balanced current draw from each motor.

Today it is not the practice of engineers to install multiple machinery sets in bascule bridges. It is not likely that this unique problem will be encountered, however as engineers we must always be thinking about the unique design that we encounter and use basic engineering principles to affect a positive outcome.

Appendix I

Torsional Imbalance Calculations

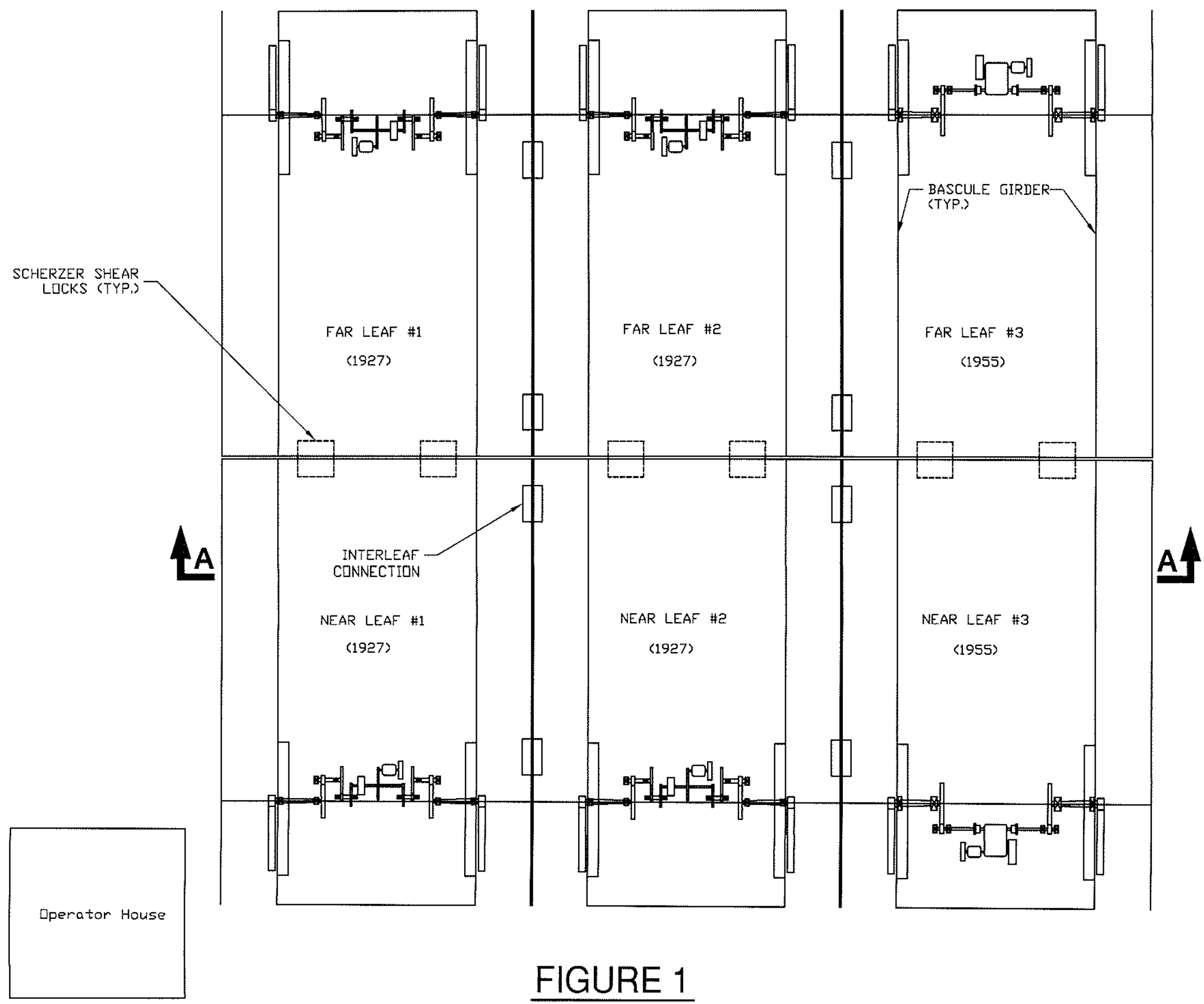


FIGURE 1

BEADES BRIDGE PLAN VIEW

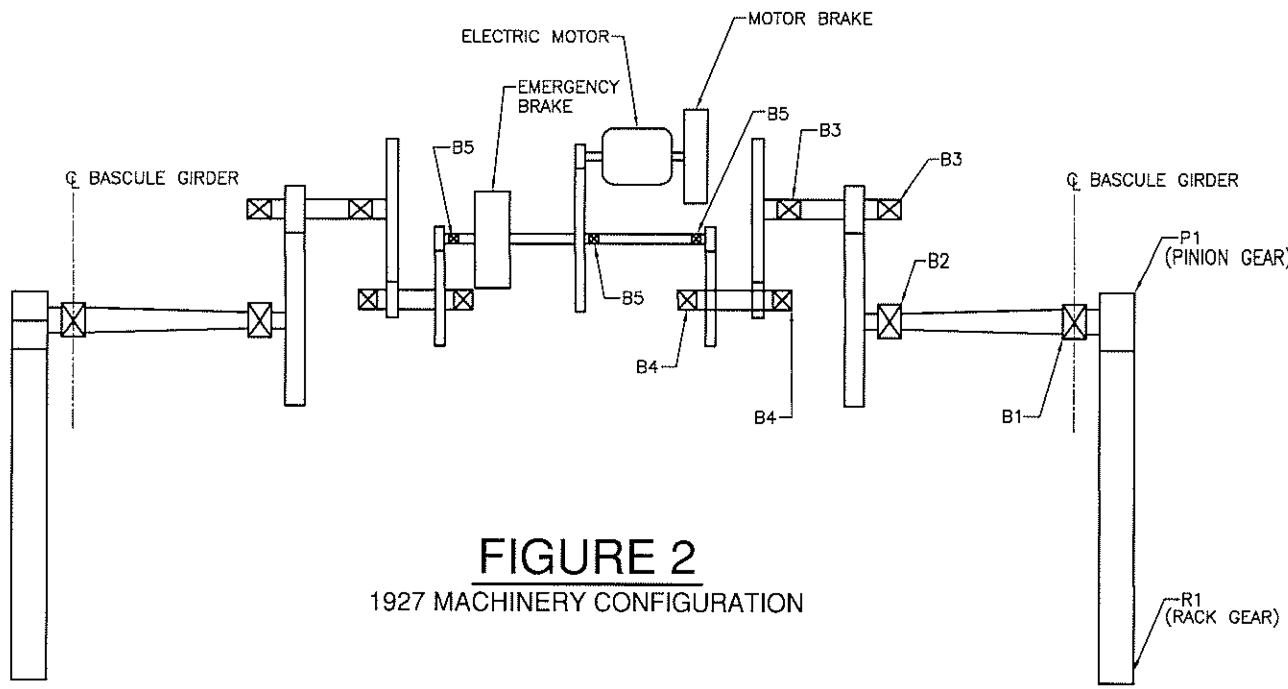


FIGURE 2

1927 MACHINERY CONFIGURATION

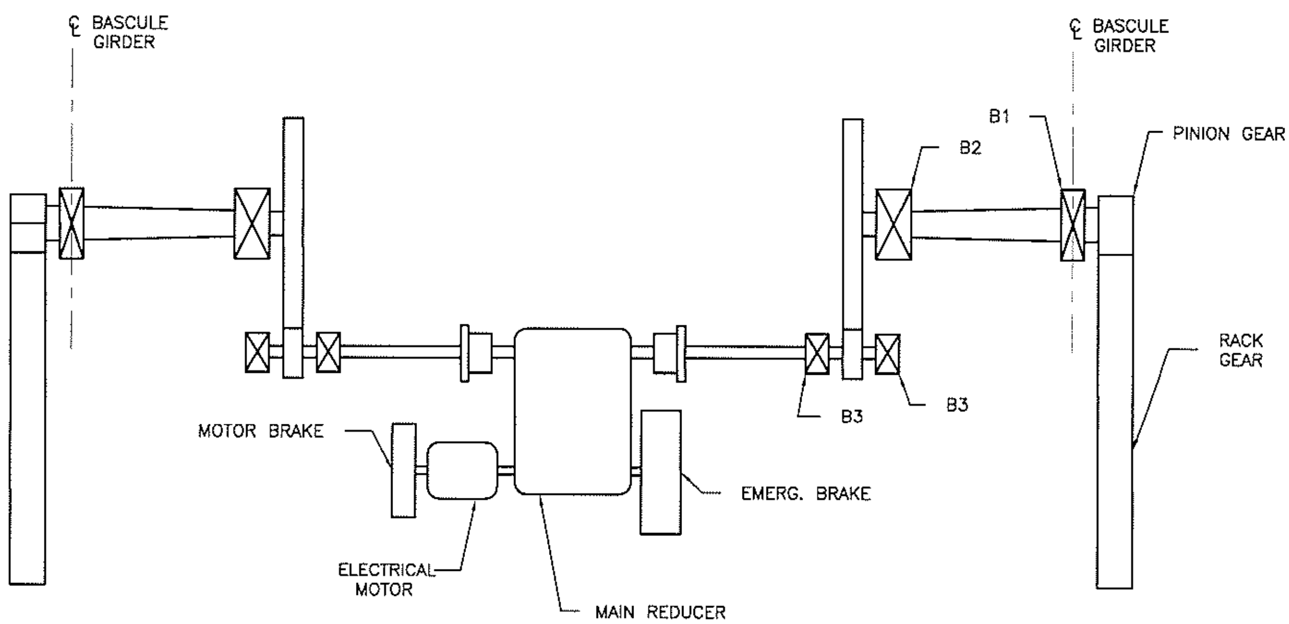


FIGURE 3
1955 MACHINERY CONFIGURATIOON

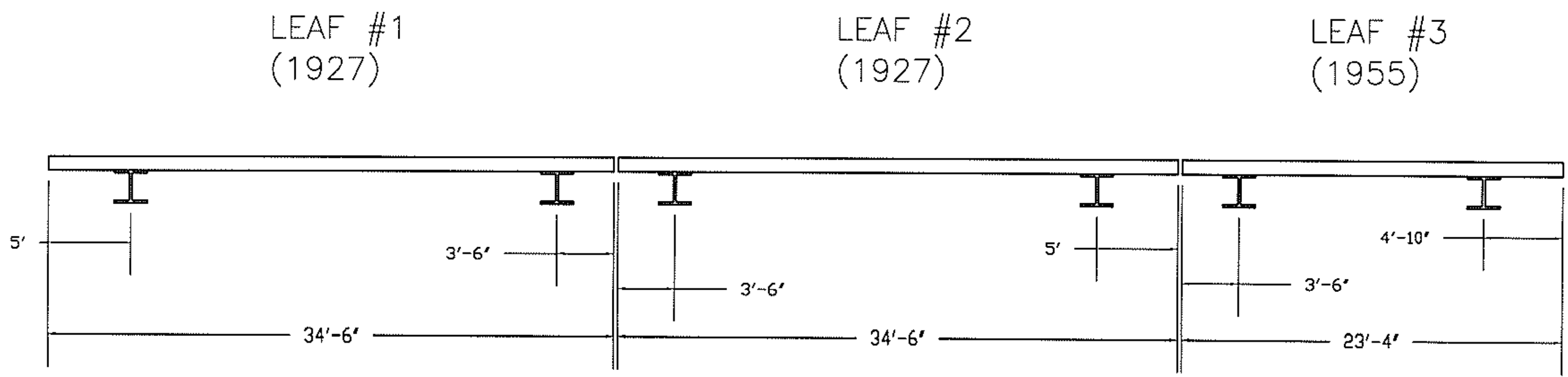


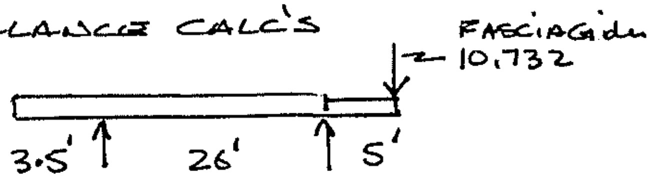
FIGURE 4
SECTION A-A

Appendix I

Torsional Imbalance Calculations

IF THE COUNTERWEIGHT IS NEGLECTED SINCE IT DOES NOT CONTRIBUTE TO THE X AXIS TORSION ON THE SPAN AND INCLUDE A CORRECTING LOAD. USE SPAN 1 TO DETERMINE THE LOAD CONDITIONS.

FROM BALANCE CALC'S



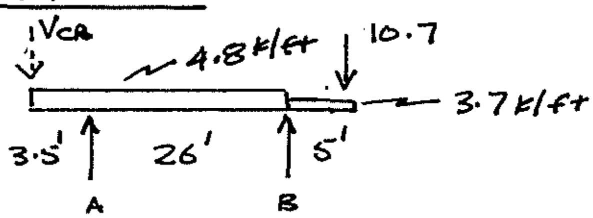
TOTAL SPAN 190,775
170,705
361,480

CTR WT
94,592 x 2 = 189,184
172,296

Sidewalk = 8119
10,562
$18,681 / 5 = 3736^{\#}/ft \Rightarrow 3.7k/ft$

172,296
(18,681)
(10,782)
$142,883 / 29.5' = 4843^{\#}/ft \Rightarrow 4.8k/ft$

FOR SPAN # 1



$\Sigma M_A = 0$

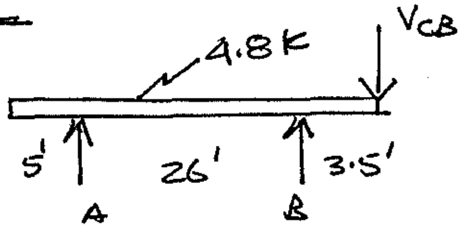
$4.8 \times 26' \times \frac{26'}{2} = 1622$
$3.7 \times 5' \times (26' + \frac{5'}{2}) = 527$
$10.7 \times 31' = 332$
2481
$4.8 \times 3.5 \times (\frac{3.5}{2}) = (29)$
2452

$\Sigma F_v = 0 \quad V_A = V_B$

$4.8 \times 29.5 = 141.6$
$3.7 \times 5 = 18.5$
$10.7 = 10.7$
170.8

$\Sigma M_A = 0$
$2452 - 26 V_B - 3.5 V_{CB} = 0$
$\Sigma F_V = 0$
$171 + V_{CB} - 2V_B = 0$
$V_B = 86 + \frac{1}{2} V_{CB}$
Subst into ΣM_A
$2452 - 26(86) + 26(+\frac{1}{2} V_{CB}) - 3.5 V_{CB}$
$2452 - 2236 + 13 V_{CB} - 3.5 V_{CB} = 0$
$216 = 16.5 V_{CB} \quad V_{CB} = 13k$
$V_B = V_A = 86 + \frac{1}{2}(13) = 92.5k$

SPAN 2



$\Sigma M_A = 0$

$4.8 \times 29.5 \times \left(\frac{29.5}{2}\right) = 2089$

$4.8 \times 5 \times \frac{5}{2} = (60)$

2039

$\Sigma F_v = 0 \quad V_A = V_B$

$4.8 \times 34.5 = 165.6$

$\Sigma M_A = 0$

$2039 - V_B \times 26 + V_{CB} \times 29.5$

~~$29.5 V_{CB} = 2039 - 26 V_B$~~

$2039 - 26 V_B + 29.5 V_{CB} = 0$

$165.6 + V_{CB} = 2 V_B \quad V_B = \frac{1}{2} V_{CB} +$

substituting

~~$29.5 V_{CB} = 2039 - 26(83) - 26(\frac{1}{2}$~~

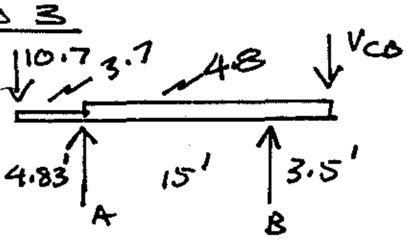
$2039 - 26(\frac{1}{2} V_{CB} + 83) + 29.5 V_{CB} = 0$

$2039 - 2158 - 13 V_{CB} + 29.5 V_{CB} = 0$

$16.5 V_{CB} = 119 \quad V_{CB} = 7.2K$

$V_B = V_A = \frac{1}{2}(7.2) + 83 = 86.6K$

SPAN 3



$\Sigma M_A = 0$

$4.8 \times 18.5 \times \frac{18.5}{2} = 821.4$

$3.7 \times 4.83 \times \frac{4.83}{2} = (43.2)$

778

$10.7 \times 4.83 = 52$

830

$\Sigma F_v = 0 \quad V_A = V_B$

$3.7 \times 4.83 = 17.9$

$4.8 \times 18.5 = 86.4$

10.7

115

830 (~~778~~) $+ 18.5 V_{CB} - V_B 15 = 0$

$115 + V_{CB} = 2 V_B$

$V_B = 58 + \frac{1}{2} V_{CB}$

$830 + 18.5 V_{CB} - 15(58) - \frac{15}{2} V_{CB} =$

$830 + 18.5 V_{CB} - 870 - 7.5 V_{CB} =$

$40 = 11 V_{CB} \quad V_{CB} = 3.6$

$V_B = 58 + \left(\frac{3.6}{2}\right) = 60K$

Appendix 2

Span 1	Balance Calculations
Span 2	Balance Calculations
Span 3	Balance Calculations
Span 4	Balance Block Installation Sketches

PROJECT BEADES BRIDGE
SHEET NO ______ OF ______
CALC. BY FP DATE 3/02
CHECK BY AP DATE 3/02

(A)

SOUTH WEST LEAF(PHASE I) - BALANCE CALCULATION SUMMARY
(INCLUDING BALANCE BLOCKS)

COMPONENT	WEIGHT (lbs)	X ARM (ft.)	Y ARM (ft.)	X MOMENT (ft-lbs)	Y MOMENT (ft-lbs)
EAST GIRDER					
COUNTERWEIGHT	94592	-10.33	1.75	-976852	165536
GIRDER 2	20502	9.85	0.67	201945	13736
FLOORBEAM 1	3029	6.51	-0.46	19716	-1393
BRACKET 203B2 + 203M6	467	6.51	-0.46	3040	-215
FLOORBEAM 2	1789	21.26	-1.88	38043	-3364
BRACKET 202B2 + 202M5 +202M6	502	21.26	-1.88	10673	-944
FLOORBEAM 3	1525	36.00	-2.10	54882	-3201
BRACKET 201B2 + 201M5 + 201M6	420	36.00	-2.10	15102	-881
CWT BRACKET 204B1 + 204M3 + 204M4	595	-11.51	-1.82	-6848	-1083
UPPER LEVEL CROSS BRACING	2294	11.86	-1.95	27207	-4473
LOWER LEVEL CROSS BRACING	1005	-1.33	5.63	-1337	5658
STRINGERS	11877	14.41	-3.06	171142	-36343
SIDEWALK FRAMING	171	12.80	-4.59	2189	-785
RDWY. GRID DECK	24065	6.38	-4.21	153533	-101313
SDWK. GRID DECK	172	12.65	-5.26	2176	-905
FASCIA GIRDER	0	0.00	0.00	0	0
MACHINERY FLOOR	3104	-0.44	1.32	-1366	4097
MACHINERY	4598	1.02	0.17	4690	782
EAST GIRDER SUBTOTAL	170705			-282065	34909
BALANCE BLOCKS					
8 balance blocks on 1st web panel of girder	1280	33.15	-1.80	42432	-2304
20 balance blocks on 2nd web panel of girder	3200	30.46	-1.64	97472	-5248
20 balance blocks on 3rd web panel of girder	3200	26.77	-1.29	85664	-4128
10 balance blocks on Toe FB	1329	36.19	-2.09	48097	-2778
10 balance blocks in counterweight pocket	261	-9.08	3.78	-2370	987
EAST GIRDER TOTAL	179975			-10771	21438

COMPONENT	WEIGHT (lbs)	X ARM (ft.)	Y ARM (ft.)	X MOMENT (ft-lbs)	Y MOMENT (ft-lbs)
WEST GIRDER					
COUNTERWEIGHT	94592	-10.33	1.75	-976852	165536
GIRDER 1	18039	9.27	0.79	167222	14251
FLOORBEAM 1	3029	6.51	-0.46	19716	-1393
BRACKET 203B3 + 203M4 + 203M5 + 203M6	808	6.51	-0.46	5260	-372
FLOORBEAM 2	1789	21.26	-1.88	38043	-3364
BRACKET 202B3 + 202M5	615	21.26	-1.88	13075	-1156
FLOORBEAM 3	1525	36.00	-2.10	54882	-3201
BRACKET 201B3 + 201M5	533	36.00	-2.10	19170	-1118
CWT BRACKET 204B2 + 204M5	523	-11.51	-1.82	-6020	-952
UPPER LEVEL CROSS BRACING	2294	11.86	-1.95	27207	-4473
LOWER LEVEL CROSS BRACING	1005	-1.33	5.63	-1337	5658
STRINGERS	12866	14.41	-3.06	185404	-39371
SIDEWALK FRAMING	8119	12.80	-4.59	103929	-37268
RDWY. GRID DECK	16043	6.38	-4.21	102356	-67542
SDWK. GRID DECK	10562	12.65	-5.26	133609	-55556
FASCIA GIRDER	10732	16.78	-2.93	180083	-31445
MACHINERY FLOOR	3104	-0.44	1.32	-1366	4097
MACHINERY	4598	1.02	0.17	4690	782
WEST GIRDER SUBTOTAL	190775			69071	-56889
BALANCE BLOCKS					
10 balance blocks on Toe FB	271	36.19	-2.09	9807	-566
10 balance blocks in counterweight pocket	1339	-9.08	3.78	-12158	5061
WEST GIRDER TOTAL	192385			66721	-52394
SOUTH WEST LEAF TOTAL	372360			55950	-30955

Toe reaction (lb) = **1554**
phi angle (deg.) = **28.8**

SIGN CONVENTION: X - ARM => TOWARDS TOE +VE ; TOWARDS HEEL -VE
(leaf in closed position) Y - ARM => BELOW PINION +VE ; ABOVE PINION -VE

Lichtenstein Consulting Engineers

PAGE B

JOB 2150 BEADES BRIDGE - PHASE II
SHEET NO. ____ OF ____
CALCULATED BY DA / FP DATE 10/02
CHECKED BY AP DATE 10/02

(PH II B - WITH MEDIAN & MEDIAN RAIL)

SOUTH MIDDLE LEAF (PHASE II) - BALANCE CALCULATION SUMMARY (INCLUDING BALANCE WEIGHTS)

COMPONENT	WEIGHT (lbs)	X ARM (ft.)	Y ARM (ft.)	X MOMENT (ft-lbs)	Y MOMENT (ft-lbs)
EAST GIRDER					
COUNTERWEIGHT	94621	-10.327	1.774	-977151	167858
GIRDER 4	17658	9.61	0.96	169693	16952
FLOORBEAM 4	3761	6.51	-0.64	24484	-2407
FLOORBEAM 5	2443	21.26	-1.89	51938	-4617
FLOORBEAM 6	2097	36.00	-2.11	75492	-4425
COUNTERWEIGHT BRACKETS	756	-11.45	-1.72	-8656	-1300
UPPER LEVEL CROSS BRACING	2327	12.13	-1.94	28227	-4514
LOWER LEVEL CROSS BRACING	1033	-1.49	5.68	-1539	5867
STRINGERS	13639	9.90	-2.86	135026	-39008
RDWY. GRID DECK	23736	6.49	-4.21	154047	-99929
MACHINERY FLOOR	3014	-0.46	1.33	-1386	4009
MACHINERY	4598	1.02	0.17	4690	782
EAST GIRDER SUBTOTAL	169683			-345136	39267
BALANCE WEIGHTS					
Balance Weights on Toe Floorbeam	3025	36.19	-2.09	109475	-6322
7.53' Long x Full Width Concrete Fill in Grid Deck	6917	34.20	-4.16	236561	-28775
No Concrete Fill in Openings for Railing Posts	-28	35.75	-4.16	-1001	116
Temporary Thrie Beam Rail	1963	15.67	-5.53	30760	-10855
Remove Temporary Thrie Beam Rail	-1963	15.67	-5.53	-30760	10855
Guard Railing in Median	653	14.89	-6.22	9729	-4064
Median	1419	13.44	-4.86	19067	-6895
Remove Balance Weights from Toe Floorbeam	-485	36.19	-2.09	-17552	1014
EAST GIRDER TOTAL	181184			11142	-5658
WEST GIRDER					
COUNTERWEIGHT	94621	-10.327	1.774	-977151	167858
GIRDER 3	19652	9.97	0.87	195930	17097
FLOORBEAM 4	3817	6.51	-0.64	24849	-2443
FLOORBEAM 5	2421	21.26	-1.89	51470	-4576
FLOORBEAM 6	2064	36.00	-2.11	74304	-4355
COUNTERWEIGHT BRACKETS	717	-11.45	-1.72	-8210	-1233
UPPER LEVEL CROSS BRACING	2320	12.13	-1.94	28142	-4501
LOWER LEVEL CROSS BRACING	1039	-1.49	5.68	-1548	5902
STRINGERS	14123	9.90	-2.86	139818	-40392
RDWY. GRID DECK	23736	6.49	-4.21	154047	-99929
MACHINERY FLOOR	3206	-0.46	1.33	-1475	4264
MACHINERY	4598	1.02	0.17	4690	782
WEST GIRDER SUBTOTAL	172314			-315134	38474
BALANCE WEIGHTS					
Balance Weights on Toe Floorbeam	1925	36.19	-2.09	69666	-4023
7.53' Long x Full Width Concrete Fill in Grid Deck	6917	34.20	-4.16	236561	-28775
No Concrete Fill in Openings for Railing Posts	-68	35.75	-4.16	-2431	283
Temporary Thrie Beam Rail	796	15.67	-5.53	12473	-4402
Remove Temporary Thrie Beam Rail	-796	15.67	-5.53	-12473	4402
Guard Railing in Median	1612	14.89	-6.22	23997	-10024
Median	3499	13.44	-4.86	47031	-17007
Remove Balance Weights from Toe Floorbeam	-1000	36.19	-2.09	-36190	2090
WEST GIRDER TOTAL	185199			23500	-18982
SOUTH MIDDLE LEAF TOTAL	366383			34643	-24640

Toe reaction (lb) = **912**
phi angle (deg.) = **35**

SIGN CONVENTION : X - ARM => TOWARDS TOE +VE ; TOWARDS HEEL -VE
(leaf in closed position) Y - ARM => BELOW PINION +VE ; ABOVE PINION -VE

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PAGE (D)

JOB 2150 BEADES BRIDGE - PHASE II
SHEET NO. ______ OF ______
CALCULATED BY DA / FP DATE 10/02
CHECKED BY AP DATE 10/02

PH II B - WITH MEDIAN & MED. RAIL

NORTH MIDDLE LEAF (PHASE II) - BALANCE CALCULATION SUMMARY
(INCLUDING BALANCE WEIGHTS)

COMPONENT	WEIGHT (lbs)	X ARM (ft.)	Y ARM (ft.)	X MOMENT (ft-lbs)	Y MOMENT (ft-lbs)
EAST GIRDER					
COUNTERWEIGHT	94621	-10.327	1.774	-977151	167858
GIRDER 10	17894	10.50	0.83	187887	14852
FLOORBEAM 13	1946	36.00	-1.86	70056	-3620
FLOORBEAM 14	2443	21.26	-1.89	51938	-4617
FLOORBEAM 15	3761	6.51	-0.64	24484	-2407
COUNTERWEIGHT BRACKETS	756	-11.45	-1.72	-8656	-1300
UPPER LEVEL CROSS BRACING	2327	12.13	-1.94	28227	-4514
LOWER LEVEL CROSS BRACING	1111	-1.65	5.66	-1833	6288
STRINGERS	13639	9.90	-2.86	135026	-39008
RDWY. GRID DECK	23736	6.49	-4.21	154047	-99929
MACHINERY FLOORBEAMS	3014	-0.46	1.33	-1386	4009
MACHINERY	4598	1.02	0.17	4690	782
EAST GIRDER SUBTOTAL	169846			-332672	38394
BALANCE WEIGHTS					
Balance Weights on Toe Floorbeam	2597	36.19	-1.79	93985	-4649
7.53' Long x Full Width Concrete Fill in Grid Deck	6917	34.20	-4.16	236561	-28775
No Concrete Fill in Openings for Railing Posts	-28	35.75	-4.16	-1001	116
Temporary Thrie Beam Rail	1963	15.67	-5.53	30760	-10855
Remove Temporary Thrie Beam Rail	-1963	15.67	-5.53	-30760	10855
Guard Railing in Median	653	14.89	-6.22	9729	-4064
Median	1419	13.44	-4.86	19067	-6895
Remove Balance Weights from Toe Floorbeam	-545	36.19	-1.79	-19724	976
EAST GIRDER TOTAL	180859			5945	-4896

COMPONENT	WEIGHT (lbs)	X ARM (ft.)	Y ARM (ft.)	X MOMENT (ft-lbs)	Y MOMENT (ft-lbs)
WEST GIRDER					
COUNTERWEIGHT	94621	-10.327	1.774	-977151	167858
GIRDER 9	20319	10.88	0.76	221071	15442
FLOORBEAM 13	1948	36.00	-1.86	70128	-3623
FLOORBEAM 14	2421	21.26	-1.89	51470	-4576
FLOORBEAM 15	3817	6.51	-0.64	24849	-2443
COUNTERWEIGHT BRACKETS	717	-11.45	-1.72	-8210	-1233
UPPER LEVEL CROSS BRACING	2320	12.13	-1.94	28142	-4501
LOWER LEVEL CROSS BRACING	1039	-1.65	5.66	-1714	5881
STRINGERS	14123	9.90	-2.86	139818	-40392
RDWY. GRID DECK	23736	6.49	-4.21	154047	-99929
MACHINERY FLOORBEAMS	3206	-0.46	1.33	-1475	4264
MACHINERY	4598	1.02	0.17	4690	782
WEST GIRDER SUBTOTAL	172865			-294336	37530
BALANCE WEIGHTS					
Balance Weights on Toe Floorbeam	1528	36.19	-1.79	55298	-2735
7.53' Long x Full Width Concrete Fill in Grid Deck	6917	34.20	-4.16	236561	-28775
No Concrete Fill in Openings for Railing Posts	-68	35.75	-4.16	-2431	283
Temporary Thrie Beam Rail	796	15.67	-5.53	12473	-4402
Remove Temporary Thrie Beam Rail	-796	15.67	-5.53	-12473	4402
Guard Railing in Median	1612	14.89	-6.22	23997	-10024
Median	3499	13.44	-4.86	47031	-17007
Remove Balance Weights from Toe Floorbeam	-940	36.19	-1.79	-34019	1683
WEST GIRDER TOTAL	185413			32102	-19045
NORTH MIDDLE LEAF TOTAL	366272			38048	-23942

Toe reaction (lb) = **1001**
phi angle (deg.) = **32**

SIGN CONVENTION : X - ARM => TOWARDS TOE +VE ; TOWARDS HEEL -VE
(leaf in closed position) Y - ARM => BELOW PINION +VE ; ABOVE PINION -VE

A

PROJECT BEADES BRIDGE
SHEET NO 1 OF 92
CALC. BY AP DATE 1/03
CHECK BY DA DATE 1/03

SOUTHEAST LEAF (PHASE 3) - BALANCE CALCULATION SUMMARY (INCLUDING BALANCE BLOCKS)

COMPONENT	WEIGHT (lbs)	X ARM (ft.)	Y ARM (ft.)	X MOMENT (ft-lbs)	Y MOMENT (ft-lbs)
EAST GIRDER					
COUNTERWEIGHT	52715	-9.68	1.74	-510281	91724
GIRDER 6	16235	8.84	0.47	143517	7630
FLOORBEAM 7 & BRACKETS	2755	6.50	-0.59	17908	-1625
FLOORBEAM 8 & BRACKETS	1764	21.25	-1.94	37485	-3422
FLOORBEAM 9 & BRACKETS	1540	36.02	-2.20	55453	-3387
CWT BRACKET	856	-11.54	-1.48	-9878	-1267
UPPER LEVEL CROSS BRACING	1760	12.77	-1.55	22475	-2728
LOWER LEVEL CROSS BRACING	617	-1.76	5.59	-1086	3449
STRINGERS	8156	15.18	-3.04	123808	-24794
SIDEWALK FRAMING	7996	12.82	-4.59	102509	-36702
RDWY. GRID DECK	8251	6.63	-4.21	54704	-34737
SDWK. GRID DECK	10619	12.65	-5.26	134330	-55856
FASCIA GIRDER	10341	16.69	-2.85	172591	-29472
MACHINERY FRAMING	3315	-1.97	2.72	-6531	9017
MACHINERY	2841	-2.39	-0.58	-6790	-1648
EAST GIRDER SUBTOTAL	129761			330215	-83817
BALANCE BLOCKS					
A : Bot (triangular area) steel on back of cwt.	7082	-12.65	2.38	-89581	16854
B : 3" thick steel area behind triangular area	2818	-13.00	3.01	-36628	8481
C : 19" wide steel plates above triangular area	1859	-13.00	0.92	-24167	1710
D : 3'8" h steel plates in front of cwt	2149	-7.06	5.77	-15168	12397
EAST GIRDER TOTAL	143667			164671	-44375
WEST GIRDER					
COUNTERWEIGHT	52715	-9.68	1.74	-510281	91724
GIRDER 5	16381	8.98	0.48	147101	7863
FLOORBEAM 7 & BRACKETS	2296	6.50	-0.59	14924	-1355
FLOORBEAM 8 & BRACKETS	1671	21.25	-1.94	35509	-3242
FLOORBEAM 9 & BRACKETS	1425	36.02	-2.20	51310	-3134
CWT BRACKET	890	-11.54	-1.48	-10271	-1317
UPPER LEVEL CROSS BRACING	1765	12.77	-1.55	22539	-2736
LOWER LEVEL CROSS BRACING	617	-1.76	5.59	-1086	3449
STRINGERS	9503	15.18	-3.04	144256	-28889
SIDEWALK FRAMING	295	12.82	-4.59	3782	-1354
RDWY. GRID DECK	16399	6.63	-4.21	108725	-69040
SDWK. GRID DECK	173	12.65	-5.26	2188	-910
FASCIA GIRDER	0	16.69	-2.85	0	0
MACHINERY FRAMING	3568	-1.97	2.72	-7029	9705
MACHINERY	3158	-2.39	-0.58	-7548	-1832
WEST GIRDER SUBTOTAL	110856			-5879	-1067
BALANCE BLOCKS					
A : Bot (triangular area) steel on back of cwt.	7082	-12.65	2.38	-89581	16854
B : 3" thick steel area behind triangular area.	2818	-13.00	3.01	-36628	8481
C : 19" wide steel plates above triangular area	1859	-13.00	0.92	-24167	1710
D : 3'8" h steel plates in front of cwt	2149	-7.06	5.77	-15168	12397
E: 8 balance blocks on 1st web panel of girder	1198	32.98	-1.81	39510	-2168
WEST GIRDER TOTAL	125960			-131913	36207
SOUTH EAST LEAF TOTAL	269627			32757	-8169

Toe reaction (lb) = **862**
phi angle (deg.) = **14.0**

SIGN CONVENTION : X - ARM => TOWARDS TOE +VE ; TOWARDS HEEL -VE
(leaf in closed position) Y - ARM => BELOW PINION +VE ; ABOVE PINION -VE

(B)

PROJECT BEADES BRIDGE
SHEET NO 2 OF 92
CALC. BY AP DATE 1/03
CHECK BY DA DATE 1/03

NORTHEAST LEAF (PHASE 3) - BALANCE CALCULATION SUMMARY (INCLUDING BALANCE BLOCKS)

COMPONENT	WEIGHT (lbs)	X ARM (ft.)	Y ARM (ft.)	X MOMENT (ft-lbs)	Y MOMENT (ft-lbs)
EAST GIRDER					
COUNTERWEIGHT	53225	-9.70	1.73	-516283	92079
GIRDER 12	17226	10.66	0.27	183629	4651
FLOORBEAM 18 & BRACKETS	2755	6.50	-0.59	17908	-1625
FLOORBEAM 17 & BRACKETS	1764	21.25	-1.94	37485	-3422
FLOORBEAM 16 & BRACKETS	1548	36.02	-1.98	55759	-3065
CWT BRACKET	856	-11.54	-1.48	-9878	-1267
UPPER LEVEL CROSS BRACING	1765	12.84	-1.55	22663	-2736
LOWER LEVEL CROSS BRACING	617	-1.76	5.59	-1086	3449
STRINGERS	8049	14.98	-3.04	120574	-24469
SIDEWALK FRAMING	7996	12.82	-4.59	102509	-36702
RDWY. GRID DECK	8251	6.63	-4.21	54704	-34737
SDWK. GRID DECK	10619	12.65	-5.26	134330	-55856
FASCIA GIRDER	10341	16.69	-2.85	172591	-29472
MACHINERY FLOOR	3315	-1.97	2.72	-6531	9017
MACHINERY	2841	-2.39	-0.58	-6790	-1648
EAST GIRDER SUBTOTAL	131168			361585	-85802
BALANCE BLOCKS					
A : Bot (triangular area) steel on back of cwt.	7082	-12.65	2.38	-89581	16854
B : 3" thick steel area behind triangular area	2818	-13.00	3.01	-36628	8481
C : 19" wide steel plates above triangular area	4461	-13.00	0.63	-57993	2810
D : 3'8" h steel plates in front of cwt	2149	-7.06	5.77	-15168	12397
EAST GIRDER TOTAL	147677			162215	-45260
WEST GIRDER					
COUNTERWEIGHT	53225	-9.70	1.73	-516283	92079
GIRDER 11	17513	10.73	0.27	187914	4729
FLOORBEAM 18 & BRACKETS	2296	6.50	-0.59	14924	-1355
FLOORBEAM 17 & BRACKETS	1671	21.25	-1.94	35509	-3242
FLOORBEAM 16 & BRACKETS	1496	36.02	-1.98	53886	-2962
CWT BRACKET	890	-11.54	-1.48	-10271	-1317
UPPER LEVEL CROSS BRACING	1770	12.84	-1.55	22727	-2744
LOWER LEVEL CROSS BRACING	617	-1.76	5.59	-1086	3449
STRINGERS	9456	14.98	-3.04	141651	-28746
SIDEWALK FRAMING	295	12.82	-4.59	3782	-1354
RDWY. GRID DECK	16399	6.63	-4.21	108725	-69040
SDWK. GRID DECK	173	12.65	-5.26	2188	-910
FASCIA GIRDER	0	16.69	-2.85	0	0
MACHINERY FLOOR	3568	-1.97	2.72	-7029	9705
MACHINERY	3158	-2.39	-0.58	-7548	-1832
WEST GIRDER SUBTOTAL	112527			29091	-3539
BALANCE BLOCKS					
A : Bot (triangular area) steel on back of cwt.	7082	-12.65	2.38	-89581	16854
B : 3" thick steel area behind triangular area	2818	-13.00	3.01	-36628	8481
C : 19" wide steel plates above triangular area	4461	-13.00	0.63	-57993	2810
D : 3'8" h steel plates in front of cwt	2149	-7.06	5.77	-15168	12397
E: 8 balance blocks on 1st web panel of girder	1198	32.98	-1.81	39510	-2168
WEST GIRDER TOTAL	130234			-130769	34834
NORTH EAST LEAF TOTAL	277910			31446	-10426

Toe reaction (lb) = **828**
phi angle (deg.) = **18.3**

SIGN CONVENTION : X - ARM => TOWARDS TOE +VE ; TOWARDS HEEL -VE
(leaf in closed position) Y - ARM => BELOW PINION +VE ; ABOVE PINION -VE

BEADES | 2150
CALC. By: AP 02/03
CHECKED By: DA 02/03
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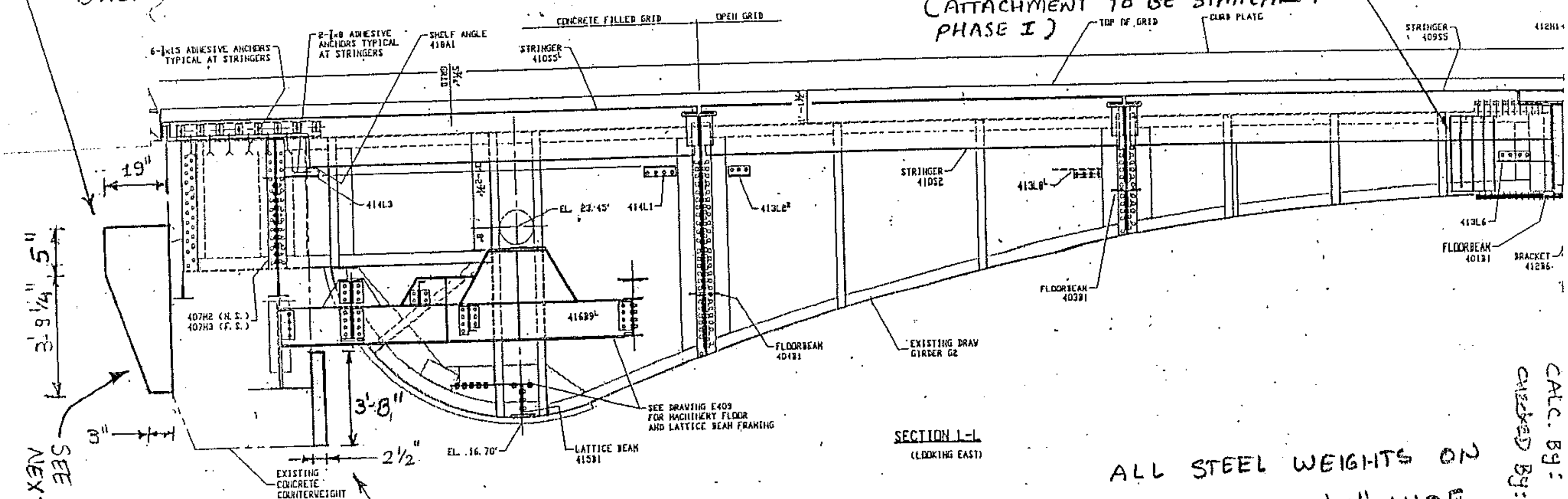
REFERENCE PAGE

TOTAL WEIGHT REQUIRED = 29008 #

8 STEEL BLOCKS 4"x4"x 33"
4 ON EACH FACE OF WEB
(WEST GIRDER ONLY)
WT. = 1198 #
(ATTACHMENT TO BE SIMILAR TO PHASE I)

TOTAL STEEL WT. ON BACK OF CWT = 23516 #



SEE PG. AFTER NEXT FOR PL SIZES

TOTAL STEEL WT. ON FRONT OF CWT = 4297 #

ALL STEEL WEIGHTS ON CWT ARE 11'-6" WIDE.

SOUTH EAST LEAF

BEADES 2150
CALC. BY: AP 02/03
CHECKED BY: DA 02/03
~~92 OF 93~~

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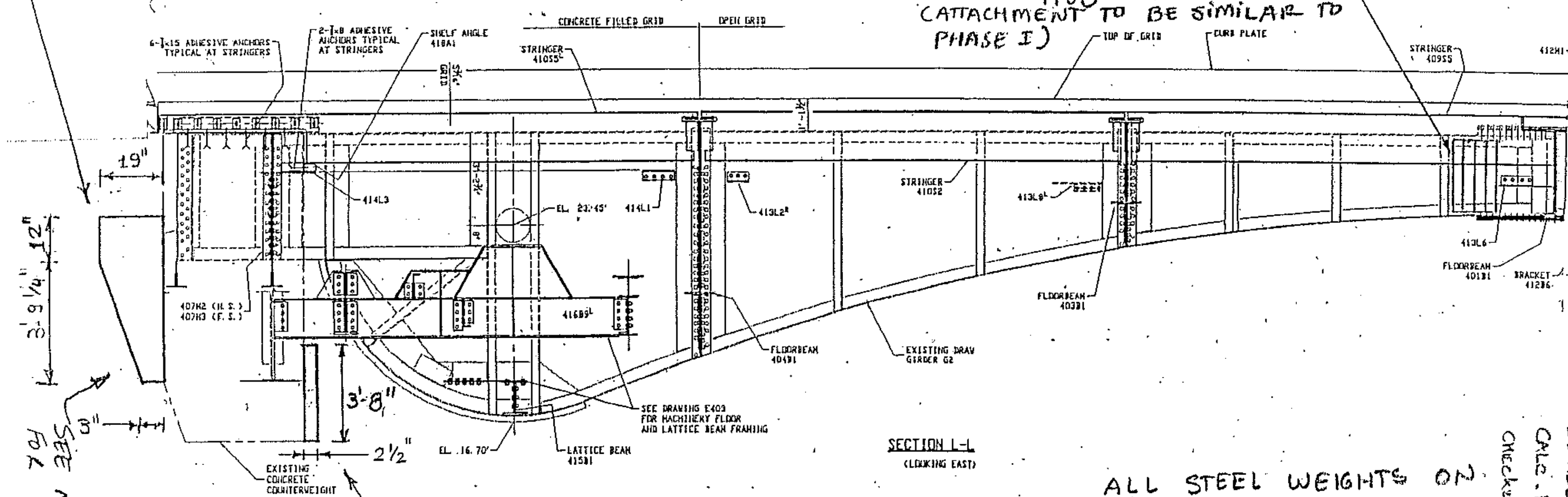
4 OF 15

TOTAL WEIGHT REQUIRED = 34213 #

8 STEEL BLOCKS 4"x4"x 33"
4 ON EACH FACE OF WEB
(WEST GIRDER ONLY)
WT. = 1198 #
(ATTACHMENT TO BE SIMILAR TO PHASE I)

TOTAL STEEL WT. ON BACK OF CWT = 28720 #.



SECTION L-L
(LOOKING EAST)

SEE NEXT PG. FOR PL SIZES

ALL STEEL WEIGHTS ON CWT ARE 11'-6" WIDE.

TOTAL STEEL WT. ON FRONT OF CWT = 4297 #

NORTH EAST LEAF