Public Works and Government Services Canada
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Public Works and Government Services Canada
Ontario Region

PWGSC Project No.: R.013514.030

BURLINGTON LIFT BRIDGE, TOWERS, AND PIERS - STRUCTURAL MODELLING, ANALYSIS and SURVEYS

PHASE II
RS6: 3D MODELLING and STRUCTURAL ANALYSIS REPORT

FINAL

MMM GROUP

MMM Group Limited
April 2014

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APPENDICES

1. INTRODUCTION

MMM Group Ltd. (MMM) was retained by Public Works and Government Services Canada (PWGSC) to undertake a structural analysis including a three-dimensional frame model, evaluation of member capacities, and a fatigue review for the Burlington Lift Bridge.

This report presents the results of the structural analysis and three-dimensional modelling of the bridge as per section RS6 of the Terms of Reference. Member demands are reported in a tabular format.

This report should be read in conjunction with a separate report by MMM Group titled RS7: Member Capacities, April 2014, which presents the results for the member capacities compared to demands including capacity over demand (C/D) ratios.

A Key Plan showing the location of the structure and a General Arrangement drawing have been provided in Appendix A.

2. EXISTING STRUCTURE

2.1 Structure Description

Owned and operated by Public Works and Government Services Canada (PWGSC), the Burlington Lift Bridge is located between the cities of Burlington and Hamilton, Ontario on Eastport Drive spanning the Burlington Canal, which provides the only navigational opening into the Hamilton Harbour. The majority of traffic crosses the canal via the provincially owned Queen Elizabeth Way (QEW) James N. Allan Skyway; however, the lift bridge provides the only alternate vehicle crossing and is the only crossing available to pedestrians and cyclists. For the purposes of this report, the bridge is considered to run in the north-south direction.

The Burlington Lift Bridge is a tower-drive steel truss vertical lift bridge designed in 1958 by C.C. Parker and Associates of Hamilton, Ontario and constructed between 1959 and 1960 by the Hamilton Bridge Division of the Bridge and Tank Company of Canada Limited. The bridge, as originally constructed, served both rail and highway traffic in a side-by-side configuration. The railway corridor ran along the eastern half of the structure and the highway corridor ran along the western half of the structure. In 1982 the bridge underwent a major rehabilitation to convert it to a highway traffic only structure through the complete removal of the railway corridor and the addition of two new lanes of traffic. Despite the removal of the railway corridor, the following report shall refer to the east truss as the “railway truss” and the west truss as the “highway truss”.

The bridge is comprised of two 12.60m (41’-4”) approach spans, two 9.75m (32’-0”) tower spans, and one 112.78m (370’-0”) lift span. There is a 2.07m (6’-9.5”) wide sidewalk with an aluminum pedestrian hand railing cantilevered from the outside of the highway truss. Two 3.375m wide northbound lanes and two 3.375m wide southbound lanes are provided on the bridge. A steel box beam barrier is located on either side of the roadway. A navigational clearance of approximately 36.58m (120’-0”) is provided at high water level.

The substructure is comprised of two concrete tower piers supporting the towers, and two concrete conventional closed abutments at each end of the approach spans.

2.1.1 Lift Span

The lift span is a steel through truss structure that is 15.54m (51’-0”) wide from centreline to centreline of the trusses with a vertical lift of 34.12m (111’-11”). Each truss is comprised of twelve 9.40m (30’-10”) panels which vary in depth from 13.87m (45’-6”) at the ends to 16.76m (55’-0”) at the midspan.

Truss members (i.e. verticals, diagonals, and top and bottom chords) are comprised of built-up steel sections. Transverse floor beams and longitudinal stringers support an open steel grating deck. The sidewalk deck consists of a thin (50mm) concrete filled steel grating.

Portal and sway bracings are provided overhead at panel points.

In the fully closed position (i.e. open to highway traffic), support for the structure is provided at all four corners from below. Articulation is provided by two fixed supports (bearings) at the south end and two expansion rocker-type supports at the north end. One centring shoe is provided at each end of the lift span.

In any open position (i.e. raised to allow marine traffic), support for the structure is provided at all four corners by wire ropes attached to lifting girders at the ends of the lift span. The wire ropes then pass over sheaves at the top of each tower and are connected to a counterweight. Guide rollers are also provided at all eight corners of the structure and run along tracks on the front columns of the towers.

2.1.2 Towers

There are two steel braced towers at either end of the lift span. Each tower is 15.90m (52’-2”) wide from centreline to centreline of the columns, 9.75m (32’-0”) long from centreline to centreline of the columns, and is approximately 65m (213’) tall.

Tower members (i.e. columns, diagonal bracings, horizontals, etc.) are comprised of built-up steel sections. The roadway passing through the towers is referred to as the “tower span” and is comprised of transverse floor beams and longitudinal stringers supporting a 190mm (7.5”) concrete deck with a 65mm (2.5”) asphalt wearing surface.

There is a 2.47m (8’-1”) wide sidewalk with an aluminum pedestrian hand railing cantilevered from the west side of the tower.

Each tower is supported on a concrete tower pier substructure.

At the top of each tower is a machine room which houses the required mechanical and electrical equipment necessary to raise and lower the lift span. Wire ropes connected to each end of the lift span pass over the sheaves and are connected to a counterweight (on each tower) which balances the weight of the lift span.

2.1.3 Approach Spans

There are two approach spans at either end of the bridge. Each is 15.90m (52’-2”) wide and 12.60m (41’-4”) in length.

Transverse floor beams and longitudinal stringers support a 190mm (7.5”) concrete deck with a 65mm (2.5”) asphalt wearing surface. There is a 2.47m (8’-1”) wide sidewalk with an aluminum pedestrian hand railing cantilevered from the west side of the approach spans.

Each approach span is simply supported by the tower piers at one end and a concrete conventional closed abutment at the other. Articulation is provided by fixed bearings at the concrete abutments, and expansion bearings at the tower piers.

3. ANALYSIS ASSUMPTIONS

3.1 General Assumptions

The Burlington Lift Bridge was designed circa 1958 using the American Railway Engineering Association (AREA) “Part 2” 1956 for all movable components and structural components which support movable components, Canadian Standards Association (CSA) S1-1950 Specifications for Steel Railway Bridges, and CSA S6-1952 Specifications for Steel Highway Bridges. Coopers E-60 and H20-S16 design live loads were used for railway and highway components respectively.

The bridge was analyzed in accordance with the Canadian Highway Bridge Design Code (CHBDC) CAN/CSA-S6-06 including Supplement No. 3 (March 2013) using Section 5 Methods of Analysis along with Section 3 Loads and Section 13 Movable Bridges.

Gross section properties were used in the analysis for all members, as provided on the 1959/1960 fabrication/erection drawings. Further discussion is provided in the MMM Group report titled RS7: Member Capacities, April 2014.

For all steel, the following material properties were input into the software:

- Young’s Modulus, E = 200GPa;
- Density of Steel, γ_s = 77 kN/m^3; and
- Coefficient of thermal expansion, α_s = 11.7x10^{-6}/K.

For further discussion of the material properties used in the model, refer to the MMM Group report titled RS7: Member Capacities, April 2014.

4. LOADING

4.1 General

For the analysis of the Burlington Lift Bridge, two loading scenarios were considered:

1. Bridge fully closed (i.e. lift span seated on bearings in locked position); and
2. Bridge fully raised (i.e. lift span at the top of its vertical range of movement).

As given by Section 13 of the CHBDC, when the bridge is in the fully closed position all loading requirements and load combinations relating to fixed bridges in Section 3 shall apply. When the bridge is in the fully raised position, only those specific loads and load combinations identified in Section 13 shall apply.

Refer to Appendix C for detailed design load calculations.

4.2 Permanent Loads

Calculated section properties, based on the 1959/1960 fabrication/erection drawings, permitted the analysis software to automatically calculate self-weight for all steel members.

A steel density of 77kN/m^3, in accordance with the CHBDC, was used for all main and auxiliary steel members. The concrete density used for the sidewalk, tower span deck, and approach span deck was 23.5kN/m^3, in accordance with the CHBDC. The lift span open grating steel deck was assumed to be 0.96kN/m^2 as provided by the manufacturer.

Self-weights for typical single and double latticed members were a by hand and the additional weight of the lacing bars was determined. This additional load was applied to all similar members.

The dead loads due to the barriers and sidewalk were applied as point loads to the bottom chords at panel point locations.

The lift span dead load in the model was increased to calibrate it with its actual measured weight, as identified in a letter to PWGSC titled Weighing the Bridge dated May 12, 2004. This approach is consistent with past practices when accounting for the additional weight of rivets, bolts, and gusset plates. This same factor was applied to all other steel in the towers and approach spans.

A small imbalance exists between the weight of the lift span and the weight of the two counterweights.

In a letter to PWGSC dated March 21, 2000 it was indicated that the structure is slightly span-heavy. This imbalance between the weight of the lift span and the combined weight of the two counterweights, in addition to the known weight of the lift span, permitted the calculation of the approximate weight of each counterweight.

An additional dead load was applied as point loads at the top of each tower to account for the sheaves, platforms, equipment, floor, roof, and live load within the machine house.

4.3 Transitory Loads

4.3.1 Live Loads

Four lanes were considered for live loading. We believe this scenario of loading is somewhat conservative: In our opinion, given the proximity of the trusses to the edges of the outside lanes, there is a low probability of four large trucks occupying the bridge simultaneously. This was used in conformance with Section 3 of the CHBDC.

The CL-625-ONT Truck Load and the CL-625-ONT Lane Load were used for the live load analysis, as given by Clause 3.8.3 of the CHBDC. Truck wheel loads were positioned directly over stringers to obtain their maximum load effects. As there is little torsional/plate stiffness in the open steel grating, the evaluation assumed no lateral distribution of live load through the grating. This slight conservative assumption increases the force effects in the stringers and floor beams only with a minimal effect on the trusses.

During the analysis, the design truck was moved longitudinally along each lane in 1.0m increments to generate force envelopes for each member. Eight unique load cases were considered for both truck and lane loading and are presented in Table 4-1 below.

Table 4-1: Live Load Cases

	Lanes Loaded			
Load Case No.	Lane 1	Lane 2	Lane 3	Lane 4
1	Yes			
2	Yes	Yes		
3	Yes	Yes	Yes	
4	Yes	Yes	Yes	Yes
5		Yes	Yes	Yes
6			Yes	Yes
7				Yes
8	Yes			Yes

The minimum sidewalk live load of 1.6kPa was considered as given by Clause 3.8.9 in the CHBDC.

4.3.2 Temperature Loads

Temperature effects were considered for truss components. A thermal gradient of 10°C was applied in two scenarios. The first load case is when the bottom chords are cooler than the top chords due to their proximity to the water and the second load case is when the east truss is warmer than the west truss due to morning warming effects from the sun.

4.3.3 Wind Loads

Design wind loads were applied to the lift span and towers. Given the span of less than 125m, an hourly mean reference wind pressure corresponding to a return period of 50 years was chosen as given by Clause 3.10.1.2 of the CHBDC. The hourly mean reference wind pressure used corresponded to the City of Burlington, Ontario as provided in Table A3.1.1 of the CHBDC, which represents hourly mean velocities recorded at the standard anemometer height of 10.0m above ground. A gust coefficient was given by Clause 3.10.1.3 of the CHBDC. An exposure coefficient was given by Clause 3.10.1.4 of the CHBDC based on the height from the water level to the mid-depth of the trusses. Two different wind exposure coefficients were calculated for the lift span; one for the fully closed position and one for the fully raised position. A horizontal wind drag coefficient of 2.0 was used, as given by Clause 3.10.2.2, which accounts for the suction force applied to the back face of a member.

Horizontal drag was applied to both the windward and leeward trusses of the lift span, as it was assumed that there was no significant shielding. Vertical drag was applied to the lift span deck. Given the open grating, the floor plan area was assumed to be 85% of a solid deck as given by Clause 13.7.3.5 of the CHBDC. For truss members, the horizontal drag forces were distributed along the members as a uniformly distributed load, as a function of member width.

A horizontal drag load was applied to live load, in the fully closed position, assuming the entire length of the lift span and a vehicle height of 3.0m. This load was distributed along the length of the east bottom chord.

Similar to the lift span, horizontal wind loads were applied to the columns, horizontals, diagonal members, and machine house and elevator shaft cladding in the towers. The wind exposure coefficient was calculated from the top of the towers down in three steps rather than as a variable to simplify the analysis. Wind was applied at both right angles to the towers as well as on an oblique line at 45°. Shielding was not considered in the towers. These calculated wind loads were compared to the wind pressures specified in Clause 13.7.3.10 of the CHBDC (1.5kPa) and were found to be greater; therefore, the calculated wind loads were used.

In determining wind loads, PWGSC provided MMM with a maximum operating wind velocity of 80km/h for comparison to the design wind loading used in the model. The maximum operating wind velocity is the maximum velocity, based upon readings taken on-site, at which the lift span will be raised.

As given by CAN/CSA S6-06 Commentary PP 99, the following equation was used to convert the provided wind velocity to wind pressure:

$$q = 0.05v^2 = 0.05 \times (80)^2 = 320Pa = 0.32kPa \quad (1)$$

where $v =$ wind velocity in km/h and an air density of 1.29kg/m^3 has been assumed and incorporated.

For the purposes of comparison, the provided maximum operating wind velocity is measured by on-site by an anemometer located near the top of the operator's house, approximately 16m above ground. It is our opinion that any amplification due to exposure would be minimal between this height and the fully open height.

Furthermore, the provided maximum operating wind velocity is measured in real-time by the anemometer on-site and provides wind velocities including gusts; therefore, no amplification related to gusts is required. On the contrary, the hourly wind reference pressures used when calculating the design wind have been averaged and do not account for wind gusts.

Finally, for the purposes of comparison only, the horizontal drag coefficient will not be used when calculating the design wind load. The reasoning for this is the 80km/h maximum operating wind velocity likely accounts for a load applied to *one face only* of a member, not accounting for any horizontal drag/suction applied to a back face.

Based on the above assumptions, the unfactored design wind loading used for the purposes of comparison is approximately four (4) times the maximum operating wind velocity. Nevertheless, even if gust and exposure coefficients were applied to the 80km/h maximum operating wind velocity, the unfactored design wind loading is calculated to be 1.4 times the maximum operating wind velocity.

4.4 Exceptional Loads

The only exceptional load considered was ice accretion. As given by Clause 3.12.6.2 of the CHBDC, ice accretion was assumed to consist of a 31mm radial build-up on all surfaces of all members, including the inside surfaces of built-up members without solid plates. The weight of ice was assumed to be $9.8kN/m^3$.

Ice accretion was only considered for the fully closed position. The operational season is typically during months where ice accretion is not expected. Moreover, if a build-up of ice were to form on the lift span surfaces, it is unlikely the mechanical and electrical equipment used to raise the span would be able to overcome this additional load.

4.5 Vertical Lift Bridges - Special Loads

An operating impact load consisting of 20% of the lift span dead load was evenly distributed as a point load to each of the sheave girders in the towers, as given by Clause 13.7.10.2 of the CHBDC.

4.6 Load Combinations - Fully Closed Position (Lowered)

The above loads were combined as applicable for the calculation of ultimate limit states ULS1, ULS2, ULS3, ULS4, and ULS7 as given by Clause 3.5.1 of the CHBDC to determine the demands on each member. Serviceability limit states were not assessed as they are related to vibration of the structure. Given the substantial depth of the truss, the light pedestrian volumes, and the original design as a rail carrying structure, low deflections were obtained.

4.7 Load Combinations - Fully Open Position (Raised)

The above loads were combined as applicable for the calculation of ultimate limit states ULSV1, ULSV2, and ULSV3 as given by Clause 13.7.10.2 of the CHBDC to determine the demands on each member.

4.8 Fatigue

To assess the fatigue limit state, FLS1 as given by Clause 3.5.1 of the CHBDC, a single truck load was placed in a single lane down the centre of the bridge and combined with dead loads to determine the demands on each member. Further discussion on fatigue is provided in the MMM Group report titled RS8: Fatigue Study, April 2014.

5. ANALYSIS/MODELLING

A three-dimensional frame analysis model was created and analyzed using S-Frame Version 11 for both the fully closed and open positions. Each model is comprised of the north and south approach spans, north and south towers, and the lift span. The models are provided under separate cover.

Globally, the X-axis is along the longitudinal axis of the bridge, increase from south to north. The global Y-axis is along the transverse axis of the bridge, increasing from east to west. The global Z-axis represents the vertical axis of the bridge, increasing in the direction opposite of gravity. Locally, the x-axis represents the axial direction along a member. The local y-axis always corresponds with the horizontal plane of a member of the transverse axis of the bridge. The local z-axis always corresponds with the vertical axis of a member or the longitudinal axis of the bridge.

All member types have been modelled as beam elements. Where intermediate nodes split one physical member into several constituent analytical members, a new feature in the software was used to convert the analytical members into a single physical member.

In total, the models each contain approximately 1093 nodes and 1174 physical members consisting of 120 unique sections. All members have been numbered according to groups based on member type/location. All unique sections have been named based on span, element, and sub element. For example, LIFT-RLYT-L0U0 refers to the lift span, railway truss, member L0U0. Refer to Appendix B for details of the member numbering system and section naming conventions.

All main truss and tower members have been named in accordance with the original 1958 design drawings. Refer to Appendix A for drawings containing the naming conventions.

The majority of member end releases are all pin-pin, which indicates that moments about the local y-axis and z-axis have been released. Please note that every node is rigidly attached to at least one member, to avoid creating a “mechanism” and subsequent model instability. For diagrams of all member end releases, refer to Appendix B.

All spans have had support conditions applied that reflect what is physically present. The approach spans at the abutments have been released for rotation about the global Y-axis and translation about the global X-axis, and fixed in all other degrees of freedom. The tower supports at the base of each column have been released for moments about the global X-axis and Y-axis only, and fixed about all other degrees of freedom. Please see the following section for further discussion regarding modelling and results of the tower support conditions.

In the fully closed position, the lift span is simply supported at the lower four corners with translation fixed in the upper four corners along the global Y-axis, to simulate the effects of the guide rollers.

In the raised position, vertical support is provided at the top four corners to simulate the support provided by the wire ropes. Translational degrees of freedom are restricted to model the guide rollers. For diagrams of the support conditions, refer to Appendix B.

The top and bottom chords of the lift span were modelled as continuous members between every other panel point, in accordance with what is shown on the original design drawings and what is physically present (e.g. L0L2, L2L4, L4L6, etc.). Further discussion of this modelling approach is provided in the following section.

6. RESULTS

Results were obtained through the use of a linear elastic analysis type for both static and moving loads.

While performing quality control on the analysis results, it was observed that the top and bottom lateral bracings of the lift span and the lateral bracing of the tower span were developing forces under dead load. Due to the probable construction sequence and our understanding of the original design methodology, we modified the analysis as follows:

1. The dead load cases were analyzed with the area of the above noted bracings greatly reduced (so as not to attract significant load);

2. The remaining load cases were analyzed with the full area of the above noted bracings reinstated; and

3. The results of the two methods were superimposed on one another.

For the lift span truss members, the dead load results were compared to the stresses identified on the original 1958 design drawings. The results were found agree within 5%.

When modelling the structure using continuous top/bottom chords between every other panel point (as described in the previous section), bending moment was developed in addition to that from self-weight. MMM reviewed a version of the model without continuous top and bottom chords (i.e. all members are pin connected) and made the following observations:

- Axial force for top/bottom chords increased by 2-5% while moments decreased by 20%;
- Axial force for diagonals increased by 3% while moments remained unchanged; and
- Axial force and moments for vertical remained unchanged.

Further discussion of the moments is provided in the report by MMM Group titled RS7: Member Capacities.

For the towers, adding “torsional support” was investigated (i.e. restricting bending about the global Y axis) at the tower support locations. It was observed that deflections at the top of the towers were reduced by approximately 13% and moments were generated at the base of the towers (approximately 1430kN.m on the front columns and 790kN.m on the rear columns). MMM has reviewed the foundation/column base connection and is of the opinion that the actual connection is somewhere between fully fixed and fully pinned. Our evaluation/analysis has assumed the fully pinned connection which is conservative for deflections and forces in the bracing. We have also reviewed the column capacity for the fully fixed connection and have found this to be satisfactory.

As part of quality control, an approximate analysis of the dead load deflection for the lift span at mid-span under dead load and live loads (two lane loads) and at the top of the towers with the lift span in the fully closed position under longitudinal wind loading (i.e. wind blowing along the centreline of the roadway) was completed. The calculated deflections were compared to output from the S-Frame model and were found to be in agreement after making an allowance for additional 20%-30% web stiffening. This approximate check verifies the general validity of the model. It is also noted that the dead load forces in the lift span were compared to the dead load forces shown in the original design stress sheets as another independent review of the lift span model. These forces were observed to be very similar.

Refer to Appendix D for calculation summaries and results, containing the governing axial forces, moments, and shears for each section as well as hand calculations for the floor beam, stringer, and lifting girder demands.

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APPENDIX A
KEY PLAN AND GENERAL ARRANGEMENT DRAWINGS

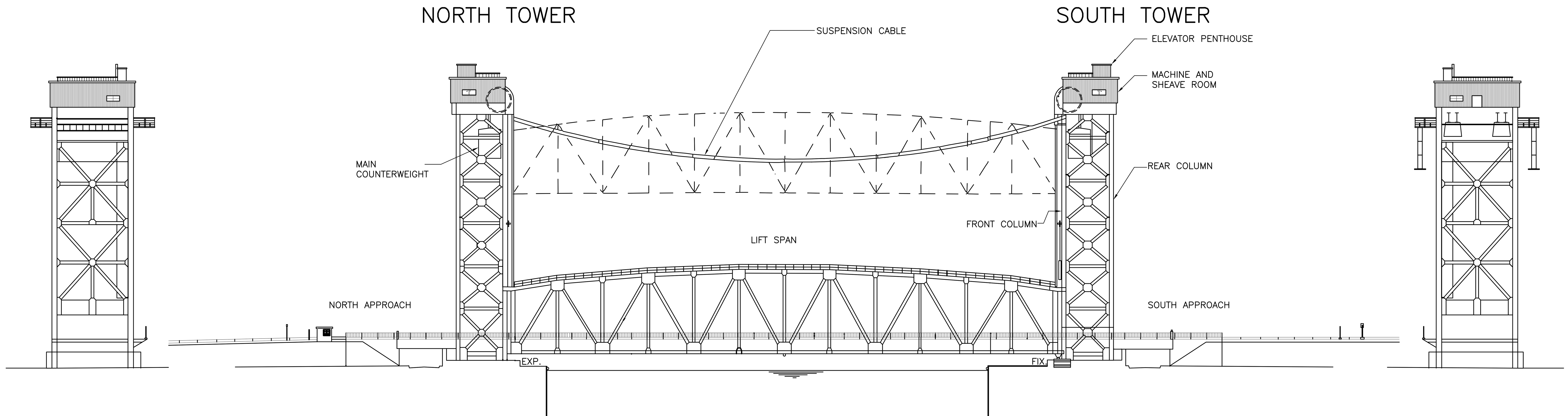
KEY PLAN

Burlington Lift Bridge, Burlington Ontario

Scale: N.T.S.

04 11

0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 millimetres

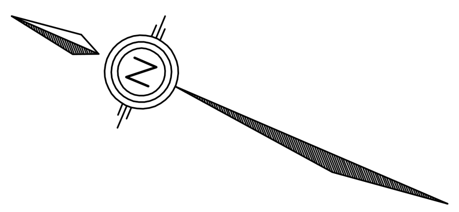


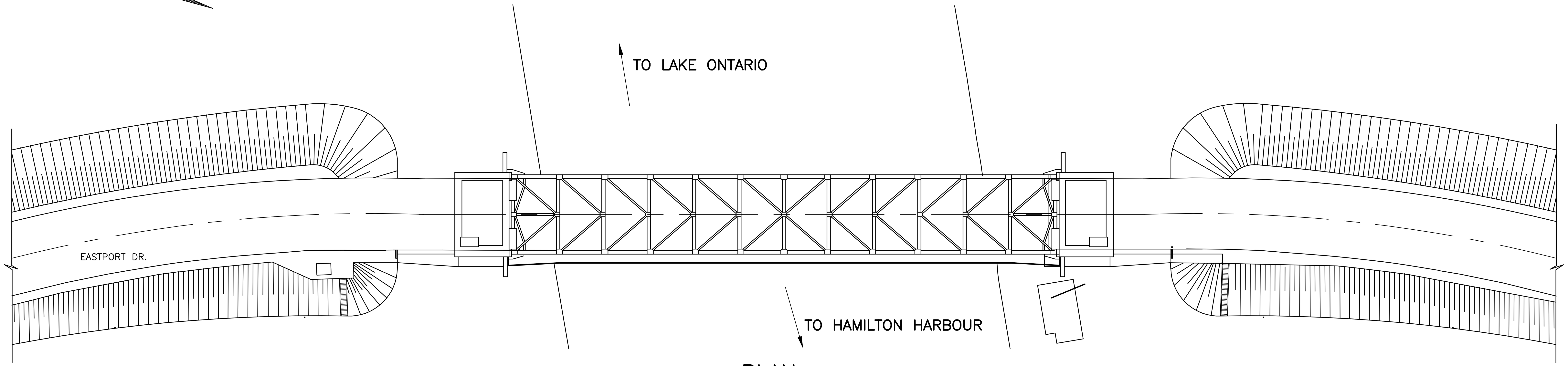
TOWER — REAR VIEW

ELEVATION

(WEST ELEVATION SHOWN, EAST ELEVATION SIMILAR)

TOWER — FRONT VIEW

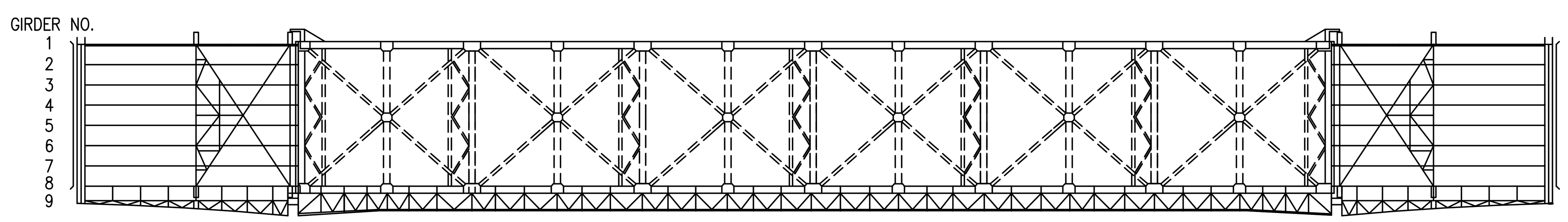




PLAN

CITY OF BURLINGTON

CITY OF HAMILTON



PLAN VIEW — LIFT SPAN BOTTOM CHORD

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revision		date
04		
03		
02		
01		

Do not scale drawings.
Verify all dimensions and conditions on site and immediately notify the Departmental Representative of all discrepancies.

A Detail No. / No. du détail
B drawing no. — where detail required / dessin no. — où détail exigé
C drawing no. — where detailed / dessin no. — où détaillé

project title / titre du projet
Ontario

drawing title / titre du dessin
BURLINGTON CANAL
LIFT BRIDGE

GENERAL ARRANGEMENT

drawn by / dessine par

designed by / conc par

approved by / approuve par

bid / offre

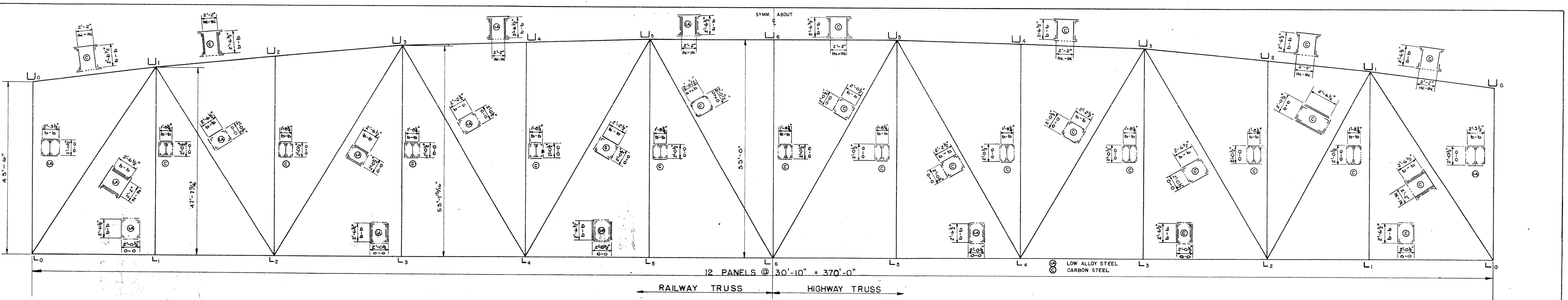
project manager / administrateur de projets

project date / date du projet: 2014-04-09

project no. / no. du projet: S3213009

drawing no. / dessine no.: S-1

GSC-A1 DATE PLOTTED: YYYY-MM-DD PLOT SCALE: 1:? CAD FILE:



RAILWAY TRUSS

BOTTOM CHORDS / TOP CHORDS

	L0 L2	L2 L4	L4 L6	U0 U1	U1 U3	U3 U5	U5 U6
DEAD LOAD	-538	-1182	-1482		+925	+1380	+1525
LIVE LOAD RAILWAY	-596	-1275	-1535		+1004	+1468	+1572
HIGHWAY	-57	-124	-156		+97	+146	+160
IMPACT RAILWAY (D)	-150	-320	-386		+252	+368	+395
(R)	-7	-16	-19		+12	+18	+19
HIGHWAY	-6	-13	-16		+10	+15	+16
	-1354 @ NUS	-2930 @ NUS	-3594 @ NUS		+2300	+3395	+3687
½ MINOR STRESS							
TOTAL							
BRAKING	-243	-208	-151				
30#/□' TRANS. WIND (DIRECT)	-96	-238	-308				
(OVERTURNING)	-64	-140	-175				
	-1757 @ 1.25 NUS = -1405 NUS	-3516 @ 1.25 NUS = -2810	-4228 @ 1.25 NUS = -3380				
DESIGN STRESS (KIPS)	-1405	-2930	-3594		+2300	+3395	+3687
BENDING MOM. (FT. KIPS)	24	46	56		54	65	70
L/R					29.0	30.3	31.6
L/B					9.8	9.8	9.8
ALLOWABLE UNIT STRESS KIPS/SQ. IN. (DIRECT)	27	27	27		16.26	19.58	18.54
(BENDING)	27	27	27		19.00	23.37	23.37
SECTION AREA REQ'D SQ. IN. (GROSS)					145.0	177.2	194.6
(NET)	53.5	112.0	137.3				
SECTION USED	2 WEB Rs. 30×7/16 (-8) 4 Ls. 8×6×½ (-8) 2 PERF. COV. Rs. (23-8)×3/8 (-4)	4 WEB Rs. 30×11/16 (-8) 2 DO. 14×½ (-4) 4 Ls. 8×6×½ (-8) 2 PERF. COV. Rs. (21-8)×3/8 (-4)	4 WEB Rs. 30×11/16 (-8) 2 DO. 30×½ (-8) 2 DO. 14×½ (-4) 4 Ls. 8×6×½ (-8) 2 PERF. COV. Rs. (20-8)×3/8 (-4)	2 WEB Rs. 30×½ 4 Ls. 4×4×7/16 1 TOP COV. R. 38×½ 1 PERF. R. (38×14)×½	4 WEB Rs. 30×½ 2 TOP Ls. 4×4×7/16 2 BOTTOM Ls. 8×6×3/4 1 TOP COV. R. 38×1 1 PERF. BOTT. COV. R. (42-14)×7/8	4 WEB Rs. 30×3/4 2 TOP Ls. 4×4×7/16 2 BOTTOM Ls. 8×6×3/4 1 TOP COV. R. 38×1 1 PERF. BOTTOM COV. R. (42-14)×7/8	4 WEB Rs. 30×3/4 2 DO. 18×7/16 2 TOP Ls. 4×4×7/16 2 BOTTOM Ls. 8×6×3/4 1 TOP COV. R. 38×1 1 PERF. BOTT. COV. R. (42-14)×7/8
AREA OF SECTION SQ. IN. (GROSS)					149.0	179.0	194.8
(NET)	54.4	112.4	137.2				
SECTION MODULUS (CU. IN.)	491.0	706.0	815.0		1550	1680	1728
ACTUAL UNIT STRESS KIPS/SQ. IN. (DIRECT)	25.9	26.0	26.2		15.45	18.95	18.95
(BENDING)	0.58	0.8	0.83		0.419	0.46	0.49
fa/Fa + fb/Fb	0.982	.995	1.001		0.972	0.990	0.998
MATERIAL	LOW ALLOY	LOW ALLOY	LOW ALLOY	CARBON	CARBON	LOW ALLOY	LOW ALLOY

DIAGONALS

	L0 U1	U1 L2	L2 U3	U3 L4	L4 U5	L4 U5	U5 L6	U5 L6
DEAD LOAD	+985	-707	+520	-392	+212	+212	-86	-57
LIVE LOAD RAILWAY	+1090	-810	+650	-553	+428	-188	-346	+248
HIGHWAY	+110	-83	+68	-58	+46	-20	-38	+28
IMPACT RAILWAY (D)	+274	-203	+163	-139	+108	-47	-87	+62
(R)	+14	-10	+8	-7	+5	-2	-4	+3
HIGHWAY	+11	-8	+7	-6	+5	-6	-4	+3
	+2484	-1821	+1416	-1155	+804	-51	-565	+287
½ MINOR STRESS	(+56) (2½%)				+26	-26	-163	+143
TOTAL					+830	-77	-708	+430
DESIGN STRESS (KIPS)	+2540	-1821	+1416	-1155	+830	-77	-708	+430
BENDING MOM. (FT. KIPS)	(1120)Y-Y (69) X-X	78	78	60	67	67	51	51
L/R	59.0		69.2		79.3			80.2
L/B	(12) Y-Y (18) X-X		30.1		30.8			30.9
ALLOWABLE UNIT STRESS KIPS/SQ. IN. (DIRECT)	+18.41	27	19.32	27	14.74	20	20	14.69
(BENDING)	(22.69)Y-Y (21.86)X-X	27	20.21	27	14.79	20	20	14.78
SECTION AREA REQ'D SQ. IN. (GROSS)	207.0		79.9		64.5			35.6
(NET)		72.7		46.9		10.1	40	
SECTION USED	4 WEB Rs. 30×3/4 2 DO. 18×3/4 2 TOP Ls. 4×4×7/16 2 BOTTOM Ls. 8×6×3/4 1 TOP COV. R. 38×1" 1 PERF. BOTT. COV. R. (42-14)×7/8	2 WEB Rs. 30×5/8 (-8) 2 WEB Rs. 30×½ (-8) 4 Ls. 4×4×3/8 (-8) 2 PERF. COV. Rs. (22-8)×3/8 (-4)	4 WEB Rs. 30×½ 4 Ls. 4×4×3/8 2 PERF. COV. R. (22-8)×3/8	2 WEB Rs. 26×3/4 (-8) 4 Ls. 4×4×3/8 (-8) 2 PERF. COV. Rs. (22½-8)×3/8 (-4)	2 WEB Rs. 26×7/8 4 Ls. 4×4×3/8 2 PERF. COV. Rs. (22-8)×3/8		2 WEB Rs. 24×9/16 4 Ls. 4×4×3/8 2 PERF. COV. Rs. (23-8)×3/8	
AREA OF SECTION SQ. IN. (GROSS)	206.00		81.5		66.9			48.7
(NET)		74.1		48.8		52.3	39.8	
SECTION MODULUS (CU. IN.)	(1761)X-X (1886)Y-Y	502	589	329	445 GROSS	342 NET	269 NET	341 GROSS
ACTUAL UNIT STRESS KIPS/SQ. IN. (DIRECT)	12.32	-24.6	+17.40	-23.70	+12.40	-1.48	-17.80	+8.92
(BENDING)	(7.13)Y-Y (0.47)X-X	-1.9	+1.58	-2.17	+1.81	-2.35	-2.26	+1.79
fa/Fa + fb/Fb	1.005	0.982	0.979	0.960	0.963	0.192	1.003	0.730
MATERIAL	LOW ALLOY	LOW ALLOY	LOW ALLOY	LOW ALLOY	CARBON	CARBON	CARBON	CARBON

VERTICALS

	U0 L0	U1 L1	U2 L2	U3 L3	U4 L4	U5 L5	U6 L6
DEAD LOAD	-991	-80	+35	-88	+40	-91	+42
LIVE LOAD RAILWAY		-211		-211		-211	
HIGHWAY		-41		-41		-41	
IMPACT RAILWAY (D)	-195 (D.L.)	-123		-123		-123	
(R)		-3		-3		-3	
HIGHWAY		-12		-12		-12	
	-1186	-470		-478		-481	
DESIGN STRESS (KIPS)	-1186	-470	+35	-478	+40	-481	+42
BENDING MOM. (FT. KIPS)	755	478	478	478	478	478	478
L/R			56.1				
L/B			27.2				
ALLOWABLE UNIT STRESS KIPS/SQ. IN. (DIRECT)	24	20	13.32	20	13.32	20	13.32
(BENDING)	24	20	18.45	20	18.45	20	18.46
SECTION AREA REQ'D SQ. IN. (GROSS)			39.9		40.3		40.4
(NET)	101.6	57.4		57.9		58.0	
SECTION USED	2 Rs. OUTSIDE WEB 23×½ 1 CENTRE WEB 23×7/8 4 Ls. 5×5×3/4 4 Ls. 4×4×3/4 2 COVER Rs. 27×½ 2 CENTRE WEB 13×3/4	1 CENTRE WEB 23×½ 2 SIDE PERF. R. (23-10)×3/8 4 Ls. 5×5×5/8 4 Ls. 4×4×½ 2 FLG. Rs. 19½×½	1 CENTRE WEB 23×½ 2 SIDE PERF. Rs. (23-10)×3/8 4 Ls. 5×5×½ 4 Ls. 4×4×3/8 2 FLG. Rs. 19½×3/8	AS U1 L1	AS U2 L2	AS U1 L1	AS U2 L2
AREA OF SECTION SQ. IN. (GROSS)			66.3		66.3		66.3
(NET)	104.24	60.6		60.6		60.6	
SECTION MODULUS (CU. IN.)	744 NET	512 NET	555 GROSS	512 NET	555 GROSS	512 NET	555 GROSS
ACTUAL UNIT STRESS KIPS/SQ. IN. (DIRECT)	11.21	7.76	0.53	7.90	0.61	7.91	0.64
(BENDING)	12.18	11.20	10.36	11.20	10.36	11.20	10.36
fa/Fa + fb/Fb	0.975	0.948	0.602	0.955	0.608	0.956	0.610
MATERIAL	LOW ALLOY	CARBON	CARBON	CARBON	CARBON	CARBON	CARBON

HIGHWAY TRUSS

BOTTOM CHORDS / TOP CHORDS

	L0 L2	L2 L4	L4 L6	U0 U1	U1 U3	U3 U5	U5 U6
DEAD LOAD	-538	-1182	-1482		+925	+1380	+1525
LIVE LOAD RAILWAY	-154	-331	-400		+261	+381	+408
HIGHWAY	-115	-254	-318		+188	+297	+327
SIDEWALK	-27	-60	-75		+47	+70	+77
IMPACT RAILWAY (D)	-39	-83	-100		+66	+96	+102
(R)	-7	-16	-19		+12	+18	+19
HIGHWAY	-12	-26	-32		+20	+30	+33
	-892	-1952	-2426		+1529	+2272	+2492
½ MINOR STRESS							
TOTAL							
BRAKING	±77	±66	±49				
30#/□' TRANS. WIND (DIRECT)	±96	±238	±308				
(OVERTURNING)	±64	±140	±175				
	-1129 @ 1.25 N.U.S. = 904	-2396 @ 1.25 N.U.S. = 1917	-2958 @ 1.25 N.U.S. = 2366				
DESIGN STRESS (KIPS)	-904	-1952	-2426		+1529	+2272	+2492
BENDING MOM. (FT. KIPS)	24	42	42		39	55	57
L/R					29.4	28.9	29.2
L/B					9.8	9.8	9.7
ALLOWABLE UNIT STRESS KIPS/SQ. IN. (DIRECT)	20	20	27		16.26	16.27	16.26
(BENDING)	20	20	27		19.00	19.00	19.00
SECTION AREA REQ'D SQ. IN. (GROSS)					96.5	145.0	156.5
(NET)	46.8	102.6	92.6				
SECTION USED	2 WEB Rs. 30×7/16 4 Ls. 8×6×½ 2 PERF. COV. Rs. (23-8)×3/8	2 WEB Rs. 30×11/16 2 WEB Rs. 30×7/16 2 WEB Rs. 14×½ 4 Ls. 8×6×½ 2 PERF. COV. Rs. (21-8)×3/8	2 WEB Rs. 30×7/16 2 WEB Rs. 30×11/16 2 WEB Rs. 14×½ 4 Ls. 8×6×½ 2 PERF. COV. Rs. (20-8)×3/8	2 WEB Rs. 30×½ 4 Ls. 4×4×7/16 1 TOP COV. R. 38×½ 1 PERF. R. (38×14)×½	2 WEB Rs. 30×11/16 2 Ls. 4×4×7/16 TOP 2 Ls. 8×6×9/16 BOTT. 1 TOP COV. R. 38×11/16 1 PERF. BOT. COV. R. (42-14)×5/8	2 WEB Rs. 30×1 2 Ls. 4×4×7/16 TOP 2 Ls. 8×6×3/4 BOTT. 1 TOP COV. R. 38×1 1 BOTT. PERF. R. (42-14)×7/8	2 Ls. 4×4×7/16 2 WEB Rs. 30×½ 2 WEB Rs. 30×5/8 2 Ls. 8×6×3/4 1 TOP COV. R. 38×1 1 PERF. B. COV. R. (42-14)×7/8
AREA OF SECTION SQ. IN. (GROSS)					100.5	149.0	156.5
(NET)	55.5	101.8	101.00				
SECTION MODULUS (CU. IN.)	501 NET	535 NET	649 NET		1025 GROSS	1547 GROSS	1581 GROSS
ACTUAL UNIT STRESS KIPS/SQ. IN. (DIRECT)	16.30	19.20	24.00		15.20	15.25	15.90
(BENDING)	0.56	0.93	0.76		0.46	0.42	0.43
fa/Fa + fb/Fb	0.843	1.007	0.917		0.959	0.959	1.00
MATERIAL	CARBON	CARBON	LOW ALLOY	CARBON	CARBON	CARBON	CARBON

DIAGONALS

	L0 U1	U1 L2	L2 U3	U3 L4	L4 U5	L4 U5	U5 L6	U5 L6
DEAD LOAD	+968	-707	+520	-392	+212	+212	-86	-57
LIVE LOAD RAILWAY	+283	-211	+168	-142	+110	-49	-90	+64
HIGHWAY	+224	-170	+137	-118	+94	-41	-78	+58
SIDEWALK	+50	-37	+30	-25	+19	-7	-15	+11
IMPACT RAILWAY (D)	+71	-53	+42	-36	+28	-12	-23	+16
(R)	+14	-10	+8	-7	+5	-2	-4	+3
HIGHWAY	+23	-17	+14	-12	+10	-12	-8	+6
	+1650	-1205	+919	-732	+478	+89	-304	+101
½ MINOR STRESS	(+94) (W+2½%)						-51	+51
TOTAL	+1744 @ 1.25 NUS = 1395						-355	+152
DESIGN STRESS (KIPS)	+1395	-1205	+919	-732	+478		-355	+152
BENDING MOM. (FT. KIPS)	1500	72	65	51	58		51	51
L/R	59.0		67.0		76.8			80.2
L/B	14.0		30.1		30.8			30.9
ALLOWABLE UNIT STRESS KIPS/SQ. IN. (DIRECT)	15.53	20	15.26	20	14.85		20	14.70
(BENDING)	(18.92)Y-Y (18.23)X-X	20	15.00	20	14.79		20	14.78
SECTION AREA REQ'D SQ. IN. (GROSS)	199.0		66.9		32.9			16.3
(NET)		66.5		40.8			22.3	
SECTION USED	2 Ls. 4×4×7/16 4 WEB Rs. 30×3/4 2 WEB Rs. 18×3/4 2 Ls. 8×6×3/4 BOTT. 1 TOP COV. R. 38×1. 1 P.B. COV. R. (42-14)×7/8	2 WEB Rs. 30×1. 4 Ls. 4×4×3/8 2 PERF. COV. Rs. (22-8)×3/8	2 WEB Rs. 30×3/4 4 Ls. 4×4×3/8 2 PERF. COV. Rs. (22-8)×3/8	2 WEB Rs. 26×9/16 4 Ls. 4×4×3/8 2 PERF. COV. Rs. (22½-8)×3/8	2 WEB Rs. 26×11/16 4 Ls. 4×4×3/8 2 PERF. COV. Rs. (22-8)×3/8		2 WEB Rs. 24×9/16 4 Ls. 4×4×3/8 2 PERF. COV. Rs. (23-8)×3/8	
AREA OF SECTION SQ. IN. (GROSS)	206.0		66.6		57.1			48.7
(NET)		69.3		41.8			40.8	
SECTION MODULUS (CU. IN.)	(1886)Y-Y (1761)X-X	485.2 NET	517 GROSS	307 NET	405 GROSS		277 NET	341 GROSS
ACTUAL UNIT STRESS KIPS/SQ. IN. (DIRECT)	6.77	-17.40	+13.80	17.50	8.40		-8.70	+3.13
(BENDING)	(9.64)Y-Y (0.47)X-X	-1.78	+1.50	1.99	1.72		-2.19	+1.78
fa/Fa + fb/Fb	0.966	0.960	1.004	0.975	0.577		0.545	0.334
MATERIAL	CARBON	CARBON	CARBON	CARBON	CARBON	CARBON	CARBON	CARBON

VERTICALS

	U0 L0	U1 L1	U2 L2	U3 L3	U4 L4	U5 L5	U6 L6
DEAD LOAD	-991	-80	+35	-88	+40	-91	+42
LIVE LOAD RAILWAY		-55		-55		-55	
HIGHWAY		-80		-80		-80	
SIDEWALK	-195 (D.L.)	-27		-27		-27	
IMPACT RAILWAY (D)		-32		-32		-32	
(R)		-3		-3		-3	
HIGHWAY		-24		-24		-24	
	-1186	-301		-309		-312	
DESIGN STRESS (KIPS)	-1186	-301	+35	-309	+40	-312	+42
BENDING MOM. (FT. KIPS)	755	392	392	392	392	392	392
ALLOWABLE UNIT STRESS KIPS/SQ. IN. (DIRECT)	24	20	13.32	20	13.32	20	13.32
(BENDING)	24	20	18.45	20	18.45	20	18.45
SECTION AREA REQ'D SQ. IN. (GROSS)			33.1		33.5		33.6
(NET)	101.6	43.0		43.3		43.5	
SECTION USED	2 Rs. OUTSIDE WEB 23×½ 1 CENTRE WEB 23×7/8 4 Ls. 5×5×3/4 4 Ls. 4×4×3/4 2 COVER Rs. 27×½ 2 CENTRE WEB 13×3/4	1 CENTRE WEB 23×½ 2 SIDE PERF. Rs. (23-10)×3/8 4 Ls. 5×5×5/8 4 Ls. 4×4×½ 2 FL. Rs. 19½×½	1 CENTRE WEB 23×½ 2 SIDE PERF. Rs. (23-10)×3/8 4 Ls. 5×5×½ 4 Ls. 4×4×3/8 2 FL. R. 19½×3/8	AS U1 L1	AS U2 L2	AS U1 L1	AS U2 L2
AREA OF SECTION SQ. IN. (GROSS)			66.3		66.3		66.3
(NET)	104.84	60.6		60.6		60.6	
SECTION MODULUS (CU. IN.)	744 NET	512 NET	555 GROSS	512 NET	555 GROSS	512 NET	555 GROSS
ACTUAL UNIT STRESS KIPS/SQ. IN. (DIRECT)	11.21	4.97	0.53	5.10	0.61	5.15	0.64
(BENDING)	12.18	9.20	8.48	9.20	8.48	9.20	8.48
fa/Fa + fb/Fb	0.975	0.709	0.499	0.715	0.505	0.718	0.607
MATERIAL	LOW ALLOY	CARBON	CARBON	CARBON	CARBON	CARBON	CARBON

LIFTING GIRDER

VERTICAL SHEAR (KIPS)	ROPE LOAD	1201
	GIRDER WEIGHT	-31
	TOTAL	1170
VERTICAL MOMENT (FT.-KIPS)	ROPE LOAD	11002
	GIRDER WEIGHT	-296
	TOTAL	10706
HORIZONTAL SHEAR TEMPERATURE (KIPS)		7.73
HORIZONTAL MOMENT TEMPERATURE (FT. KIPS)		57.2
WEB REQ'D. SQ. IN.		117
SECTION	WEB	169 × 7/8
	ANGLES	4 Ls. 8×8×3/4
	SIDE PLATES	4 Rs. 16×½
	TOP COVER PLATES	1 R. 34×½
	BOTTOM COVER PLATES	1 R. 26×3/4
	TOP FLANGE ANGLES	2 Ls. 4×3×½
	BOTTOM FLANGE ANGLES	2 Ls. 4×3×½
NET SECTION MODULUS VERT. BENDING (CU. IN.)		9015
NET SECTION MODULUS HORIZ. BENDING (CU. IN.)		177 (TOP FLG.)
MAXIMUM KIPS/SQ. IN. BENDING STRESS	VERT. MOMENT	14.3
	HORIZ. MOMENT	2.9
	TOTAL	17.2 (TOP)
ALLOWABLE UNIT STRESS (KIPS/SQ. IN.)		15.2 (BOTT.) 18.0 (TOP)
WEB AREA PROVIDED SQ. IN.		146.0
MATERIAL		CARBON

GENERAL NOTES:

1. GENERAL NOTES ON SHEET NO. 2 APPLY HERE.
2. CAMBER: THE LIFT SPAN TRUSSES SHALL BE SO CAMBERED THAT THE STRUCTURE WILL RETAIN ITS GEOMETRIC SHAPE UNDER FULL DEAD LOAD PLUS HALF LIVE LOAD.
3. MATERIAL: MEMBERS FOR WHICH STRUCTURAL LOW-ALLOY STEEL SHALL BE USED ARE DESIGNATED WITH Ⓐ. ALL OTHER MEMBERS ARE STRUCTURAL CARBON STEEL. CONNECTING MATERIALS BETWEEN LOW-ALLOY MEMBERS AND BETWEEN LOW-ALLOY AND CARBON STEEL MEMBERS SHALL BE LOW-ALLOY STEEL, AND ALL OTHER CONNECTING PARTS, LACING AND DIAPHRAGMS SHALL BE CARBON STEEL. ALL RIVETS TO BE CARBON STEEL.
4. RIVETS: 1" ø RIVETS TO BE USED FOR RAILWAY SIDE MAIN TRUSS. 7/8" ø RIVETS FOR HIGHWAY SIDE MAIN TRUSS AND ALL FLOOR AND BRACING SYSTEMS, EXCEPT AS NOTED.
5. ALLOWABLE ERECTION STRESSES:
   D.L. + ERECTION LOAD - 1.25 NORMAL UNIT STRESSES.
   D.L. + ERECT. LOAD + 30 P.S.F. WIND - 1.33 NORMAL UNIT STRESSES.
6. SIGN CONVENTIONS:
   + FOR COMPRESSION.
   - FOR TENSION.
7. MOMENT:
   MX-X FOR MOMENT ABOUT HORIZONTAL AXIS.
   MY-Y FOR MOMENT ABOUT VERTICAL AXIS.
8. MINIMUM THICKNESS OF MATERIAL: 3/8" EXCEPT FOR FILLS AND WHERE NOTED OTHERWISE.
9. MINIMUM THICKNESS OF GUSSET PLATES: ½" UNLESS NOTED OTHERWISE.

RECOMMENDED	DATE 1-12-58	DESIGN D.J.D.	CHKD. G.W.A.
C.C. Parker		DRAWN D.L.	CHKD. R.K.C.C.
C.C. PARKER & ASSOC. LTD.		TRACED M.E. & D.H.	CHKD. A.T.
		JOB NO. H-538	

NO.	REVISIONS	BY	DATE

DEPARTMENT OF PUBLIC WORKS
CANADA
DEVELOPMENT ENGINEERING BRANCH
STRUCTURES DIVISION

C.C. PARKER & ASSOCIATES LTD.
CONSULTING ENGINEERS
HAMILTON ONTARIO

REGISTERED PROFESSIONAL ENGINEER — CIVIL — I. M. WALLACE — PROVINCE OF ONTARIO

BURLINGTON CANAL LIFT BRIDGE

LIFT SPAN TRUSSES - STRESS SHEET

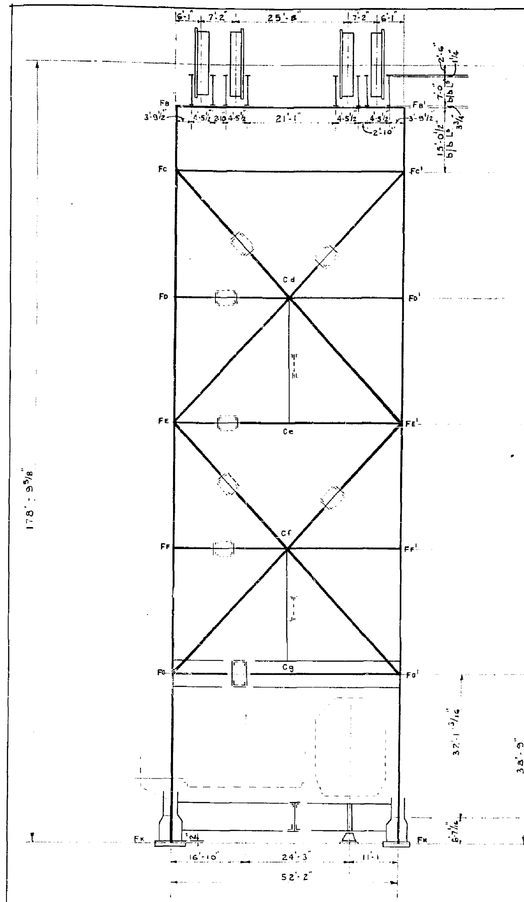
APPROVED DATE 13/11/58 — CHIEF, STRUCTURES DIVISION

APPROVED DATE 14-11-58 — CHIEF ENGINEER

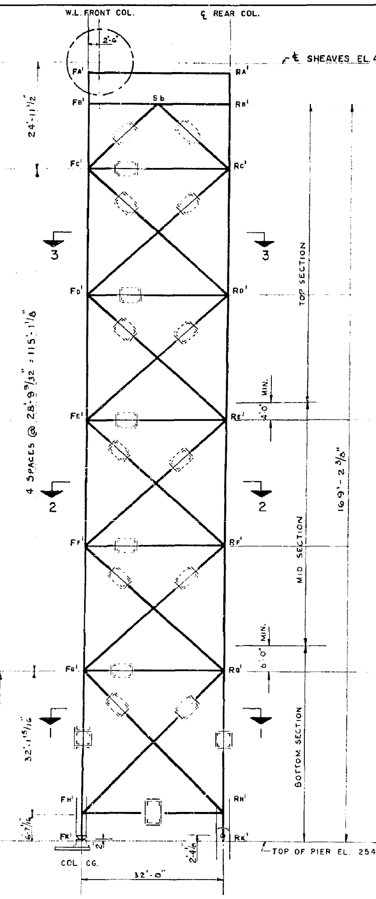
DEPARTMENT PROJECT NO. SD6-4-77

CONTRACT NO. 2.

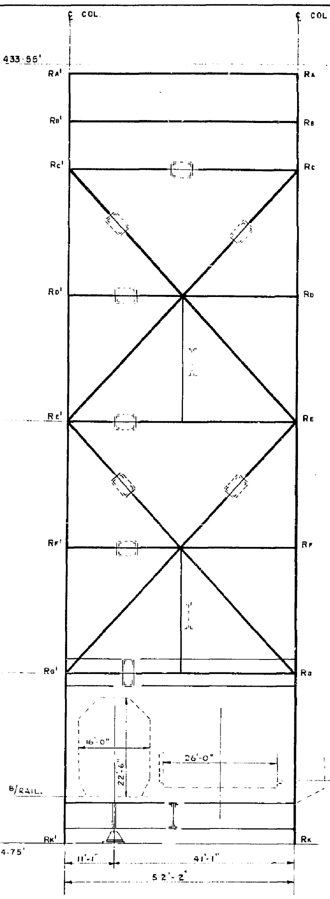
SHEET 3 OF 62



FRONT FACE BRACING (ADJACENT TO LIFT SPAN)



SIDE FACE BRACING



REAR FACE BRACING

LOAD TO LIFT 4000,000 LBS.

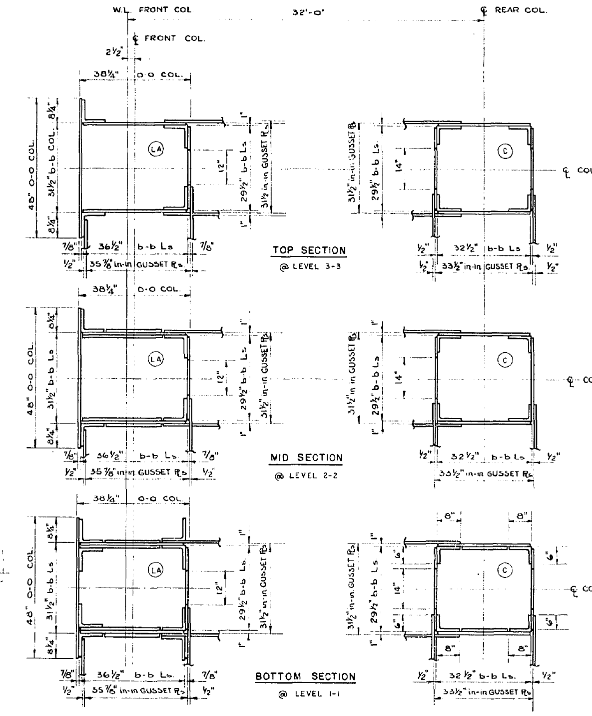
SHEAVE LOAD

SPAN 4000 x 1/8 =	500
COUNTERWEIGHT	500
ROPES & ATTACHMENTS	35
SHEAVE SHAFT & BEARINGS	65
OPERATING FORCE & IMPACT	40
TOTAL PER SHEAVE	1140

BEARING LOADS

554 PER BEARING AT G1 & G4

586 PER BEARING AT G2 & G3



TOWER COLUMNS

SCALE: 1/2" = 1'-0"

SHEAVE GIRDERS — LONGITUDINAL / TRANSVERSE

GIRDER		G1 & G1A MOMENT	SHEAR	G2,G2A,G3,G3A MOMENT	SHEAR	G4 G4A MOMENT	SHEAR	G6 G6A MOMENT	SHEAR	G7 MOMENT	SHEAR	G8 MOMENT	SHEAR
DEAD LOAD		37 IK	25 K	36 IK	31 K	900 IK	79 K				254 K		22.5 K
SHEAVE LOAD		1282	513	1355	542	850	512				2109		172
IMPACT SHEAVE LOAD		258	103	270	108	170	103				422		34
DL + SL + IMPACT		1577	641	1661	681	1920	694	312 IK	31 K	28187 IK	2825	4768 IK	432
COUNTERWEIGHT ON GIRDERS				3500	350								
DL + CTWT ON GIRDERS				3802	429								
NET SECTION	@ 18-0 7/8"	1052				1280		208					
MODULUS REQ'D	@ 22-5/8"			2025								3180	
IN³	@ 24-0 7/8"									14100			
GROSS AREA OF	@ 11-0 5/8"		58.5		62		63.2		3				
WEB REQ'D IN²	@ 14-0 5/8"										202		59.3
SECTION	WEB FLANGE	84 x 3/4		84 x 3/4		84 x 3/4		84 x 1/2		[illegible]		PL 132 x 1/2	
	Ls AND	4 Ls-8 x 6 x 3/4		4 Ls-8 x 6 x 7/8		4 Ls-8 x 6 x 3/4		4 Ls-6 x 6 x 1/2		4 Ls-8 x 8 x 1		4 Ls-8 x 6 x 5/8	
	FLANGE PLs												
	COVER PLs									4 PLs-26 x 7/8		2 PLs 20 x 1/2	
GROSS AREA OF WEB PROV'D IN²		63.0		63.0		63.0		42.0		247		66	
NET SECTION MODULUS PROV'D IN³		1800		2260		1800				14300		3640	
MATERIAL		CARBON		CARBON		CARBON		CARBON					
STIFFENERS @ SUPPORT		8 Ls-5 x 4 x 7/8		8 Ls-7 x 4 x 7/8		8 Ls-7 x 4 x 7/8				8 Ls-8 x 4 x 3/4			
STIFFENERS UNDER CONC. L.		8 Ls-6 x 4 x 7/8		8 Ls-7 x 4 x 7/8		8 Ls-7 x 4 x 7/8				8 Ls-8 x 4 x 3/4			
INTERMEDIATE STIFFENERS		2 Ls-5 x 3 1/2 x 3/8		2 Ls-6 x 4 x 3/8		2 Ls-5 x 3 1/2 x 3/8		2 Ls-5 x 3 1/2 x 3/8		2 Ls-8 x 4 x 3/4		2 Ls-7 x 4 x 5/8	
MATERIAL		CARBON STEEL								LOW ALLOY		CARBON STEEL	

REACTION IN KIPS PER COLUMN

		FRONT COLUMN SPAN UP RWY.	HWY.	SPAN DOWN RWY.	HWY.	CTWT JACKED RWY.	HWY.	REAR COLUMN SPAN UP RWY.	HWY.	SPAN DOWN RWY.	HWY.	CTWT JACKED RWY.	HWY.
VERTICAL	DEAD LOAD	881	1002	881	1002	735	822	410	588	410	588	460	657
	SHEAVE LOAD	1920	1920	1920	1920	819	819	160	160	160	160	261	231
	MESSENGER CABLE	170	170	170	170	170	170	− 159	− 159	− 159	− 159	− 159	− 159
	TOTAL STATIC LOAD	2971	3092	2971	3092	1724	1811	411	589	411	589	552	759
	2/3 DEAD LOAD	1981	2061	1981	2061	1149	1207	274	393	274	393	368	506
	ROOF LIVE LOAD	66	66	66	66	66	66	72	72	72	72	72	72
	SHEAVE LOAD IMPACT	384	384	384	384	—	—	32	32	32	32	—	—
	TOTAL D.L. + L.L. + IMPACT	3421	3542	3421	3542	1790	1273	515	693	515	693	624	831
	30 P.S.F. TRANS. WIND	± 156	± 156	± 198	± 198			± 682	± 682	± 200	± 200		
	30 P.S.F. LONG. WIND	± 973	± 973	± 652	± 649			± 973	± 973	± 652	± 649		
	30 P.S.F. 45° WIND	± 798	± 798	± 642	± 635			± 1170	± 1170	± 651	± 611		
	MAX. D.L. + L.L. + IMPACT + 30 P.S.F. WIND	+4394	+4515	+4073	+4191			+1685	+1863	+1167	+1342		
	50 P.S.F. TRANS. WIND			± 326	± 326	± 326	± 326			± 326	± 326	± 326	± 326
	50 P.S.F. LONG. WIND			± 1080	± 1080	± 1080	± 1080			± 1080	± 1080	± 1080	± 1080
	50 P.S.F. 45° WIND			± 994	± 994	± 994	± 994			± 994	± 994	± 994	± 994
	MAX. D.L. + 50 P.S.F. WIND			± 4051	± 4172	± 2804	± 2891			± 1491	± 1669	± 1632	± 1839
	2/3 D.L. − 30 P.S.F. WIND	+1008	+1008	+1329	+1412			− 896	− 777	− 378	− 256		
	2/3 D.L. − 50 P.S.F. WIND			+ 901	+ 981	+ 69	+ 127			− 806	− 687	− 712	− 574
HORIZONTAL	MESSENGER CABLE	− 15	− 15	− 15	− 15	− 15	− 15	− 15	− 15	− 15	− 15	− 15	− 15
	TRANS. WIND	± 164	± 12	± 131	± 11	± 131	± 11	± 113	± 5	± 131	± 6	± 131	± 6
	LONG. WIND	± 138	± 138	± 137	± 137	± 137	± 137	± 138	± 138	± 137	± 137	± 137	± 137
	L.L. WIND												
	NOSING												

FRONT BRACING

		Fc Fe' / Fc' Fe	Fe Fg' / Fe' Fg	Fd Fd'	Fe Fe'	Ff Ff'	Fg Fg'	Cd Ce / Cf Cg
2 1/2 % COLUMNS KIPS		± 112	± 117	+ 75 / − 63	+ 77 / − 65	+ 78 / − 66	+ 80 / − 80	
TRANSVERSE WIND KIPS		± 184	± 280	+ 104 / − 26	+ 133 / − 15	+ 198 / − 42	+ 133 / − 15	
MOMENT FROM TRAN. WIND - FT. - KIPS				154	210	210	2795 / 210	
DESIGN STRESS KIPS		± 296	± 397	+ 179 / + 89	+ 210 / − 80	+ 276 / − 108	+ 213 / − 95	
L/T		61.0	61.3	39.7	41.0	41.2	39.4	
ALLOW. UNIT STRESS K/IN²	COMPRESSION	15.5	15.5	16.0* / 16.4**	16.0* / 16.4**	16.0* / 16.4**	16.1* / 19.0**	
	TENSION	20.0	20.0	20.0	20.0	20.0	20.0	
AREA REQ'D IN²	GROSS	21.9	28.6	20.1	25.5	30.2	115	
	NET	16.2	22.3	5.2	4.7	6.5	99	
SECTION		4 Ls 6 x 4 x 3/8, 2 PLs 24 x 3/8	4 Ls 6 x 4 x 1/2, 2 PLs 24 x 3/8	4 Ls 6 x 4 x 3/8, 2 PLs 24 x 3/8	4 Ls 6 x 4 x 3/8, 2 PLs 24 x 3/8	4 Ls 6 x 4 x 1/2, 2 PLs 24 x 3/8	4 Ls 8 x 8 x 3/4, 2 PLs 37 x 5/8, 2 PLs 70 x 1/2	4 Ls 4 x 3 x 3/8
AREA OF SECTION - IN²	GROSS	25.7	30.3	25.7	25.7	30.3	144.5	
	NET	21.2	31.5	21.2	21.2	31.5	119	
SECTION MODULUS - IN³ (GROSS)				322	336	389	3200 / 1020	
MATERIAL		CARBON STEEL						

* UNIT AXIAL STRESS ** UNIT FLEXUAL STRESS

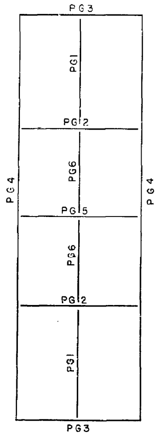
REAR BRACING

	Rc' Re / Rc Re'	Re' Rg / Re Rg'	Rc' Rc	Rd' Rd	Re' Re	Rf' Rf	Rg' Rg	Md Me / Mf Mg
2 1/2 % COLUMNS KIPS	± 22	± 25	± 25	± 17	± 19	± 21	± 18.3	
TRANSVERSE WIND KIPS	± 95	± 98	± 87	± 11	—	± 31	—	
MOMENT FROM TRAN. WIND - FT. - KIPS			544				1443	
DESIGN STRESS KIPS	± 117	± 123	± 112	± 28	± 19	± 52	± 18.1	
L/T	64.7	64.7	43.4	63.7	63.7	63.7	43	
ALLOW. UNIT STRESS K/IN² COMPRESSION	15.3	15.3	16.0* / 17.9**	15.4* / 16.3**	15.4* / 16.3**	15.4* / 16.3**	16.0* / 16.3**	
TENSION	20.0	20.0	20.0	20.0	20.0	20.0	20.0	
AREA REQ'D IN² GROSS	10.5	10.9	38.7			7.5	28.7	
NET	7.3	7.5	32.6		–	3.2	21.4	
SECTION	4 Ls 6 x 4 x 3/8, 2 PLs 24 x 3/8	4 Ls 6 x 4 x 7/8, 2 PLs 24 x 3/8	4 Ls 6 x 6 x 3/4, 2 PLs 35 x 1/2, 2 PLs 32 x 1/2	4 Ls 4 x 4 x 3/8, 2 PLs 24 x 3/8	4 Ls 4 x 4 x 3/8, 2 PLs 24 x 3/8	4 Ls 4 x 4 x 3/8, 2 PLs 24 x 3/8	4 Ls 7 x 4 x 3/4, 2 PLs 70 x 1/2, 2 PLs 32 x 1/2	4 L 4 x 3 x 3/8
AREA OF SECTION - IN² GROSS	25.7	25.7	86.8	22.7	22.7	22.7	118.8	
NET	21.2	21.2	69.8	18.2	18.2	18.2	93.8	
SECTION MODULUS - IN³ (GROSS)								
MATERIAL	CARBON STEEL							

COUNTERWEIGHT GIRDERS

NORMAL CONDITIONS		PG.1	PG.2	PG.3	PG.4	PG.5	PG.6
SHEAR KIPS	D.L.	320	257.2	257.3	253.0	—	—
	IMPACT	103	51.5	50.3	50.3	—	—
	TOTAL	623	308.7	308.0	303.3	—	—
WEB AREA REQUIRED AT 11 S.K.I.		56.6	28.1	28.1	27.6	—	—
MOMENT (FT.-KIPS)	D.L.	1499	1786	1788	1114.0	—	—
	20% IMPACT	299	353	354	230	—	—
	TOTAL	1798	2139	2142	1370	—	—
NET SECTION MOD. REQ'D AT 18 K.S.I.		1200	1423	1430	913	—	—
EMERGENCY CONDITION *							
D.L. SHEAR (KIPS)		520	257.3	257.3	253.0	—	—
WEB AREA REQ'D AT 13.75 K.S.I.		38.2	18.7	18.7	18.4	—	—
D.L. MOMENT (FT.-KIPS)		3354	1786	1788	1140	—	—
NET SECTION MOD. REQ'D AT 22.5 K.S.I.		1787	953	954	608	—	—
SECTION USED	WEB	118 x 7/8	120 x 5/8	207 x 1/2	207 x 1/2	180 x 3/8	118 x 3/8
	FLANGE Ls TOP	2 Ls 8 x 6 x 7/8	2 Ls 6 x 6 x 1/2	1 Ls 8 x 4 x 1/2	1 Ls 8 x 4 x 1/2	2 Ls 6 x 4 x 3/8	2 Ls 6 x 4 x 3/8
	FLANGE Ls BOTT.	2 Ls 8 x 6 x 7/8	2 Ls 6 x 6 x 1/2	1 Ls 5 x 3 x 1/2	1 Ls 8 x 4 x 1/2	2 Ls 6 x 4 x 3/8	2 Ls 6 x 4 x 3/8
	COVER PLATE	—	—	—	—	—	—
AREA OF WEB USED - SQ. IN.		103.3	75	103.5	103.5		
NET SECTION MOD. USED (TENSION)		2260	2580	4250	4140		
DEPTH		9'-10 1/2"	10'-0 1/2"	17'-3 1/2"	17'-3 1/2"	15'-0 1/2"	9'-10 1/2"
MATERIAL		CARBON					

* COUNTERWEIGHT HUNG FROM GIRDERS.



CWT GIRDER-LOCATION PLAN

FRONT TOWER COL / REAR TOWER COL*

MEMBER		FE FE / FE' FE'	FE FG / FE' FG'	FG FK / FG' FK'	RB RE / RB' RE'	RE RG / RE' RG'	RG RK / RG' RK'
DEAD LOAD KIPS		+ 571	+ 687	+ 781	+ 438	+ 509	+ 570
SHEAVE LOAD KIPS		+ 1920	+ 1920	+ 1920	+ 160	+ 160	+ 160
IMPACT - SHEAVE LOAD KIPS		+ 384	+ 384	+ 384	+ 32	+ 32	+ 32
AUX. CTWT + 20 % IMPACT KIPS		—	+ 89	+ 89	—	2	2
MESSENGER CABLE KIPS		+ 66	+ 120	+ 148	− 55	− 109	− 137
TOTAL DIRECT LOAD WITHOUT WIND KIPS		+ 2941	+ 3200	+ 3322	+ 575	+ 590	+ 623
TRANSV. WIND KIPS		± 73	± 333	± 635	± 35	± 127	± 261
DIRECT LOAD + TRANSV. WIND KIPS		+ 3014	+ 3533	+ 3957	+ 610	+ 717	+ 884
TRANSV. WIND MOMENT FT.-KIPS		736	1324	4000	37	604	1862
LONG. WIND KIPS		± 166	± 556	± 988	± 267	± 651	± 1082
DIRECT LOAD + LONG. WIND KIPS		+ 3107	+ 3756	+ 4310	+ 842	+ 1241 / − 61	+ 1705 / − 459
LONG. WIND MOMENT FT.-KIPS		373	373	433	—	—	—
45° WIND KIPS		± 170	± 628	± 1147	± 216	± 545	± 963
DIRECT LOAD + 45° WIND KIPS		+ 3111	+ 3828	+ 4469	+ 791	+ 1135 / + 45	+ 1586 / − 340
TRANSV. WIND MOM. (45° WIND) FT.-KIPS		579	935	2823	27	427	1315
LONG. WIND MOM. (45° WIND) FT.-KIPS		263	263	306	—	—	—
MOM. FROM SHEAVE GIRDER	TRANSV. FT.-KIPS	573	36	—	499	—	—
	LONGIT. FT.-KIPS	43	15	119	415	—	—
AREA REQ'D IN² (GR)	DL + SHEAVE	183	165	176.5	90	36	39
	DL + SHEAVE + TRANS. W.	182	206	345	76	60	121
	DL + SHEAVE + LONG. W.	167	173	200	85	85	85
	DL + SHEAVE + 45° W.	189	216	326	84	73	132
L/R		21	26.9	31.7	28.4	28.4	35.8
ALLOW. UNIT STRESS K/IN²		19.8 X 1.25 = 24.7	19.7 X 1.25 = 24.6	19.5 X 1.25 = 24.4	16.3 X 1.25 = 20.4	16.3 X 1.25 = 20.4	16.1 X 1.25 = 20.1
SECTION		PL 48 x 7/8, 4 Ls 8 x 8 x 1, 2 PLs 36 x 1, PL 29 x 7/8	PL 48 x 7/8, 4 Ls 8 x 8 x 1, 2 PLs 36 x 1, PL 29 x 7/8, 2 PLs 20 x 1, 2 PLs 28 x 1	PL 48 x 7/8, 4 Ls 8 x 8 x 1, 2 PLs 36 x 1, PL 29 x 7/8, 2 PLs 20 x 1, 2 PLs 28 x 1, 4 Ls 5 x 6 x 1	2 PLs 32 x 1, 4 Ls 8 x 6 x 1, 2 PLs 29 x 1/2	2 PLs 32 x 1, 4 Ls 8 x 6 x 1, 2 PLs 29 x 1/2	2 PLs 32 x 1, 4 Ls 8 x 6 x 1, 2 PLs 29 x 1/2, PL 16 x 1
AREA OF SECTION - IN² (GR)		188.87	284.87	345.75	131	131	163
SECTION MODULUS IN³ (GR)	TRANSV. ENTIRE SECT.	1720	2575	3250	1635	1635	2045
	LONG. ENTIRE SECT.	1920	2170	2990	1165	1165	1205
MATERIAL		LOW ALLOY			CARBON		

* REAR COLUMN STRESSES AND MOMENTS ARE CONTROLLED BY THE CONDITION WHEN SPAN IS DOWN WITH 50 P.S.F. WIND

SIDE BRACING

MEMBER		Fc' Rd' / Rc' Fd'	Fd' Re' / Rd' Fe'	Fe' Rf' / Re' Ff'	Ff' Rg' / Rf' Fg'	Fg' Rh' / Rg' Fh'	Fc' Rc'	Fd' Rd'	Fe' Re'	Ff' Rf'	Fg' Rg'	Fh' Rh'	Sb Fc' / Sb Rc'
2 1/2 % COLUMNS		± 84	± 103	± 106	± 108	± 109	± 74	± 75	± 77	± 79	± 80		± 102
MESSENGER CABLE		± 20	± 20	± 20	± 20	± 22							± 21
WIND	CASE GOVERNING			LONG. WIND			L.W.	L.W.	L.W.	L.W.	L.W.		L.W.
	STRESS	± 108	± 136	± 146	± 161	± 191		± 52	− 104	− 56	− 104		± 33
DESIGN STRESS		± 212	± 259	± 272	± 289	± 322	± 74	± 127	+ 77 OR − 181	+ 79 OR − 135	+ 80 OR − 184		± 156
DESIGN MOMENT							76	104	208	194	208		
L/R		34.7	34.7	34.7	34.7	37.2	47.4	47.4	47.4	47.4	42.8		33.4
ALLOWABLE UNIT STRESS K/IN²	COMPRESSION	16.2	16.2	16.2	16.2	16.1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		16.2
	TENSION	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0		20.0
AREA REQ'D IN² (GR)	GROSS	14.3	16.9	17.6	18.9	18.9	15.6	23.8	17.4	20.8	15.5		11.5
	NET	10.6	13.0	13.6	14.4	16.1	11.4	16.7	20.6	15.9	24.9		7.8
SECTION		4 Ls 4 x 4 x 3/8, 2 PLs 24 x 3/8	4 Ls 4 x 4 x 3/8, 2 PLs 24 x 3/8	4 Ls 4 x 4 x 3/8, 2 PLs 24 x 3/8	4 Ls 4 x 4 x 3/8, 2 PLs 24 x 3/8	4 Ls 4 x 4 x 3/8, 2 PLs 24 x 3/8	4 Ls 6 x 4 x 3/8, 2 PLs 24 x 3/8	4 Ls 6 x 4 x 3/8, 2 PLs 24 x 3/8	4 Ls 6 x 4 x 3/8, 2 PLs 24 x 3/8	4 Ls 6 x 4 x 3/8, 2 PLs 24 x 3/8	4 Ls 6 x 4 x 1/2, 2 PLs 24 x 3/8	4 Ls 8 x 6 x 1, 2 WEB PLs 71 x 1/2, 2 PLs 30 x 3/4	4 Ls 4 x 4 x 1/2, 2 PLs 24 x 3/8
AREA OF SECTION - IN²	GROSS	22.7	22.7	22.7	22.7	22.7	25.7	25.7	25.7	25.7	30.2		26.3
	NET	18.2	18.2	18.2	18.2	18.2	21.2	21.2	21.2	21.2	26.7		20.8
NET SECTION MODULUS - IN³													
MATERIAL		CARBON STEEL											

* UNIT AXIAL STRESS ** UNIT FLEXUAL STRESS IN LATERAL DIRECTION

NOTES:

1. FOR GENERAL NOTES SEE SHEET Nos. 2 & 3.
2. RIVETS: 1" Ø RIVETS TO BE USED FOR FRONT TOWER COLUMNS. 7/8" Ø RIVETS TO BE USED FOR REAR TOWER COLUMNS AND ALL BRACING MEMBERS.
3. CAMBER: TOWER COLUMNS SHALL BE CAMBERED FOR FULL TOWER DEAD LOAD AND SHEAVE LOAD.
4. LOADING CONDITIONS:
   CASE 1— SPAN UP + DIRECT LOADS + 30 P.S.F. WIND.
   CASE 2— SPAN DOWN + DIRECT LOADS + 50 P.S.F. WIND.
   CASE 3— CWT. JACKED: DIRECT LOADS + 50 P.S.F. WIND.
5. FOR JACKING GIRDER SEE SHEET NO. 13.
6. SIDE BRACING DIAGONALS FgRh AND RgFh OF WEST FACE OF NORTH TOWER TO BE CHANGED TO PROVIDE FOR STAIR CASE TO ELEVATOR, SEE SHEET No. 31 FOR MATERIALS AND SECTIONS.

NO.	REVISIONS	BY	DATE

DEPARTMENT OF PUBLIC WORKS
CANADA
DEVELOPMENT ENGINEERING BRANCH
STRUCTURES DIVISION

C. C. PARKER & ASSOCIATES LTD
CONSULTING ENGINEERS
HAMILTON ONTARIO

BURLINGTON CANAL LIFT BRIDGE

TOWER-STRESS SHEET

REGISTERED PROFESSIONAL ENGINEER — PROVINCE OF ONTARIO — CIVIL — I. M. WALLACE

APPROVED DATE 13/11/58 — CHIEF STRUCTURES DIVISION

APPROVED DATE 14/11/58 — CHIEF ENGINEER

DEPARTMENT PROJECT NO. SD6-4-77

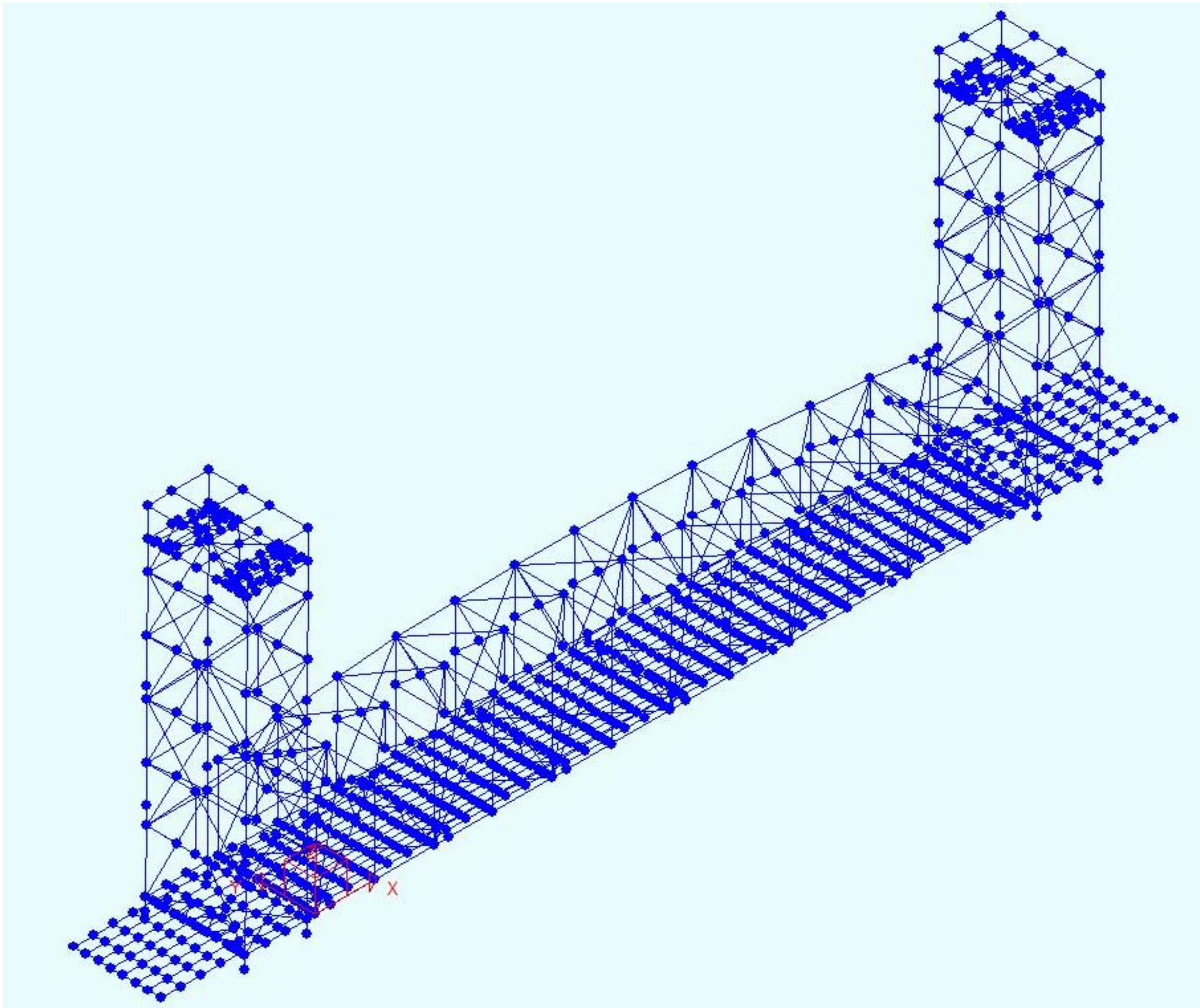
RECOMMENDED DATE 1-12-58 — C. C. PARKER & ASSOC. LTD.

DESIGN R.K.C.C. CHKD. G.W.A.
DRAWN J.B. CHKD. G.W.A.
TRACED M.C. & D.H. CHKD. R.K.C.C.

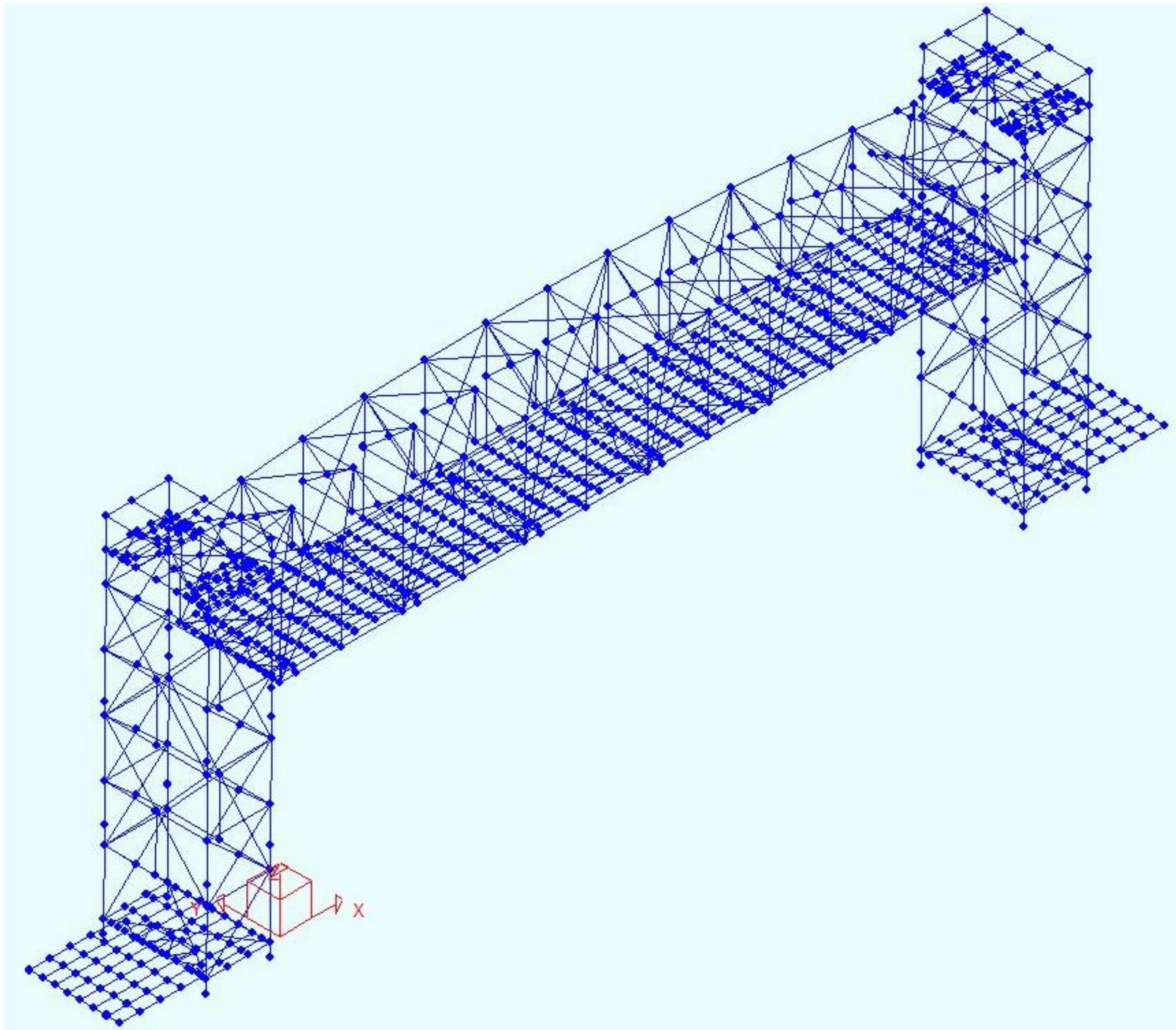
CONTRACT NO. 2

SHEET 19 OF 62

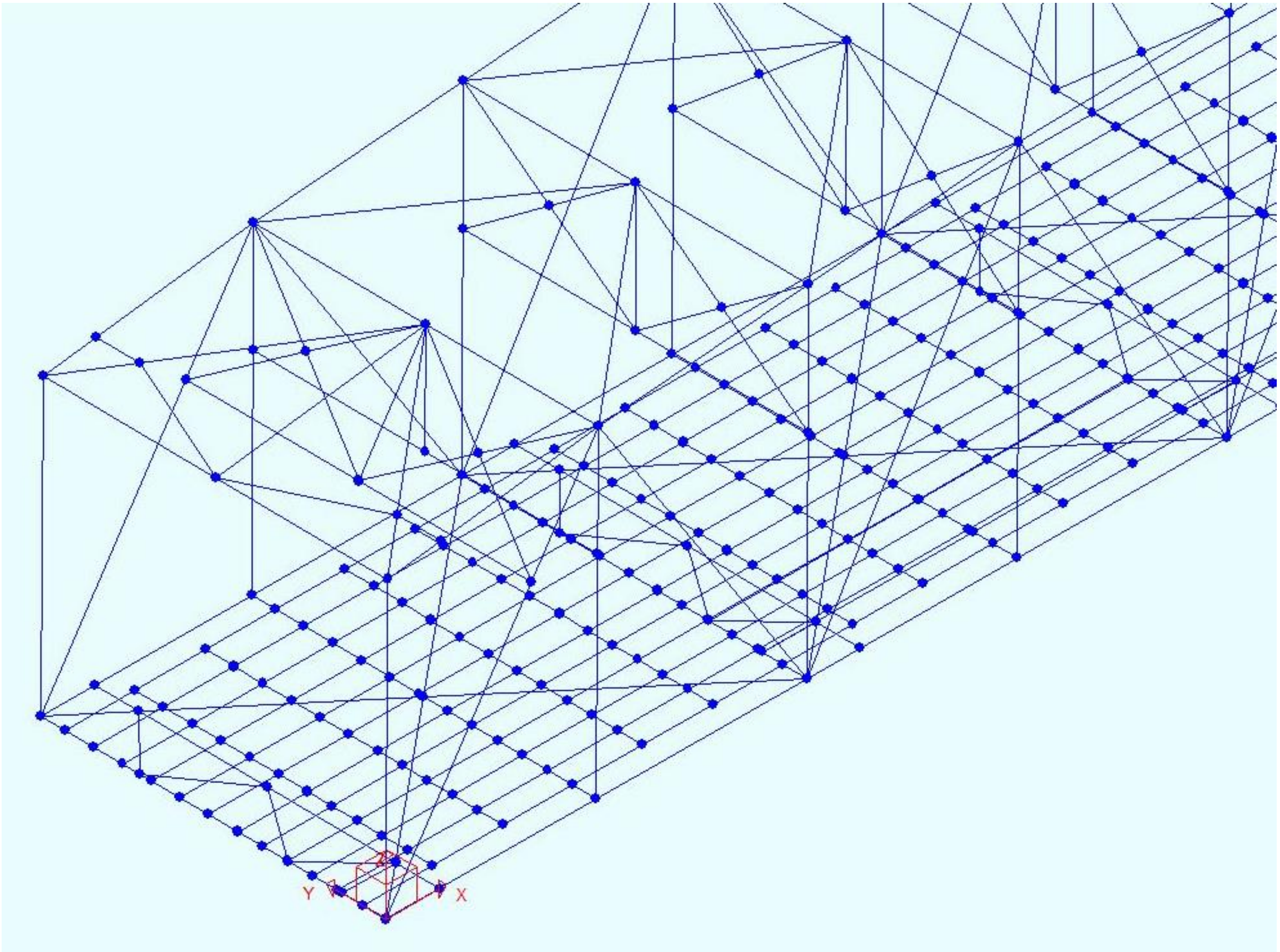
APPENDIX B.1
FRAME MODEL DIAGRAMS



Model: Fully Closed Position



Model: Raised Position



Model: Close-up of lift span at south end

APPENDIX B.2
FRAME MODEL MEMBER NUMBERING SCHEME

FRAME MODEL MEMBER NUMBERING SCHEME

LIFT SPAN 2X XXX

➢ Railway Truss	21,XXX
> Top Chord	21,1XX
> Bottom Chord	21,2XX
> Diagonals	21,3XX
> Verticals	21,4XX
➢ Highway Truss	22,XXX
> Top Chord	22,1XX
> Bottom Chord	22,2XX
> Diagonals	22,3XX
> Verticals	22,4XX
➢ Floor Beams	23,XXX
> End	23,1XX
> Interior	23,2XX
➢ Stringers	24,XXX
➢ Lifting Girder	25,XXX
➢ Diaphragms	26,XXX
➢ Traction Bracing	27,XXX
➢ Railway Stringers	28,XXX
➢ Bracing	29,XXX
> Top Lateral	29,1XX
> Bottom Lateral	29,2XX
> Portal Frame	29,3XX
> Sway Frame	29,4XX

TOWER 3X XXX

- Columns 31,XXX
  - Top 31,1XX
  - Middle 31,2XX
  - Bottom 31,3XX

- Bracing 32,XXX
  - Side 32,1XX
  - Front 32,2XX
  - Back 32,3XX

- Sheave Girders 33,XXX
  - Front 33,1XX
  - Rear 33,2XX
  - Longitudinal 33,3XX

- Diaphragms 34,XXX

- Stringers 35,XXX

- Floor Beams 36,XXX

- Lateral Bracing 37,XXX

- Traction Bracing 38,XXX

- Bracing (Sheave) 39,XXX

- Machine House 30,XXX

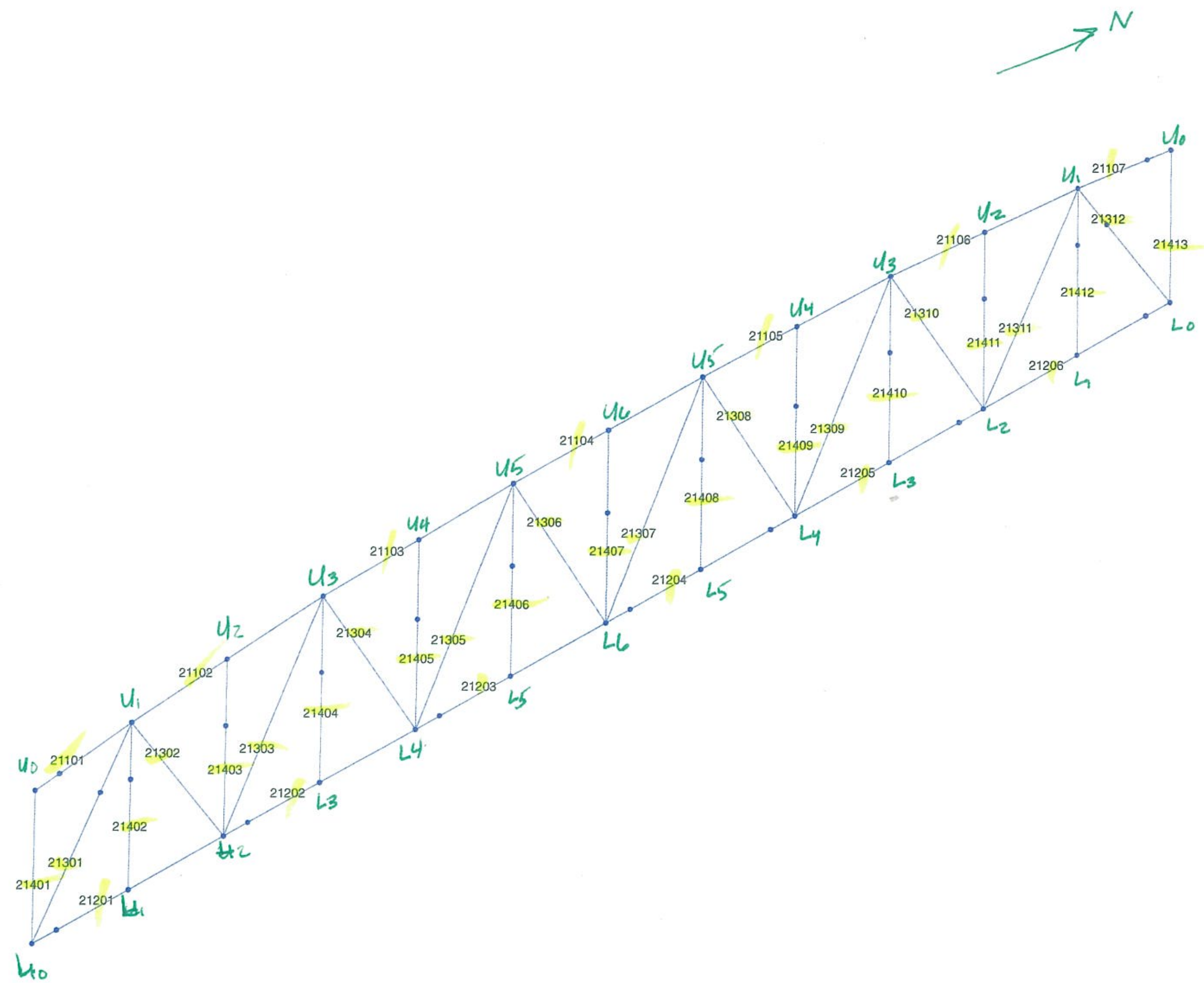
APPROACHES 4X XXX

- Stringers 41,XXX

- Diaphragms 42,XXX

MMM Group Ltd. 2655 North Sheridan Way Mississauga, Ontario 905-823-8500	**RS-6 3D Modelling and Structural Analyses** Filename: C:\Users\YusekK\Desktop\3813009 BLB S-Frame Files\Mar 5, 2014\3813009 KY BLB ANALYSIS RAISED 05.03.2014.TEL Description: Burlington Lift Bridge Engineer: KY	Page: 1 of 1

LIFT-RAILWAY TRUSS



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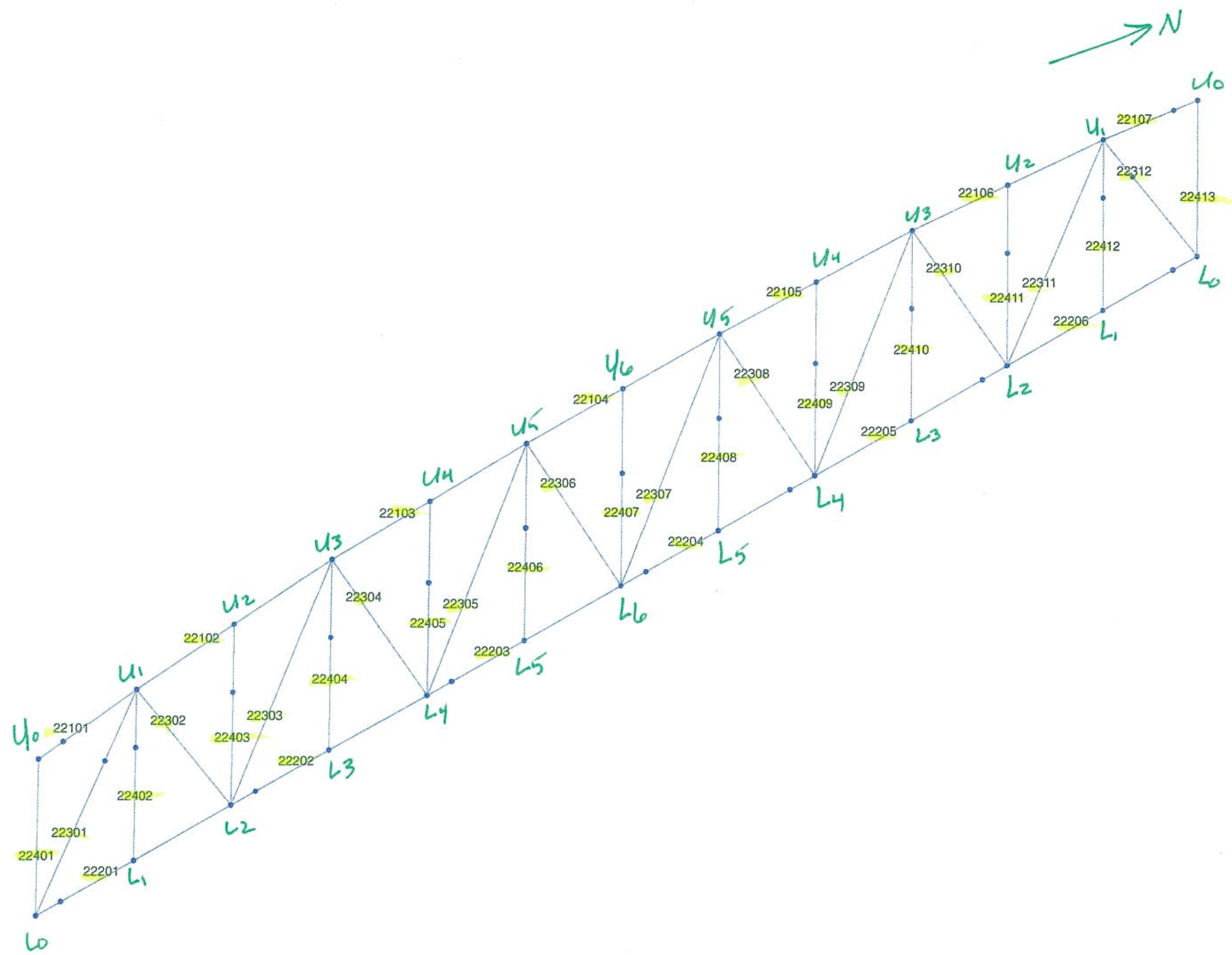
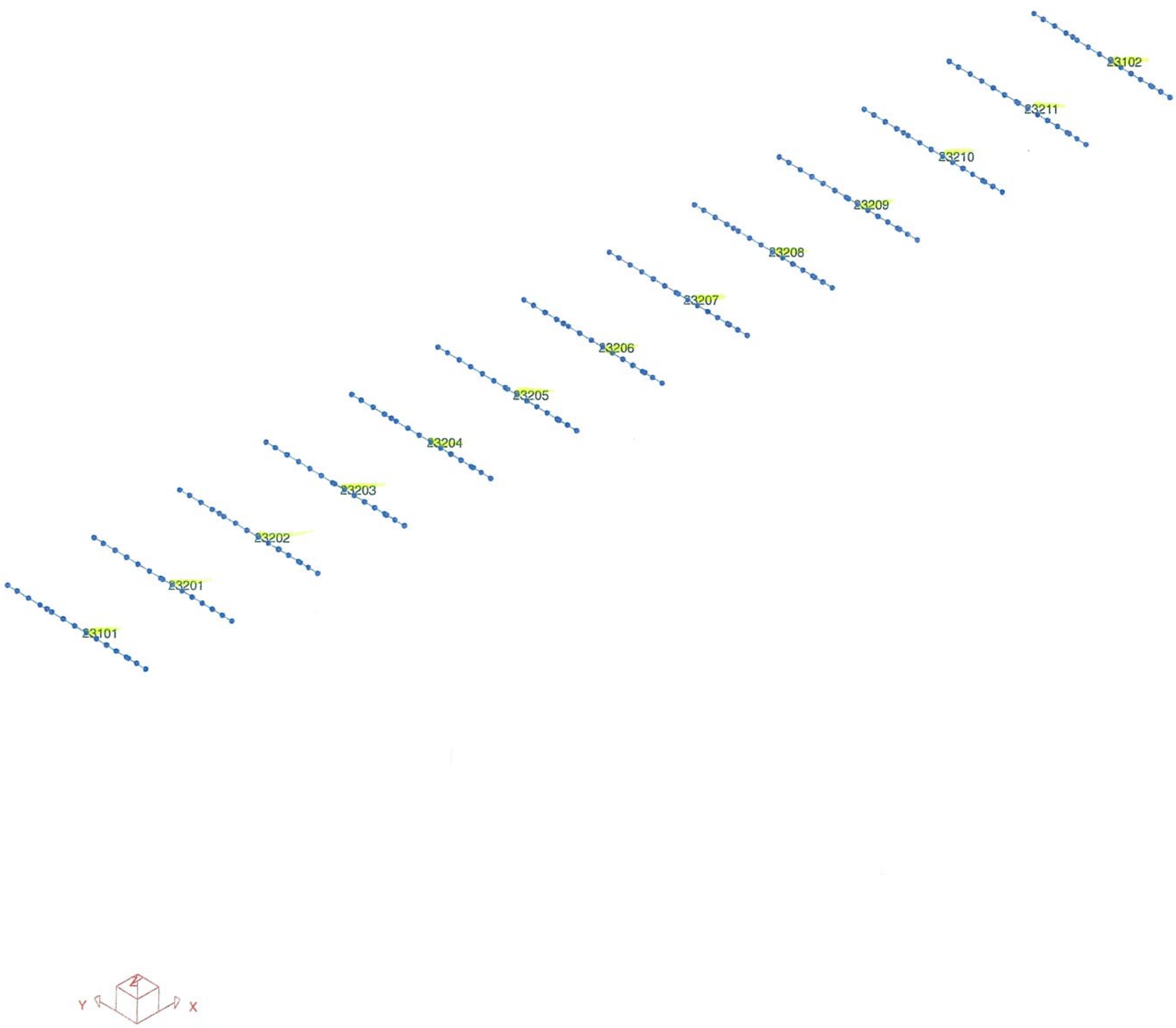
RS-6 3D Modelling and Structural Analyses
Filename: C:\Users\YusekK\Desktop\3813009 BLB S-Frame Files\Mar 5, 2014\3813009 KY BLB ANALYSIS RAISED 05.03.2014.TEL
Description: Burlington Lift Bridge
Engineer: KY

LIFT-HIGHWAY TRUSS



LIFT- FLOOR BEAMS

- END
- INT



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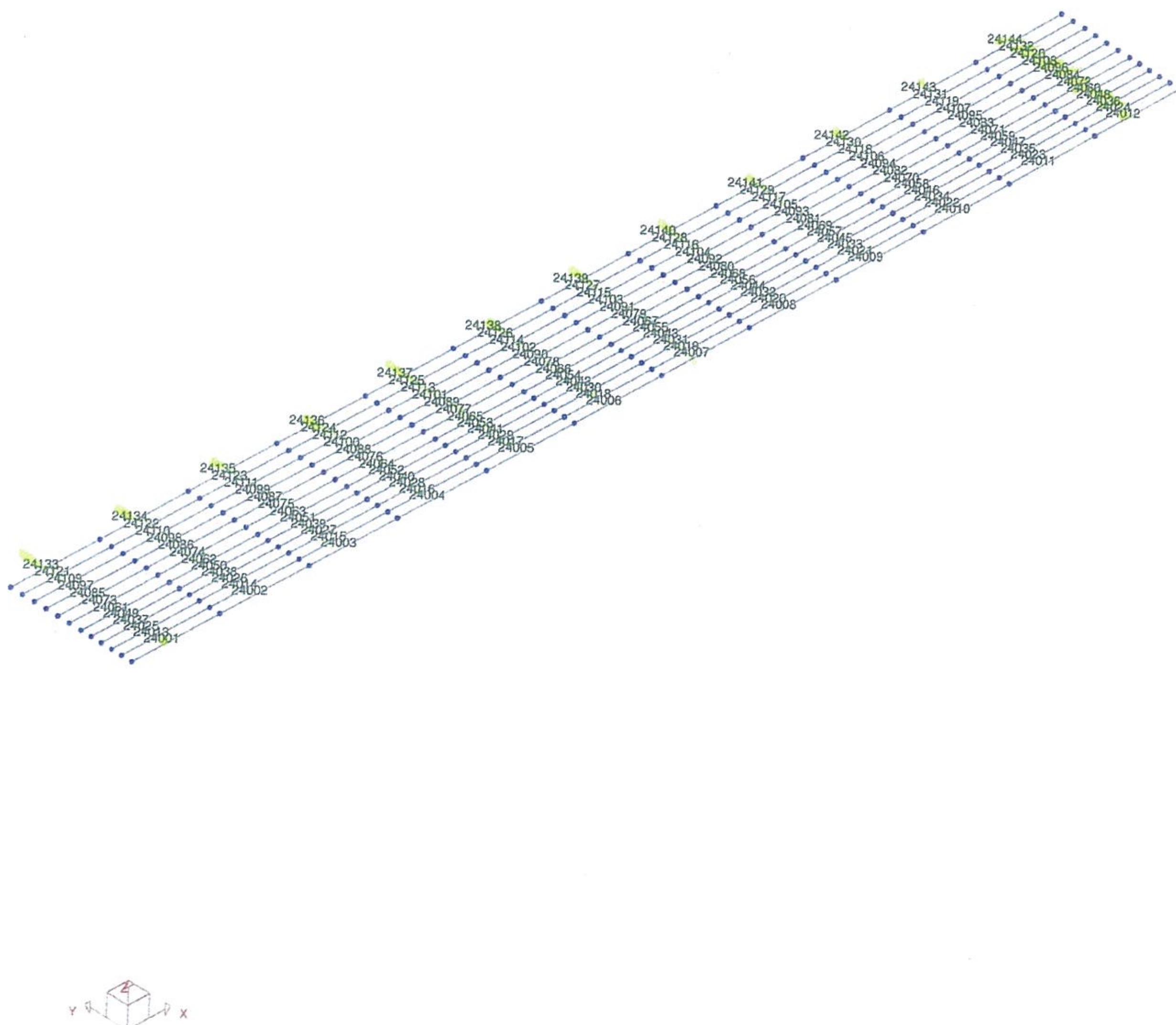
Filename: C:\Users\YusekK\Desktop\3813009 BLB S-Frame Files\Mar 5, 2014\3813009 KY BLB ANALYSIS RAISED 05.03.2014.TEL

Description: Burlington Lift Bridge

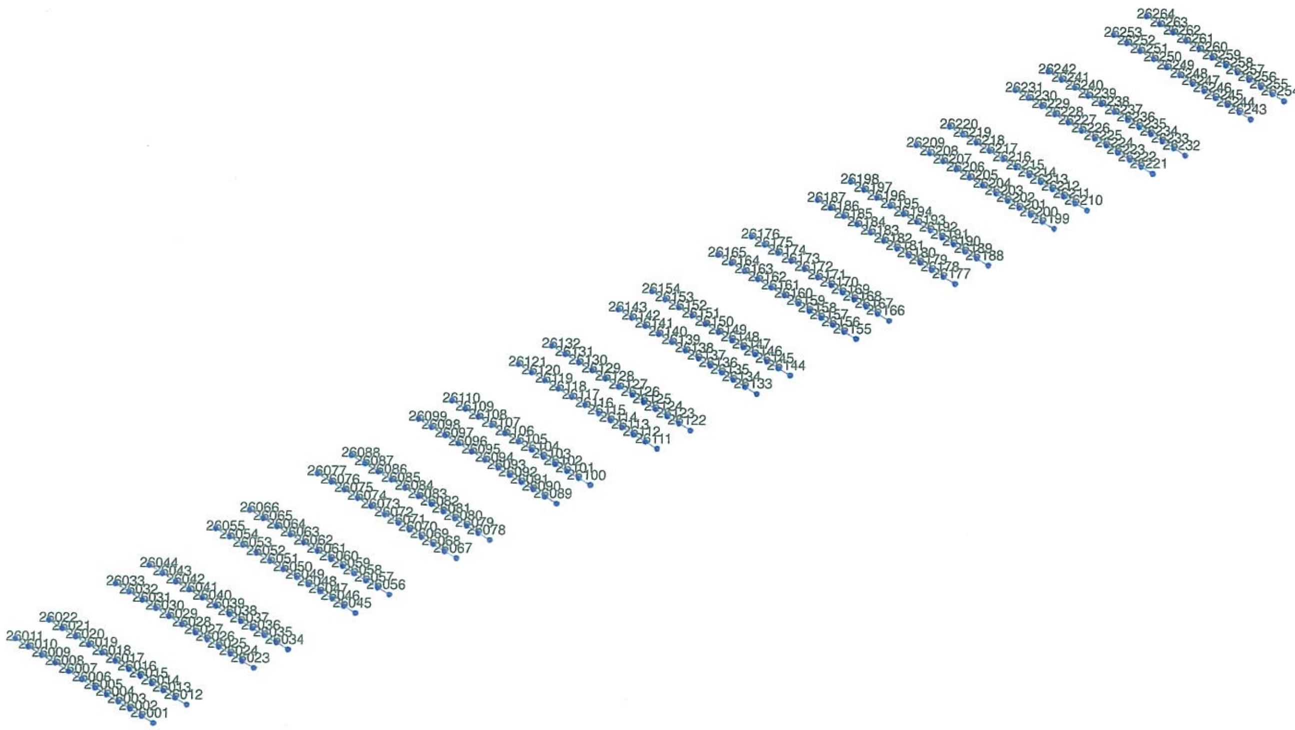
Engineer: KY

LIFT - STRINGERS



LIFT - LIFTING GIRDER

LIFT- DIAPHRAGMS



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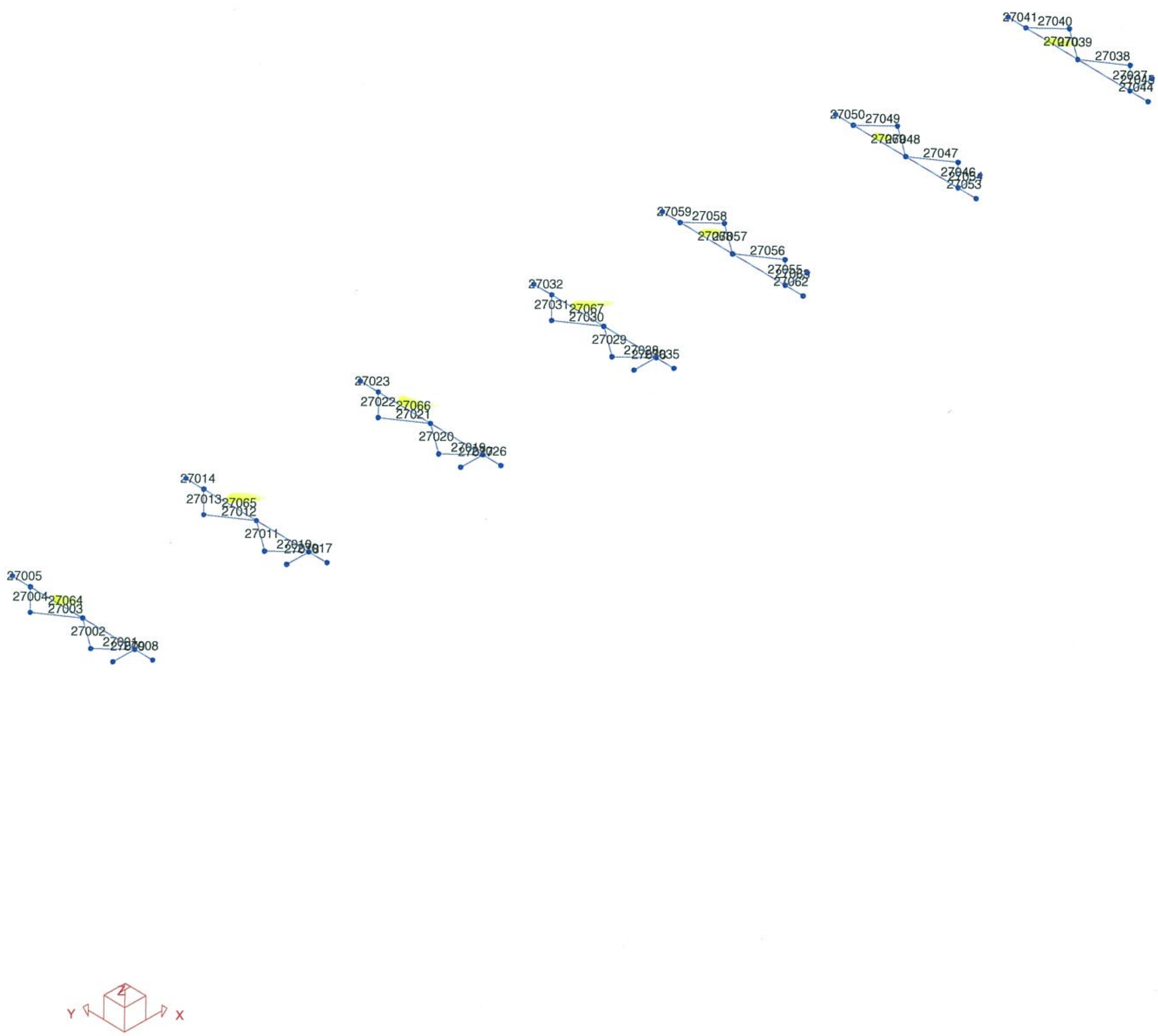
RS-6 3D Modelling and Structural Analyses

Filename: C:\Users\YusekK\Desktop\3813009 BLB S-Frame Files\Mar 5, 2014\3813009 KY BLB ANALYSIS RAISED 05.03.2014.TEL

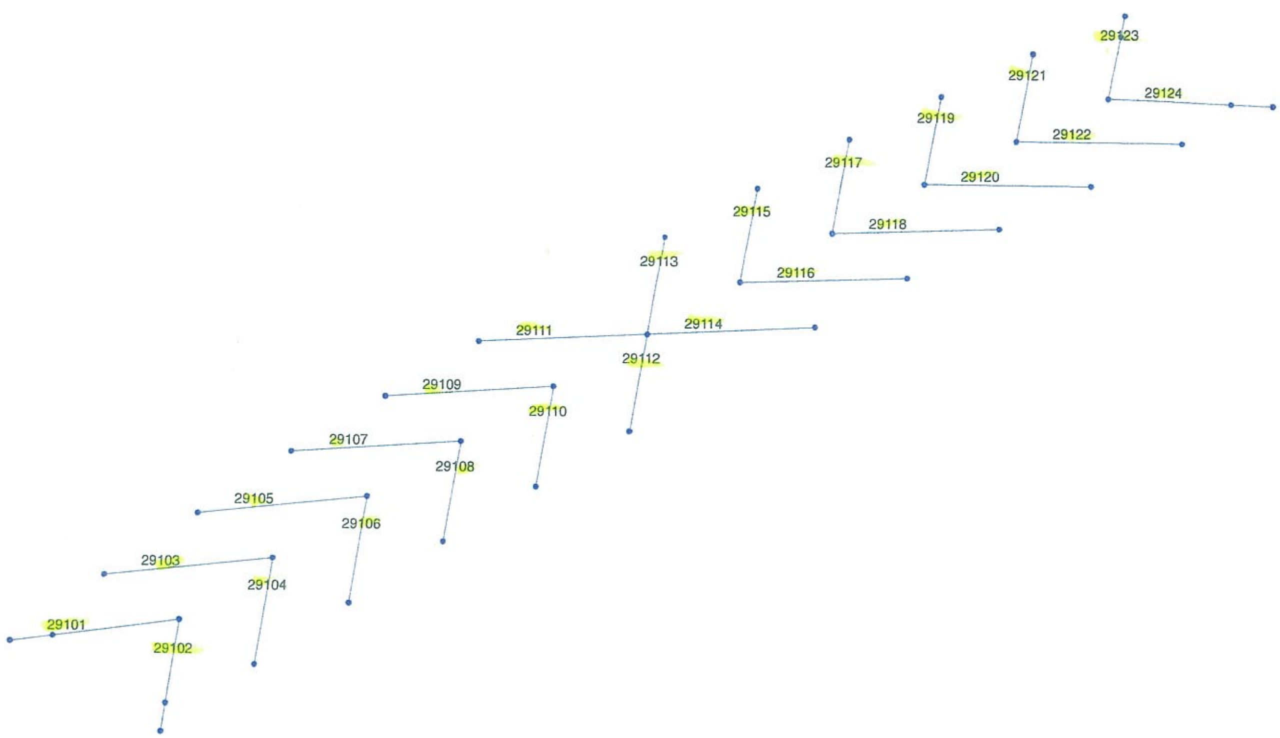
Description: Burlington Lift Bridge

Engineer: KY

LIFT - TRACTION BRACING



LIFT – TOP LATERAL BRACING



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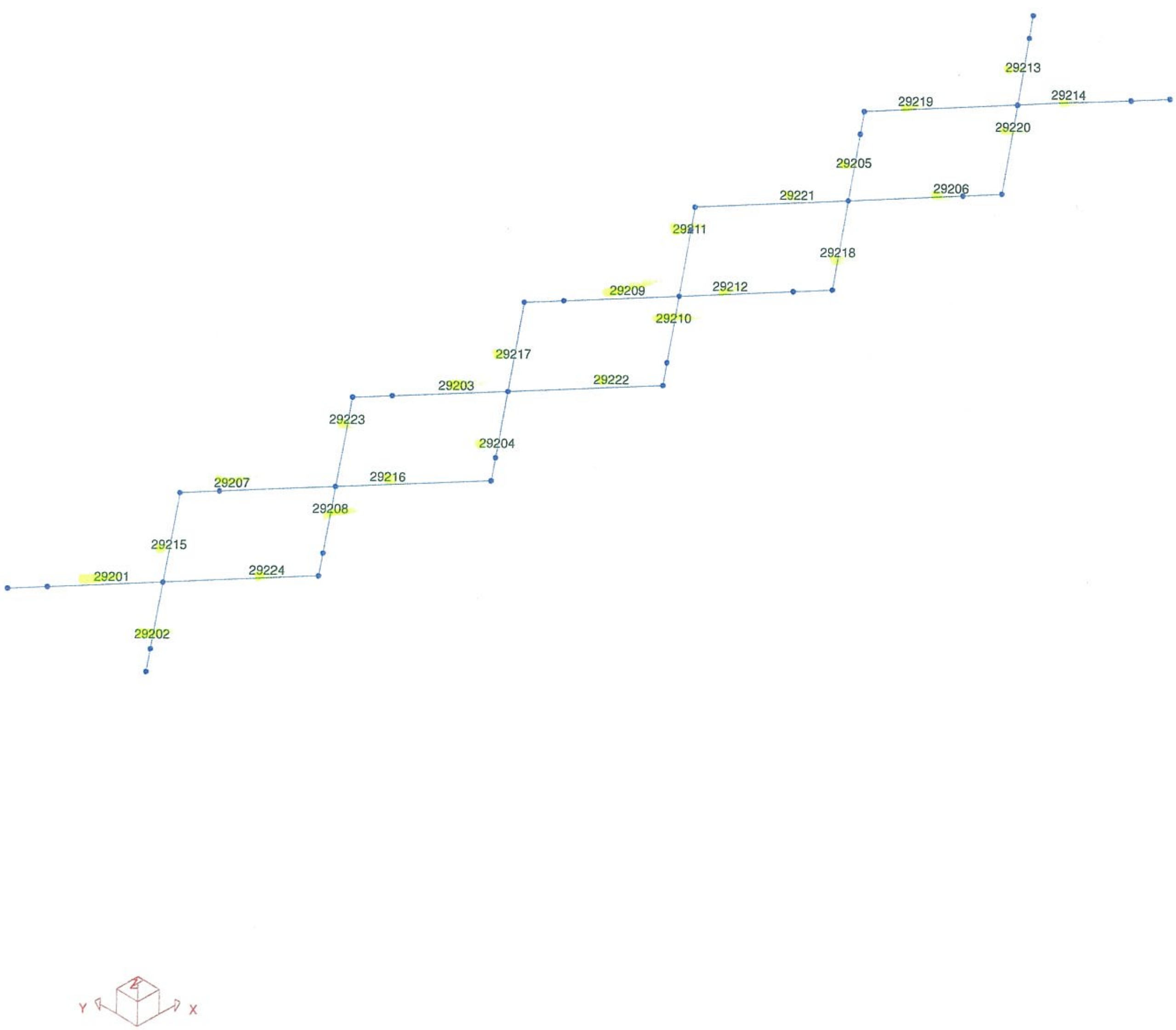
RS-6 3D Modelling and Structural Analyses

Filename: C:\Users\YusekK\Desktop\3813009 BLB S-Frame Files\Mar 5, 2014\3813009 KY BLB ANALYSIS RAISED 05.03.2014.TEL

Description: Burlington Lift Bridge

Engineer: KY

LIFT - BOT. LATERAL. BRACING



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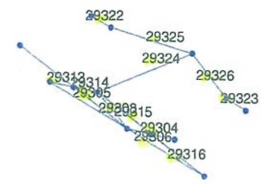
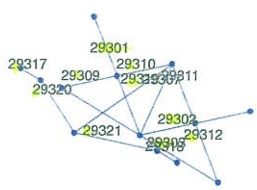
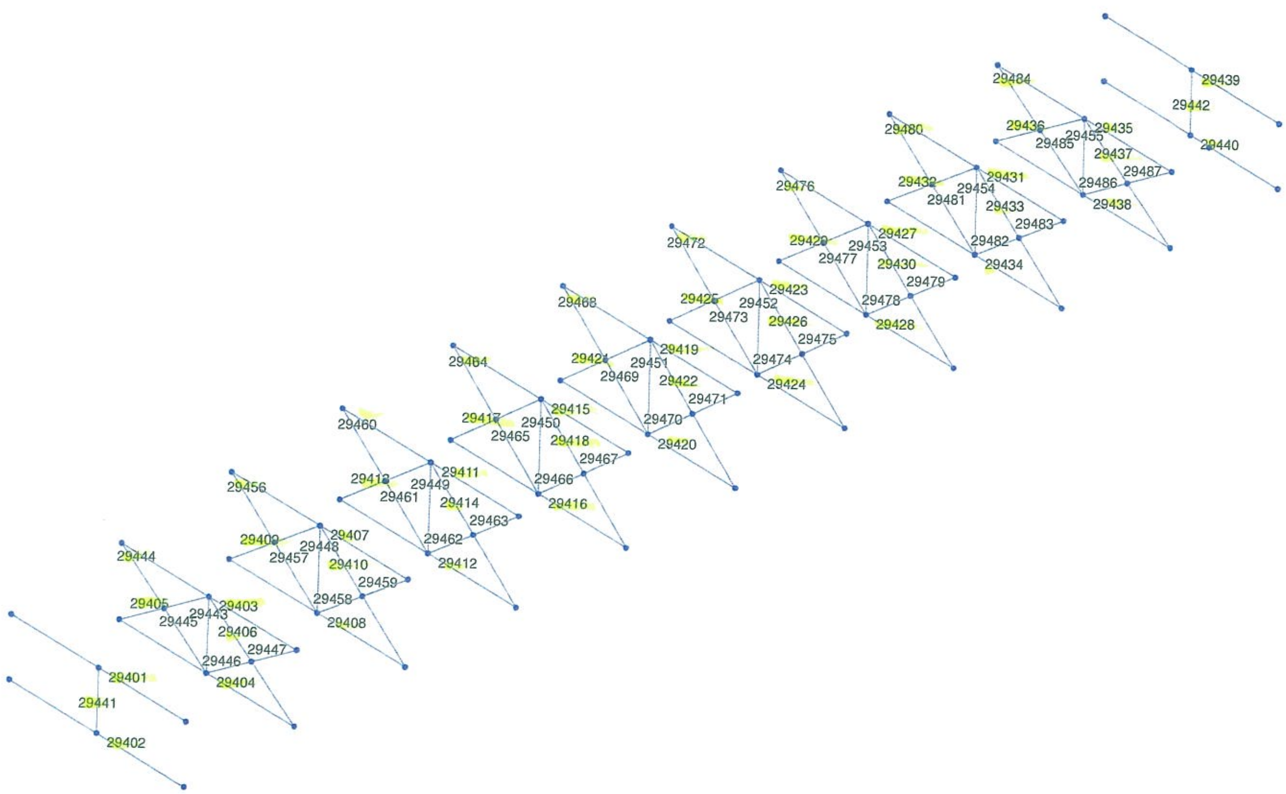
LIFT PORTAL BRACING



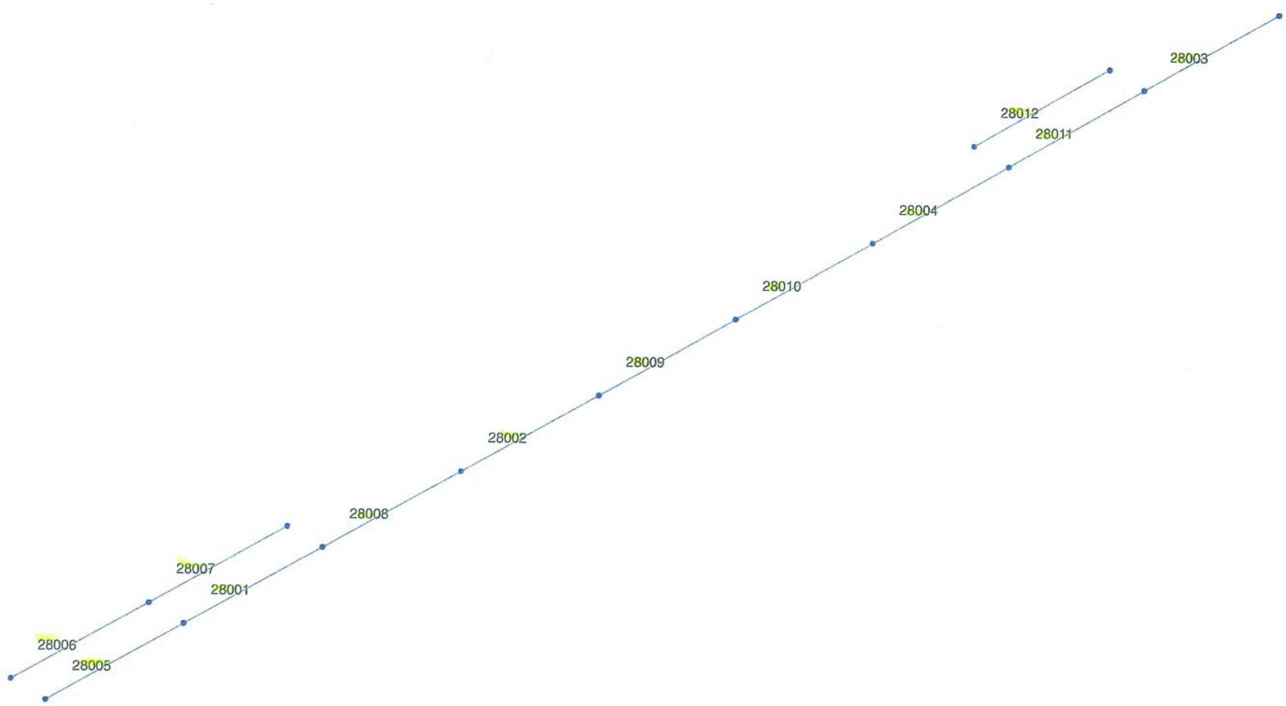


MMM Group Ltd. 2655 North Sheridan Way Mississauga, Ontario 905-823-8500	**RS-6 3D Modelling and Structural Analyses** Filename: C:\Users\YusekK\Desktop\3813009 BLB S-Frame Files\Mar 5, 2014\3813009 KY BLB ANALYSIS RAISED 05.03.2014.TEL Description: Burlington Lift Bridge Engineer: KY	

LIFT – SWAY BRACING



LIFT - RAILWAY STRINGERS



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RS-6 3D Modelling and Structural Analyses
Filename: C:\Users\YusekK\Desktop\3813009 BLB S-Frame Files\Mar 5, 2014\3813009 KY BLB ANALYSIS RAISED 05.03.2014.TEL
Description: Burlington Lift Bridge
Engineer: KY

APPROACHES – GIRDERS

APPROACHES - DIAPHRAGMS

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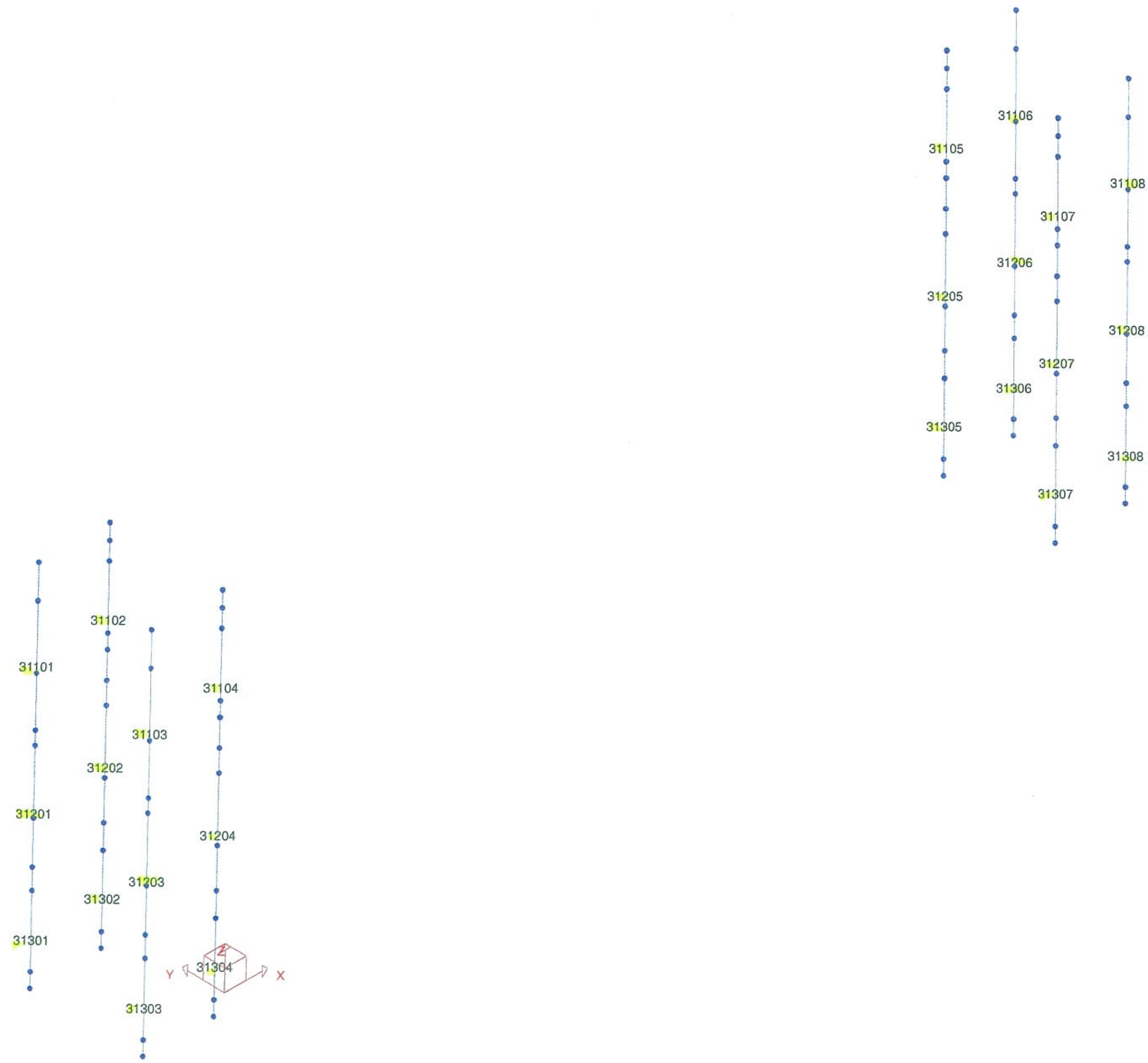
Filename: C:\Users\YusekK\Desktop\3813009 BLB S-Frame Files\Mar 5, 2014\3813009 KY BLB ANALYSIS RAISED 05.03.2014.TEL

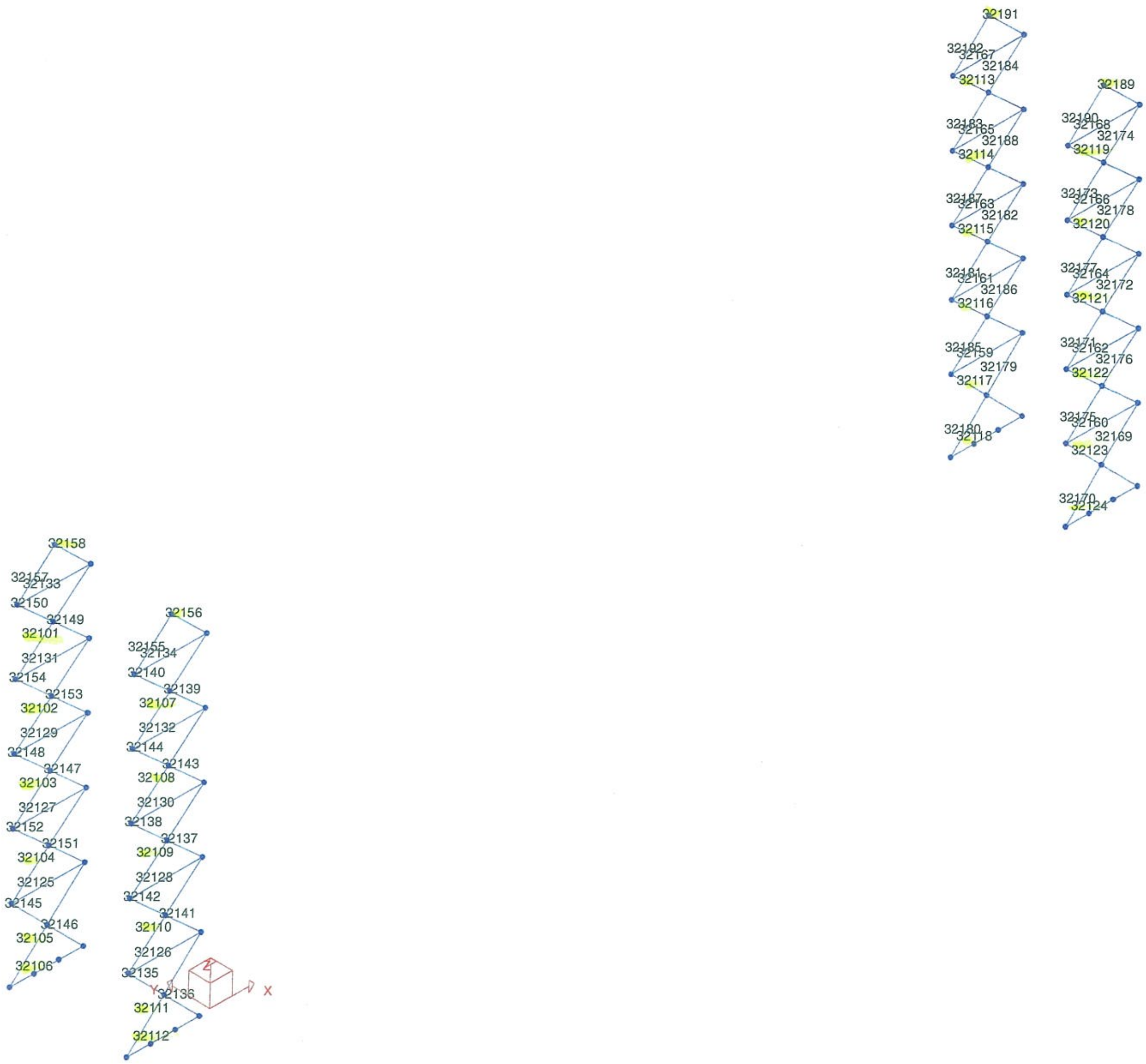
Description: Burlington Lift Bridge

Engineer: KY

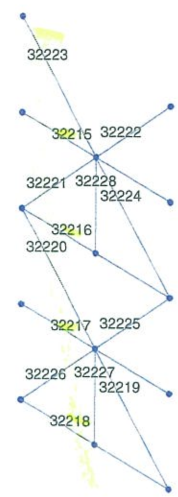
Towers – Columns

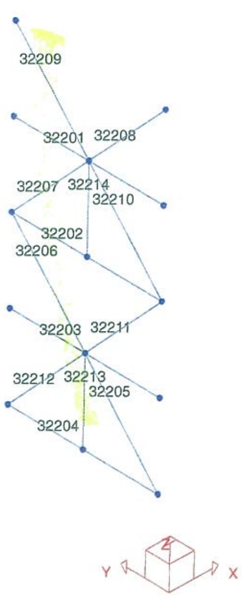


TOWERS - SIDE BRACING

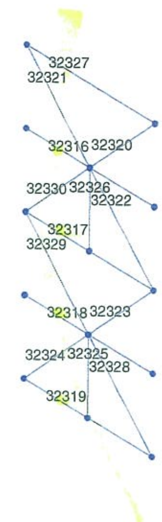


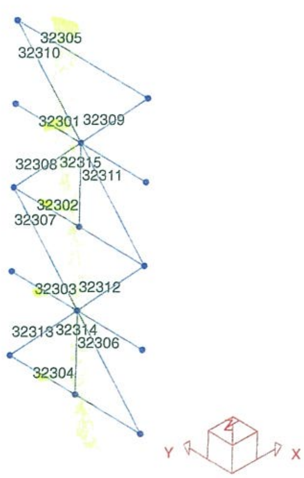
TOWERS – FRONT BRACING





TOWERS – BACK BRACING





TOWER - FRONT TRANS. SHEAVE GIRDER

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RS-6 3D Modelling and Structural Analyses
Filename: C:\Users\YusekK\Desktop\3813009 BLB S-Frame Files\Mar 5, 2014\3813009 KY BLB ANALYSIS RAISED 05.03.2014.TEL
Description: Burlington Lift Bridge
Engineer: KY

TOWERS - REAR TRANS. SHEAVE GIRDER

TOWERS – LONG. SHEAVE GIRDERS

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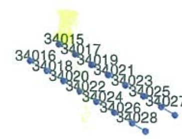
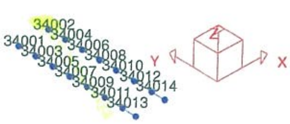
Filename: C:\Users\YusekK\Desktop\3813009 BLB S-Frame Files\Mar 5, 2014\3813009 KY BLB ANALYSIS RAISED 05.03.2014.TEL
Description: Burlington Lift Bridge
Engineer: KY

TOWERS – DIAPHRAGMS





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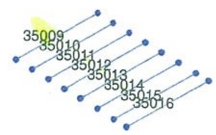
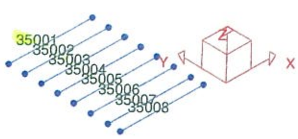
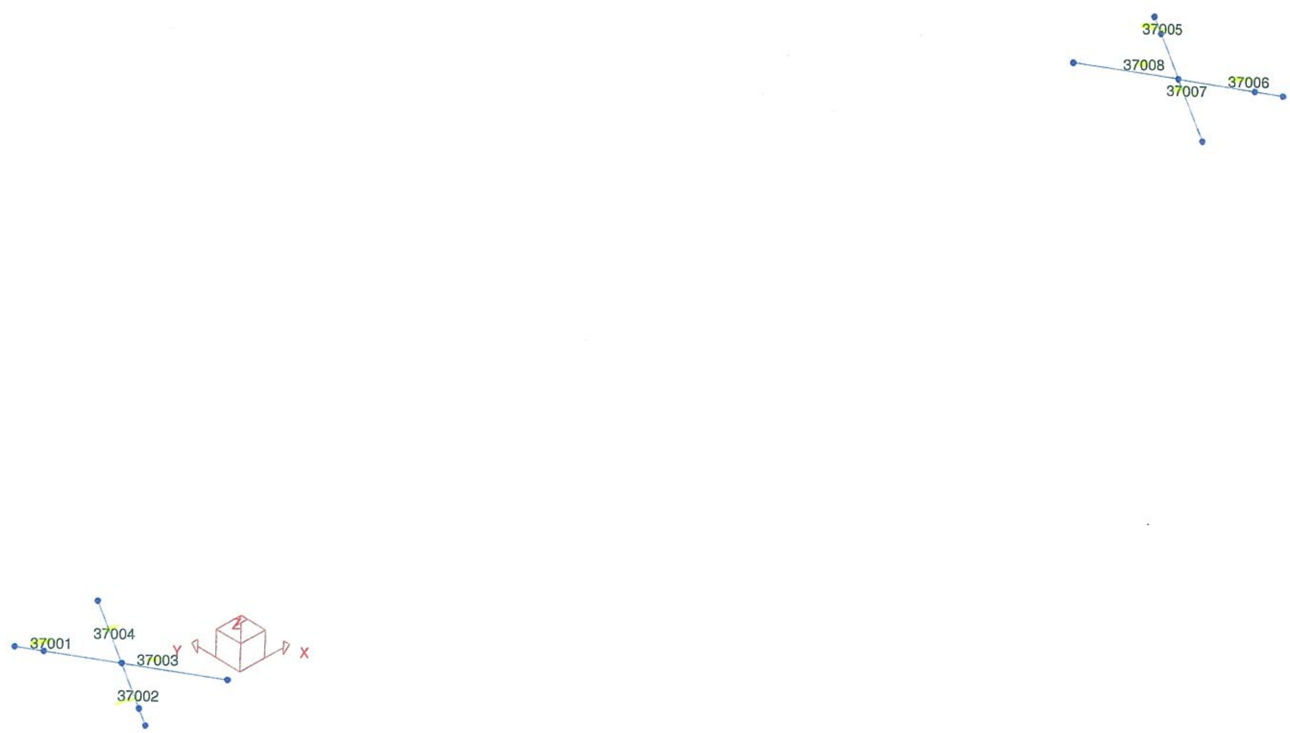
TOWERS - STRINGERS





TOWERS - FLOOR BEAMS

TOWERS – LAT. BRACING



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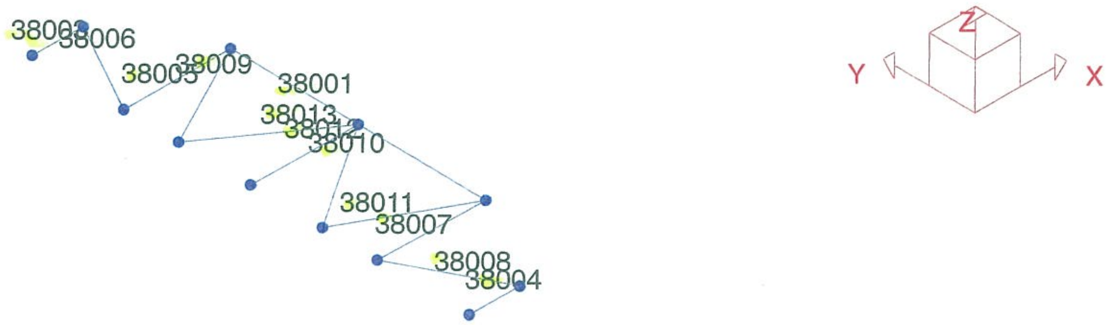
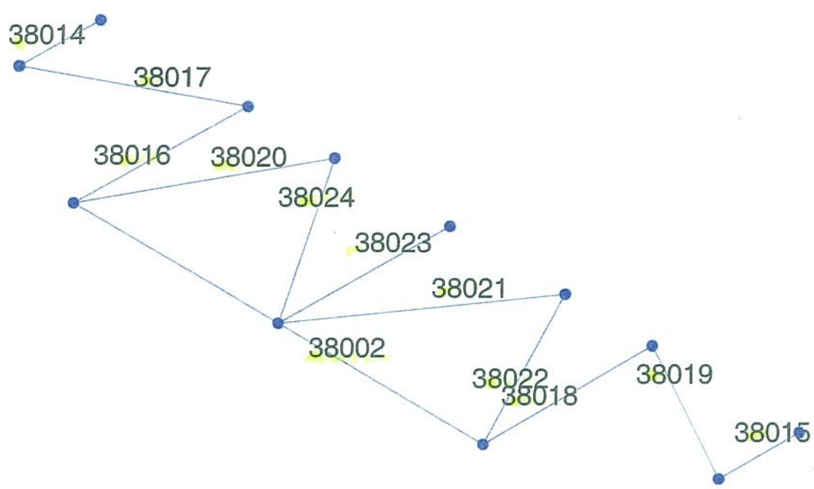
RS-6 3D Modelling and Structural Analyses
Filename: C:\Users\YusekK\Desktop\3813009 BLB S-Frame Files\Mar 5, 2014\3813009 KY BLB ANALYSIS RAISED 05.03.2014.TEL
Description: Burlington Lift Bridge
Engineer: KY

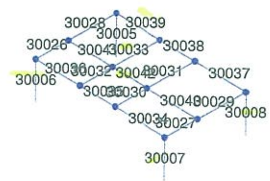
TOWERS - SOUTH TRACTION BRACING

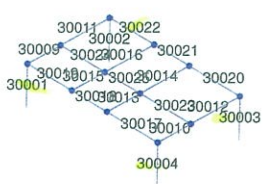


TOWERS - NORTH TRACTION BRACING

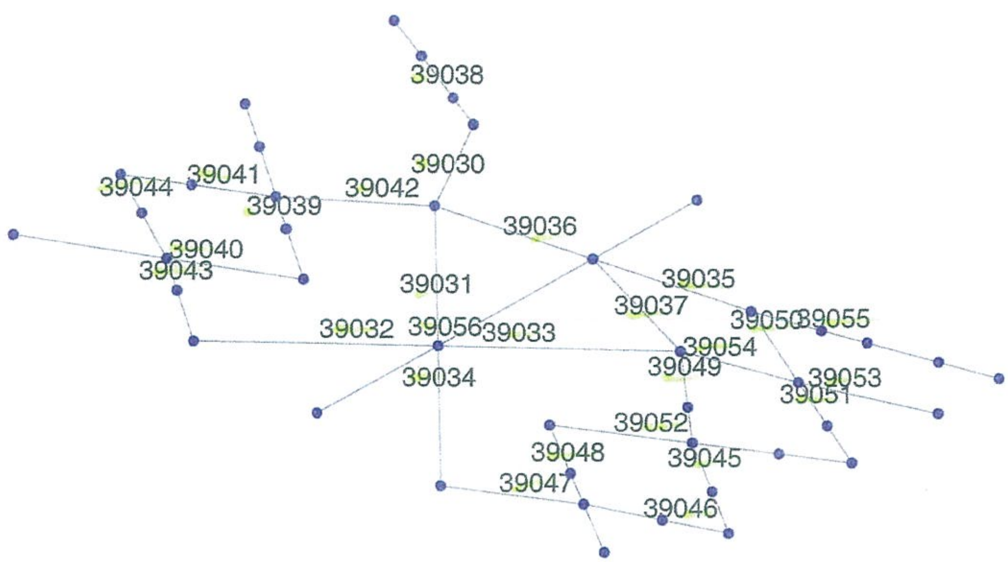


TOWERS – MACHINE HOUSE

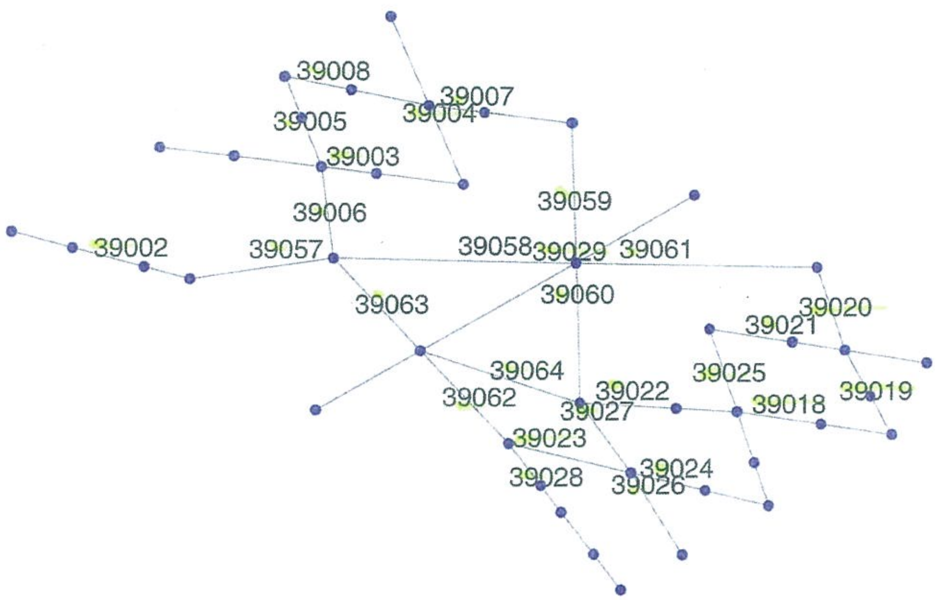




TOWERS - NORTH - SHEAVE GIRDER BRACING



TOWERS – SOUTH SHEAVE GIRDER BRACING



APPENDIX B.3
FRAME MODEL SECTION NAMING SCHEME

FRAME MODEL SECTION NAMING SCHEME

FORMAT: XXXX - XXXX - XXXX
1 2 3

1.	SPAN:	Towers	- TOWR
		Lift Span	- LIFT
2	ELEMENT:	Railway Truss	- RLYT
		Highway Truss	- HWYT
		Floor Beam	- FLBM
		Stringer	- STRG
		Diaphragm	- DIAP
		Traction Bracing	- TRBG
		Girder	- GRDR
		Portal Frame	- PORT
		Sway Frame	- SWAY
		Lifting Girder	- LFGR
		Top Lateral	- TLAT
		Bottom Lateral	- BLAT
		Railway Stringer	- RLSTR
		Front Column	- FCOL
		Rear Column	- RCOL
		Front Bracing	- FBRC
		Back Bracing	- BBRC
		Side Bracing	- SBRC
		Stringer	- STRG
		Floor Beam	- FLBM
		Diaphragm	- DIAP
		Lateral Bracing (Bot)	- BLAT
		Traction Bracing	- TBRG
		Sheave Girders	- SHVG
		Sheave Bracing	- SHVB
3	SUB-ELEMENT (If Applicable):		
		Vertical Truss Member LoUo	- LoUo (Typical for other truss members)
		Intermediate	- INT
		End	- END
		Top Strut	- TSTR
		Bottom Strut	- BSTR

Sway Bracing (Cross)	- SWBC
Sway Bracing (Vertical)	- SWBV
End Lateral Bracing	- LATD
End Lat. Bracing (Long)	- LATL
End Lat. Bracing (Trans)	- LATT
LIFT-STRG	- W24 x 84
LIFT-DIAP	- C12 x 207
LIFT-RLST	- W36 x 230
Upper Tower Column	- UCOL
Mid Tower Column	- MCOL
Lower Tower Column	- LCOL
Side Bracing Diagonals	- DIAG
Horizontals C, D, E, F	- HORIZ
Tower Front Floorbeam	- FRNT
Tower Rear Floorbeam	- REAR
Front Lateral Bracing	- FRTL
Railway Side Rear Lateral	- RLYR
Highway Side Rear Lateral	- HWYR
Member FC:FE’, FC’:FE	- UDIA
Member FE:FG, FE’:FG	- MDIA
Member Sb:FC; Sb:RC	- SbFc
Member Cd:Ce; Cf:Cg;	- CdCe
Member Md:Me; Mf:Mg	- MdMe
Member Rc’:Rc	- RcRc
Member FG:FG`	- Fg:Fg*
Member FF:FF`	- FfFf*
Member FE:FE`	- FeFe*
Member FD:FD`	- FdFd*
Member FG:RG	- FgRg
Member Fr:RH	- FhRh

* Rear Bracing similar but with “R” instead of “F”

OTHER

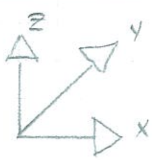
2L’S	- Miscellaneous Bracings
C’s	- Diaphramgs
W24x84	- Original Stringers
W36x23	- Railway Stringers

APPENDIX B.4
FRAME MODEL SUPPORT CONDITIONS

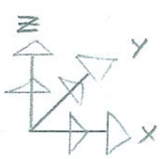
SUPPORT CONDITIONS

APPROACH SPAN 2
TOWER 3
LIFT SPAN 4

LEGEND



SINGLE ARROW:
TRANSLATION FIXED
ALONG SPECIFIED AXES



DOUBLE ARROW:
ROTATION FIXED ABOUT
SPECIFIED AXES

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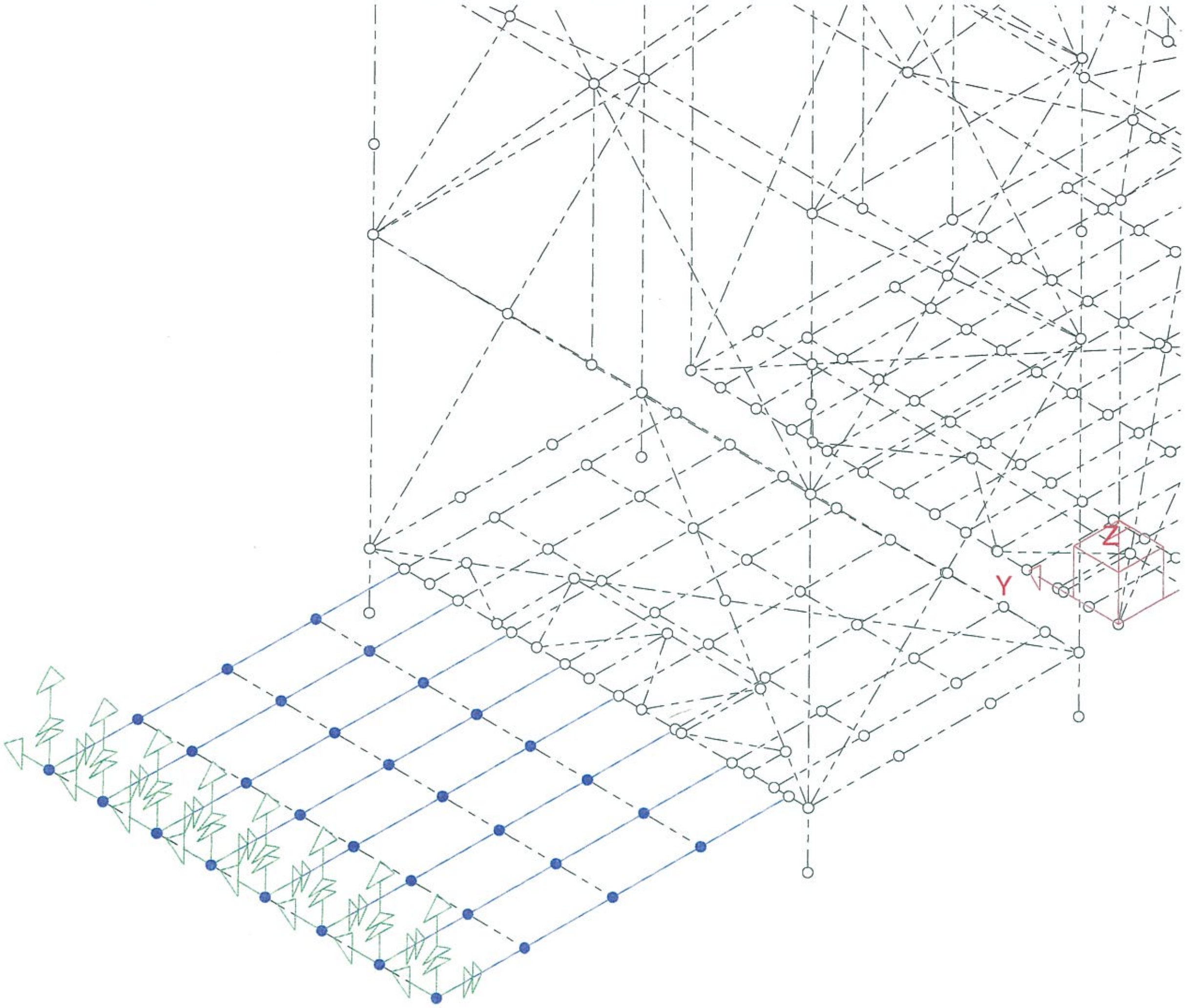
RS-6 3D Modelling and Structural Analyses
Filename: C:\Users\YusekK\Desktop\3813009 BLB S-Frame Files\24.01.2014\3813009 KY BLB ANALYSIS 24.01.2014.TEL
Description: Burlington Lift Bridge
Engineer: KY



APPROACH SPAN SUPPORT CONDITIONS

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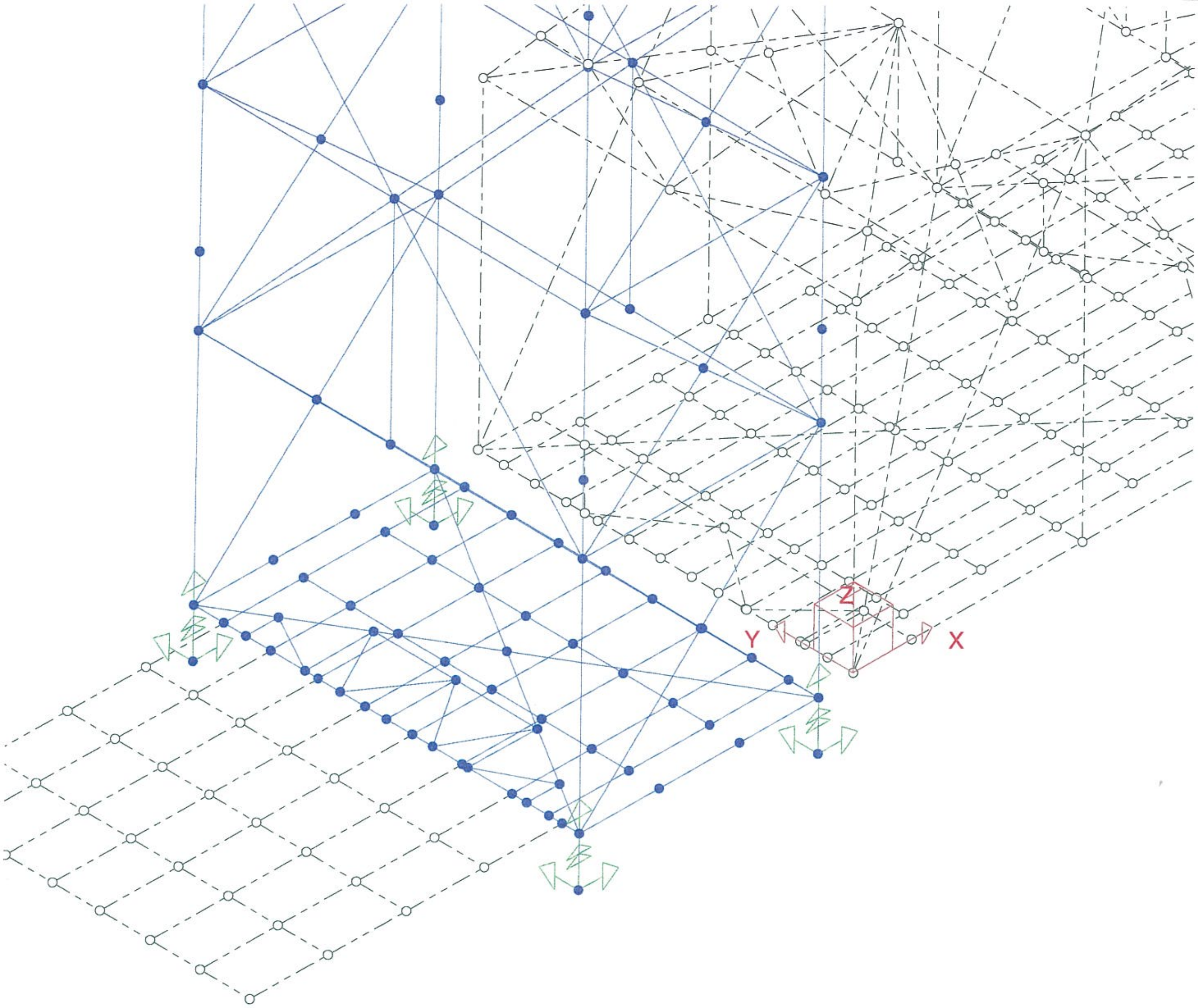

NOTE: DISREGARD INTERMEDIATE FRONT/REAR FLOORBEAM SUPPORTS

TOWER SUPPORT CONDITIONS

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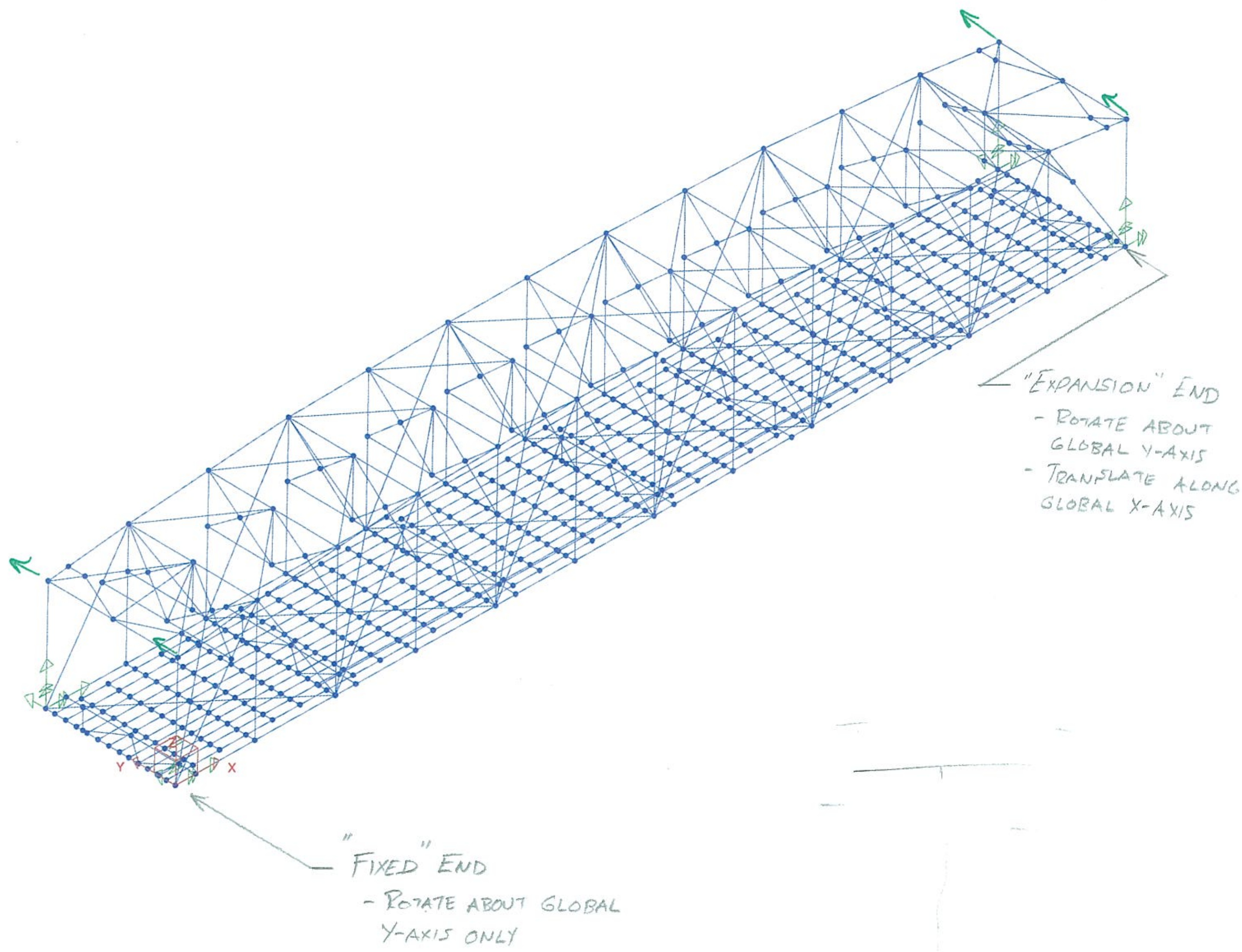
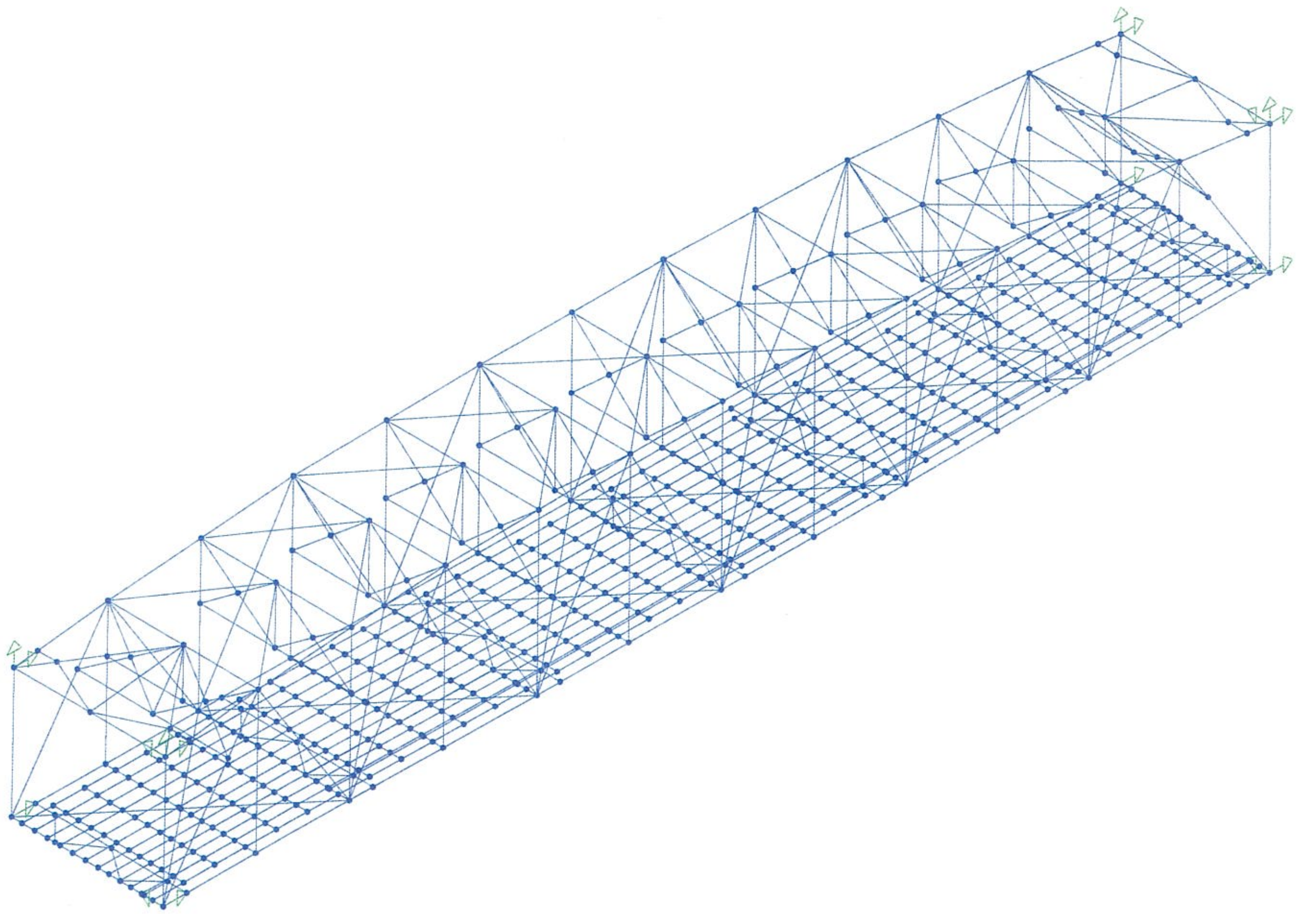
RS-6 3D Modelling and Structural Analyses
Filename: C:\Users\YusekK\Desktop\3813009 BLB S-Frame Files\24.01.2014\3813009 KY BLB ANALYSIS 24.01.2014.TEL
Description: Burlington Lift Bridge
Engineer: KY



LIFT SPAN SUPPORT CONDITIONS – CLOSED



– NOTE: SIMULATING GUIDE ROLLERS WHEN A WIND IS APPLIED ALONG THE GLOBAL Y-AXIS.

APPENDIX B.5
FRAME MODEL MEMBER END RELEASES

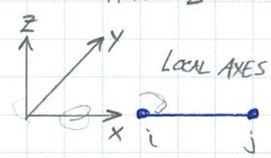
MEMBER END RELEASES - LIFT SPAN

TYPICAL SWAY FRAME	2
TRUSS	3
BOTTOM LATERAL BRACING (LIFT SPAN)	4
TOP BRACING, LATERAL AND END (LIFT SPAN)	5
FLOOR BEAMS (LIFT SPAN)	6
STRINGERS (LIFT SPAN)	7
STRINGER DIAPHRAGMS (LIFT SPAN)	8
TRACTION BRACING (LIFT SPAN)	9
RAILWAY STRINGERS (LIFT SPAN)	10

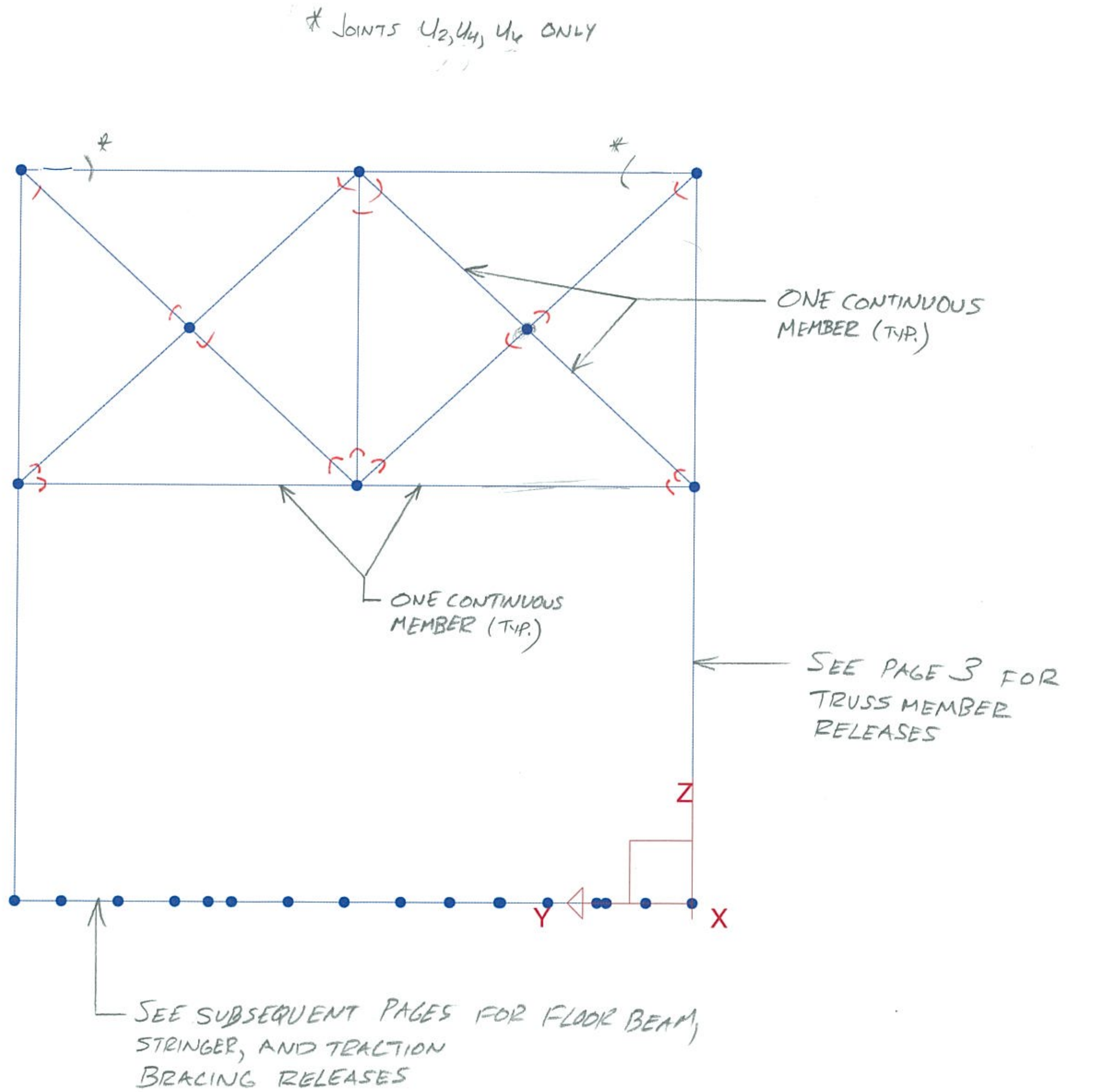
LEGEND

RELEASED MOMENT ABOUT LOCAL Y- AND Z-AXES (I.E. PIN)

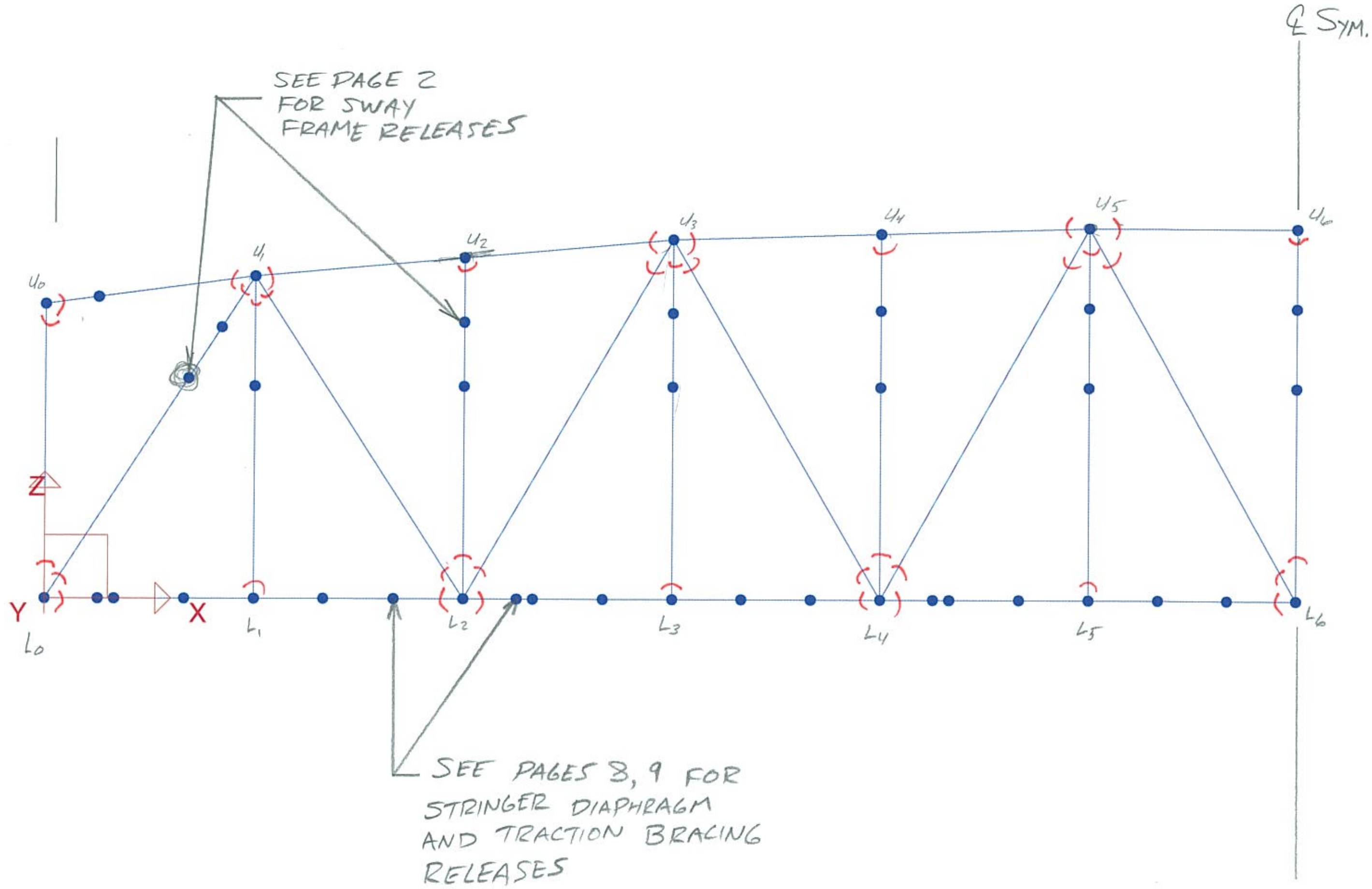
FIXED TORSION ABOUT LOCAL X-AXIS AND FIXED MOMENT ABOUT LOCAL Y- AND Z-AXES



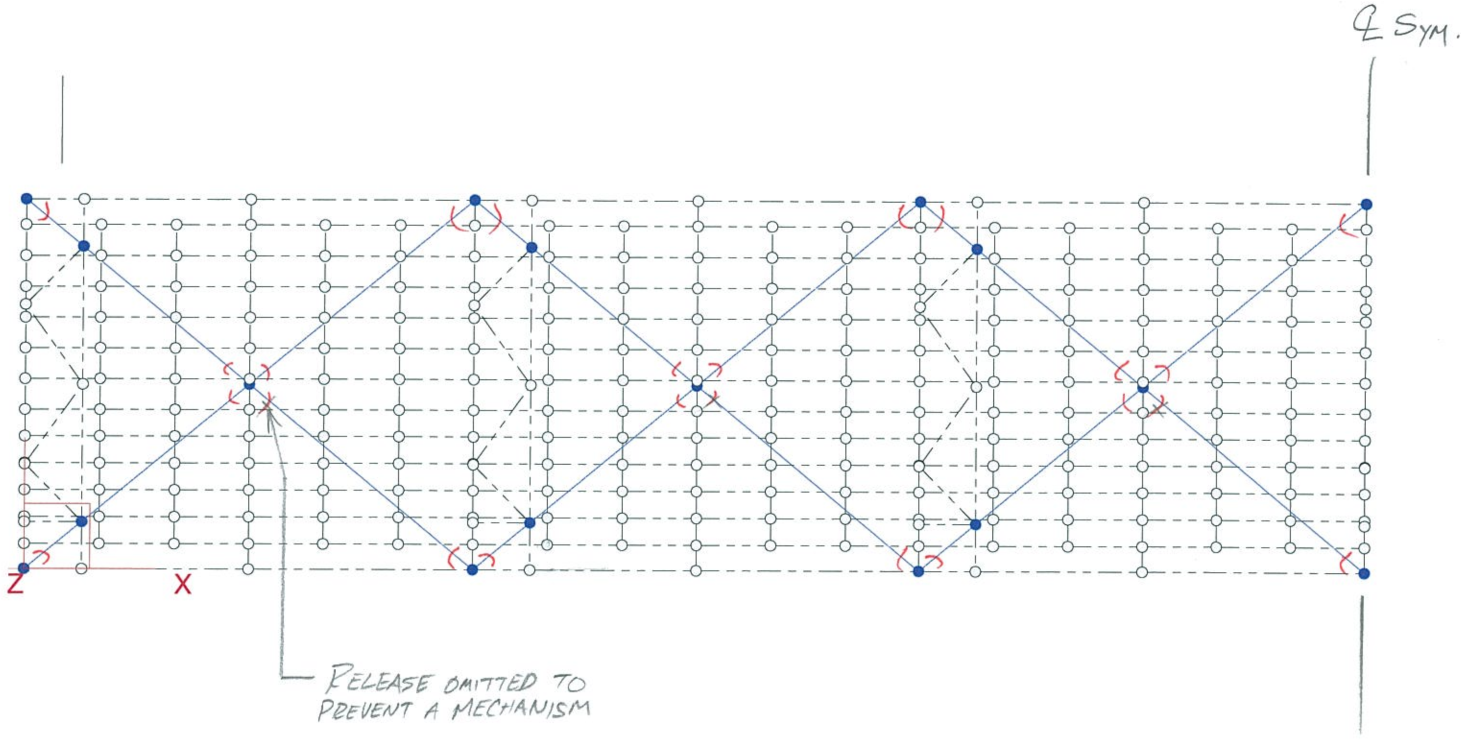
NOTE: PORTAL FRAMES AT ENDS ARE SIMILAR



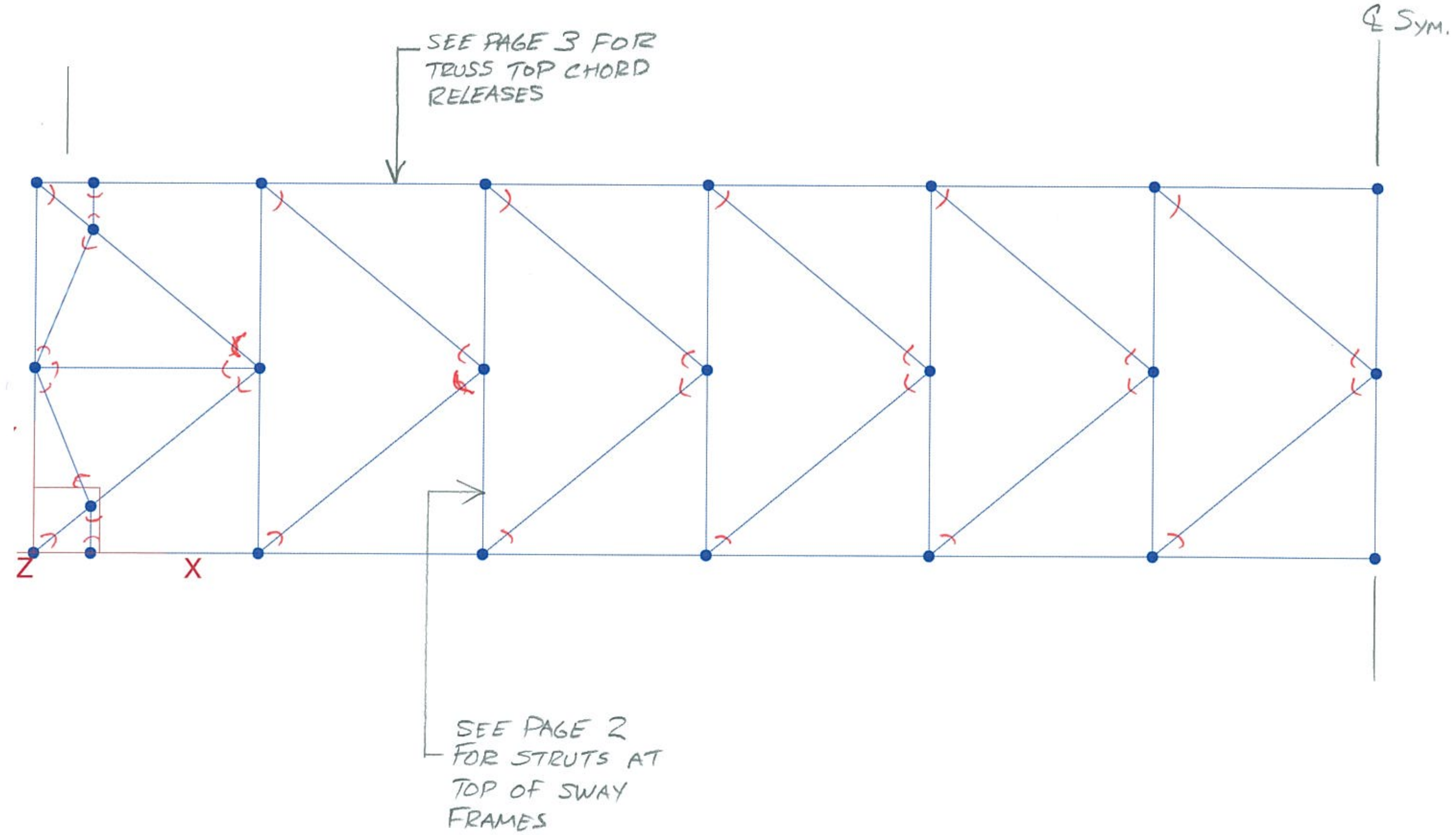
MMM Group Ltd. 2655 North Sheridan Way Mississauga, Ontario 905-823-8500	**RS-6 3D Modelling and Structural Analyses** Filename: C:\Users\YusekK\Desktop\3813009 BLB S-Frame Files\16.01.2014\Sections for Print\Truss Side.TEL Description: Burlington Lift Bridge Engineer: KY	Page: 1 of 1



TRUSS (LIFT SPAN)	**S-FRAME** *Enterprise Version 11.00.18* © Copyright 1995-2013, S-FRAME Software Inc.



℄ SYM.
Z
X
RELEASE OMITTED TO PREVENT A MECHANISM



TOP BRACING (LIFT SPAN)
- LATERAL
- END

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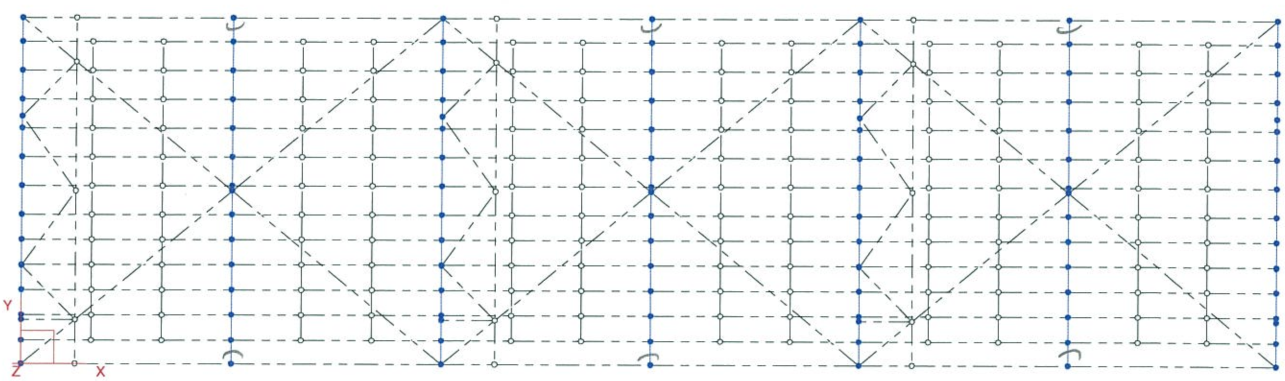
RS-6 3D Modelling and Structural Analyses

Filename: C:\Users\YusekK\Desktop\3813009 BLB S-Frame Files\16.01.2014\Sections for Print\Bottom Lateral Bracing (Lift).TEL

Description: Burlington Lift Bridge

Engineer: KY

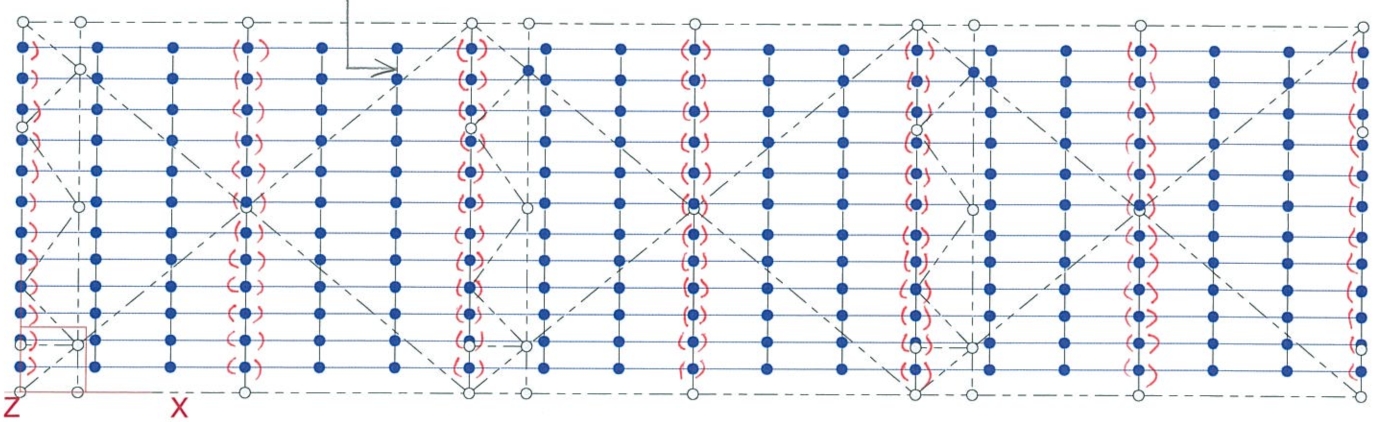


* JOINTS L1, L3, L5 ONLY

FLOOR BEAMS
(LIFT SPAN)

REV 01.22.2014

SEE PAGE 8 FOR STRINGER DIAPHRAGM END RELEASES



NOTE: STRINGERS ARE TO BE RELEASED FOR TRANSLATION IN THE GLOBAL X-AXIS (AXIAL) AT THE SOUTH ENDS ONLY.

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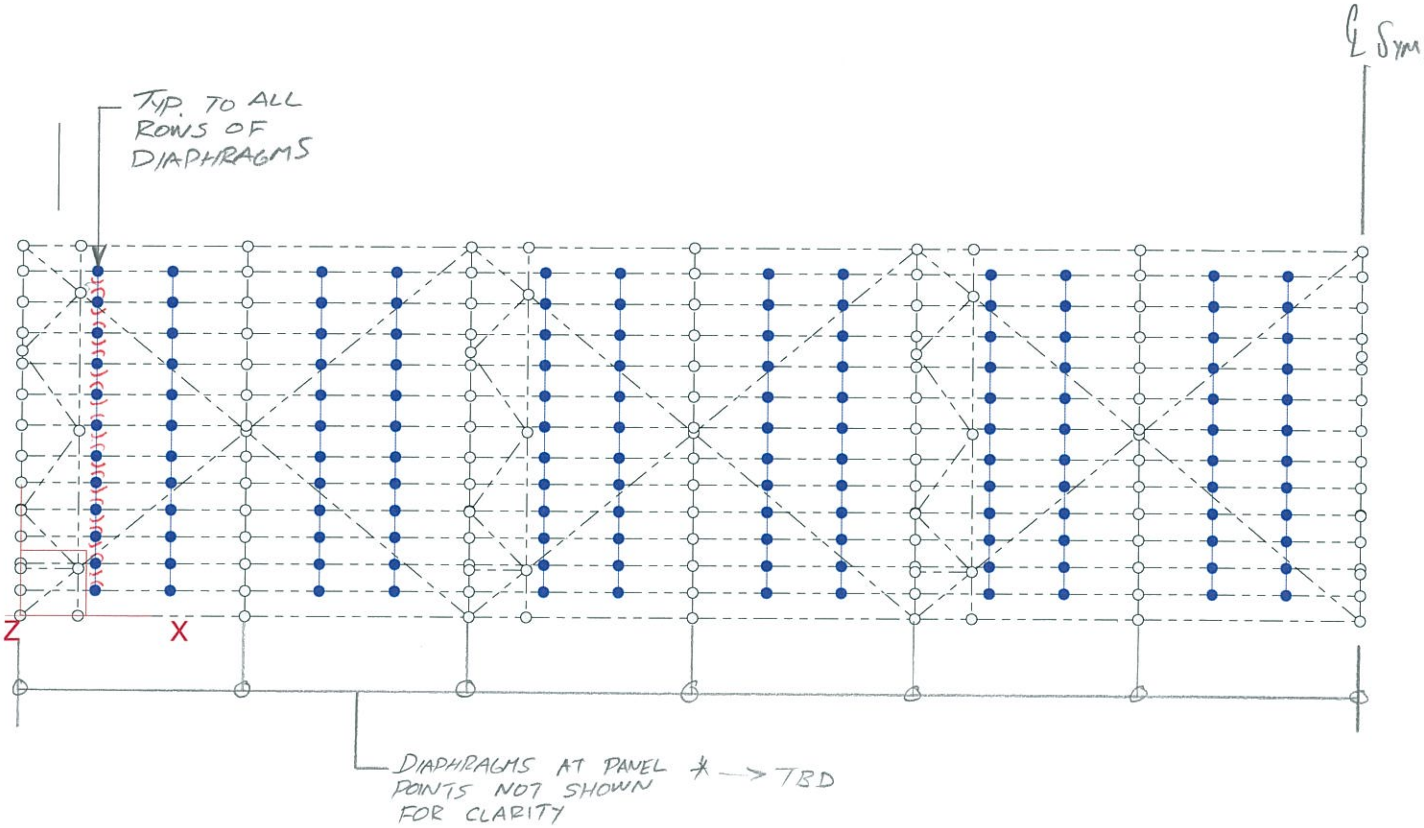
Filename: C:\Users\YusekK\Desktop\3813009 BLB S-Frame Files\16.01.2014\Sections for Print\Bottom Lateral Bracing (Lift).TEL
Description: Burlington Lift Bridge
Engineer: KY



STRINGER DIAPHRAGMS
(LIFTSPAN)

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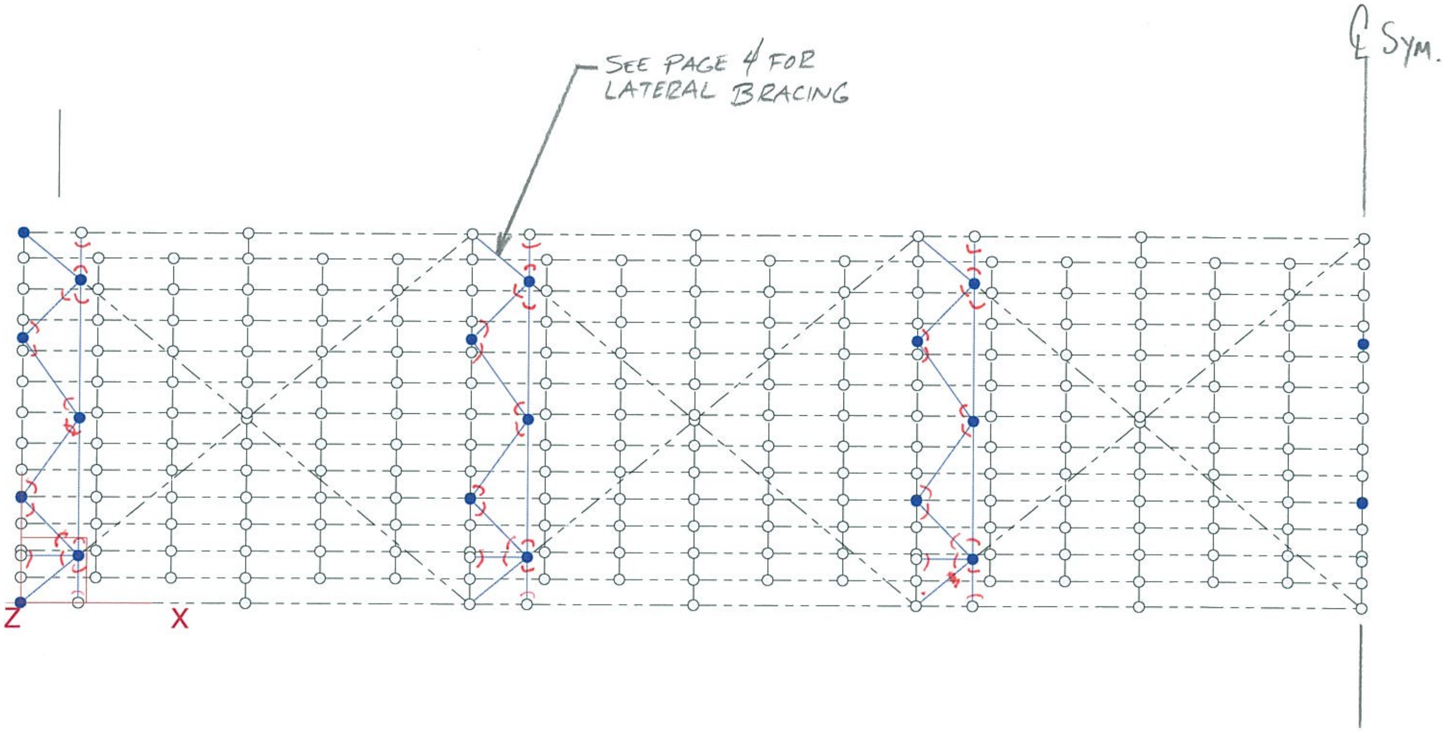
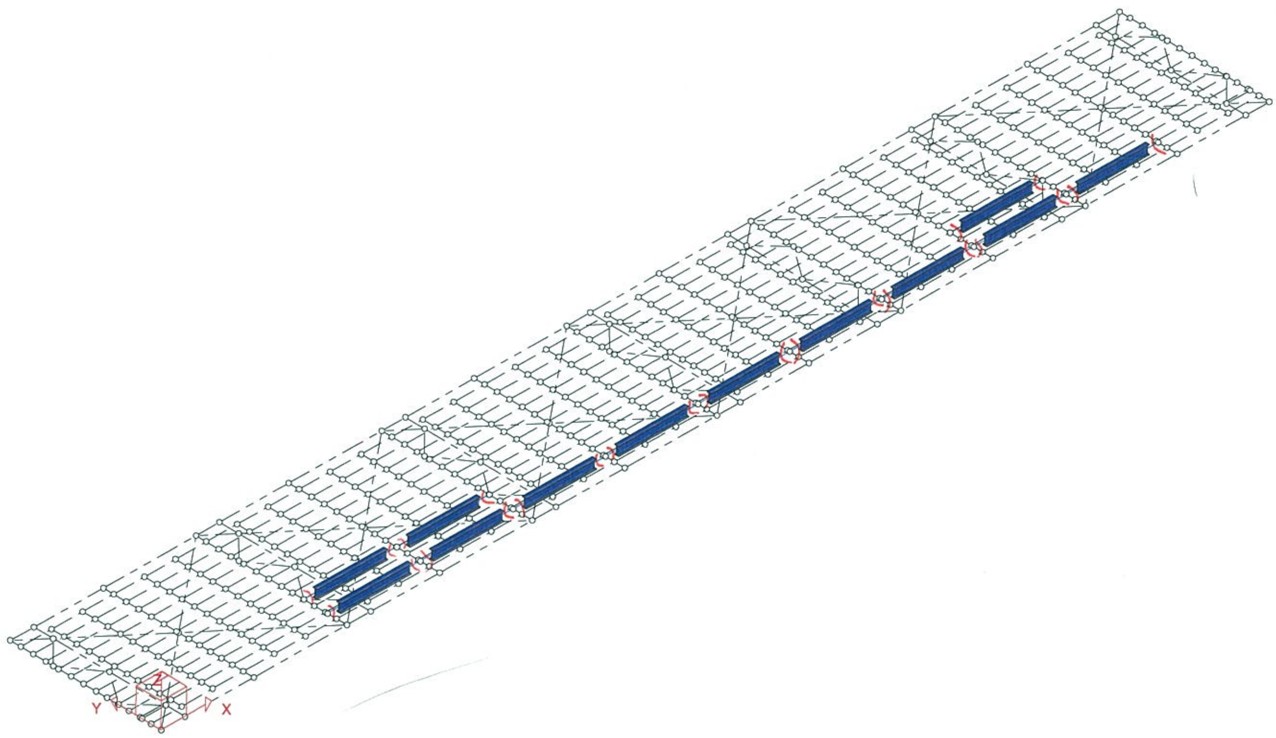
Filename: C:\Users\YusekK\Desktop\3813009 BLB S-Frame Files\16.01.2014\Sections for Print\Bottom Lateral Bracing (Lift).TEL
Description: Burlington Lift Bridge
Engineer: KY

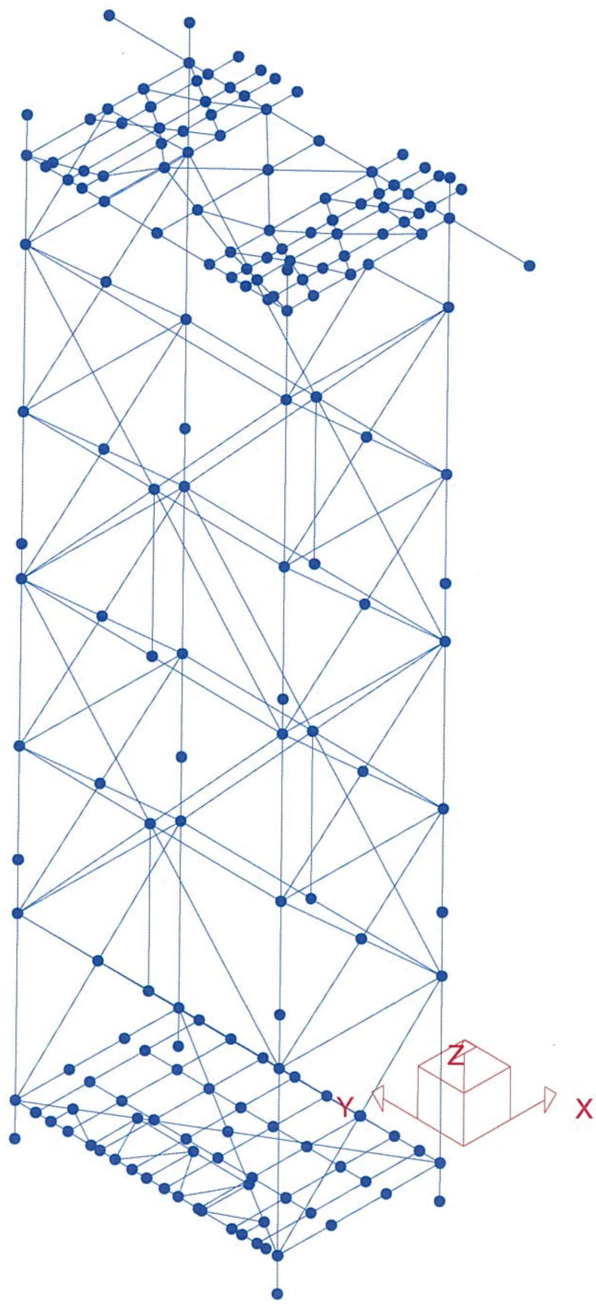


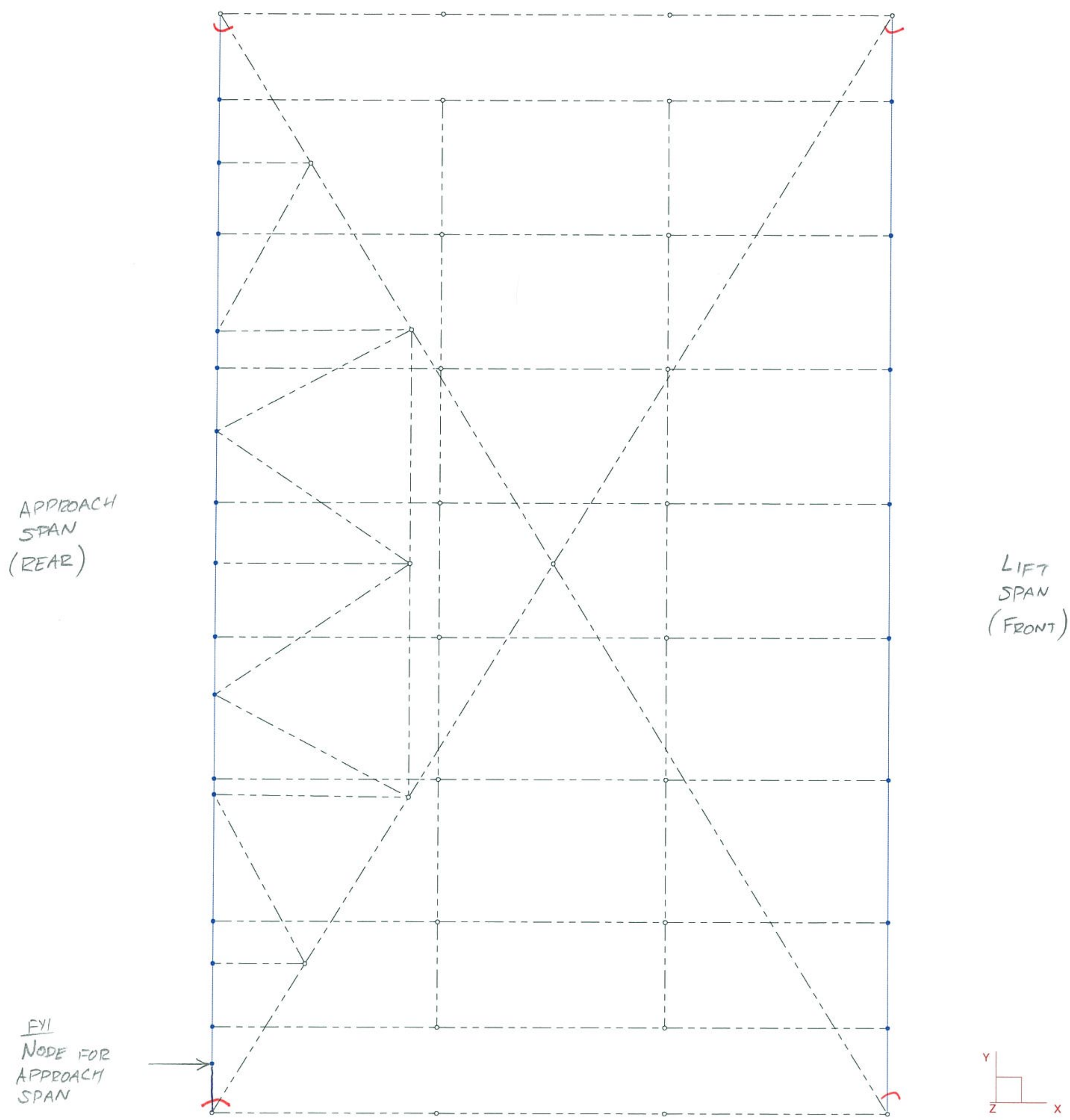
TRACTION BRACING (LIFT SPAN)



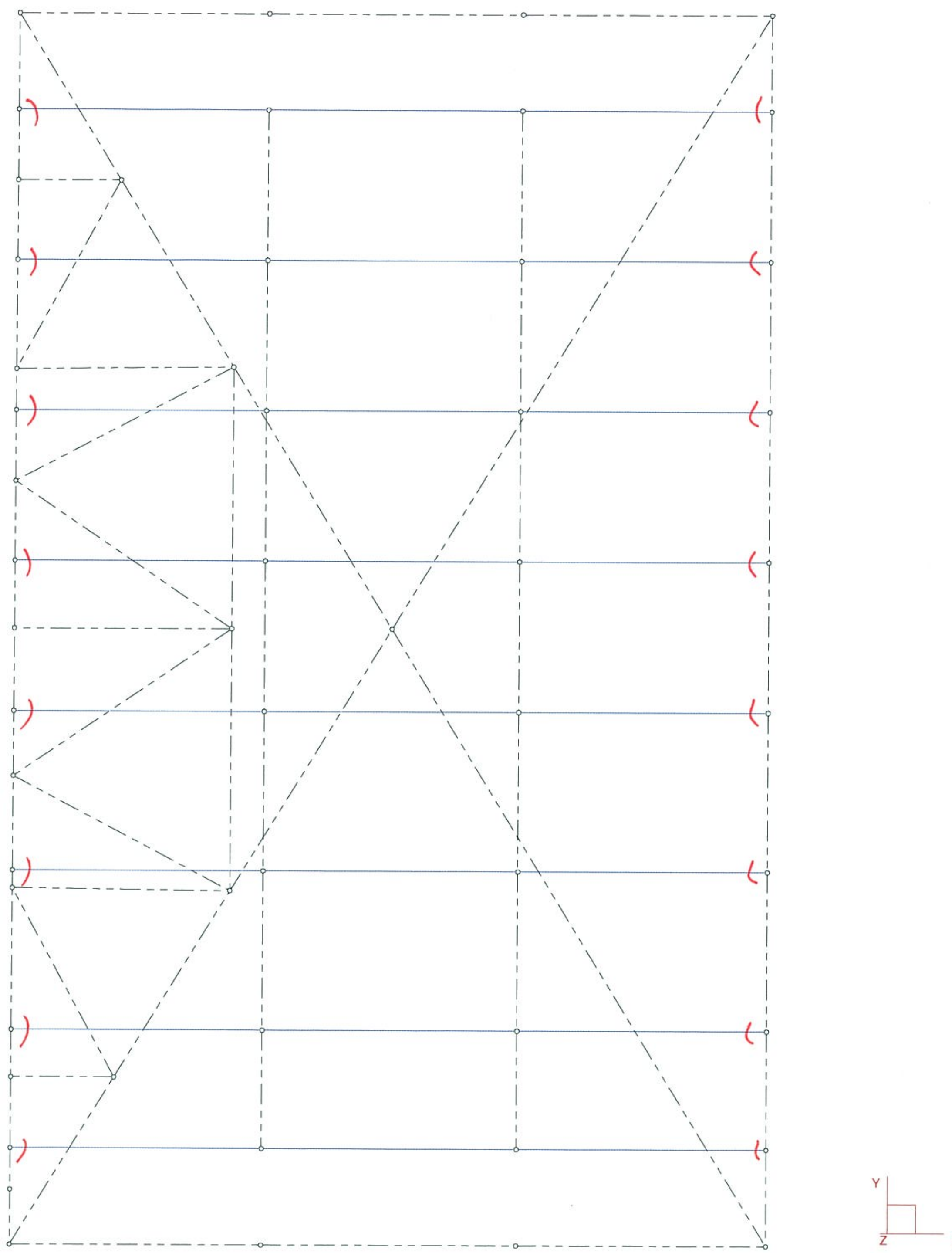
Z
Y
X

MEMBER END RELEASES - TOWER


Z
Y
X



FRONT AND REAR FLOOR BEAMS



TOWER STRINGERS

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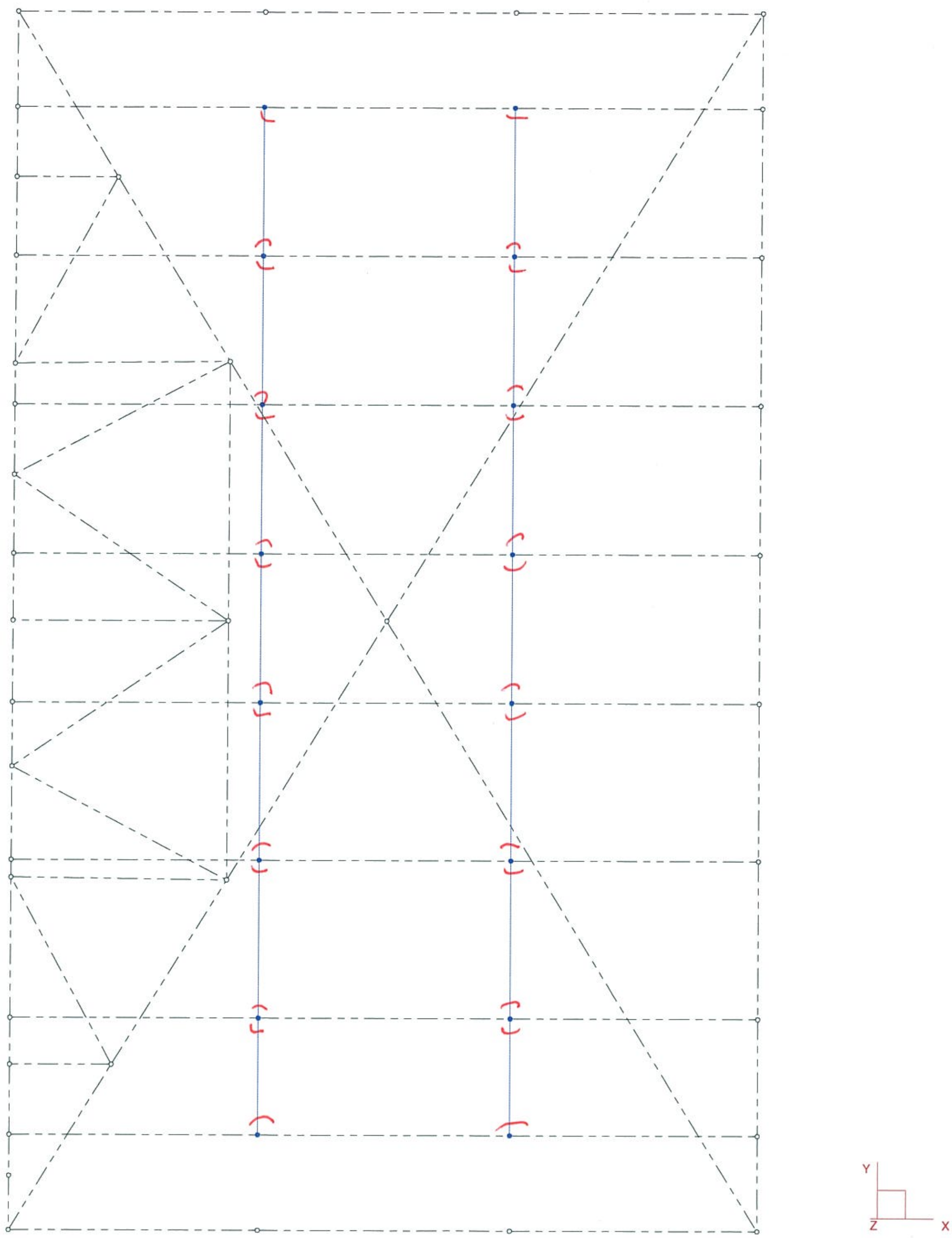
RS-6 3D Modelling and Structural Analyses
Filename: C:\Users\YusekK\Desktop\3813009 BLB S-Frame Files\23.01.2014\Print Deck.TEL
Description: Burlington Lift Bridge
Engineer: KY



TOWER DIAPHRAGMS

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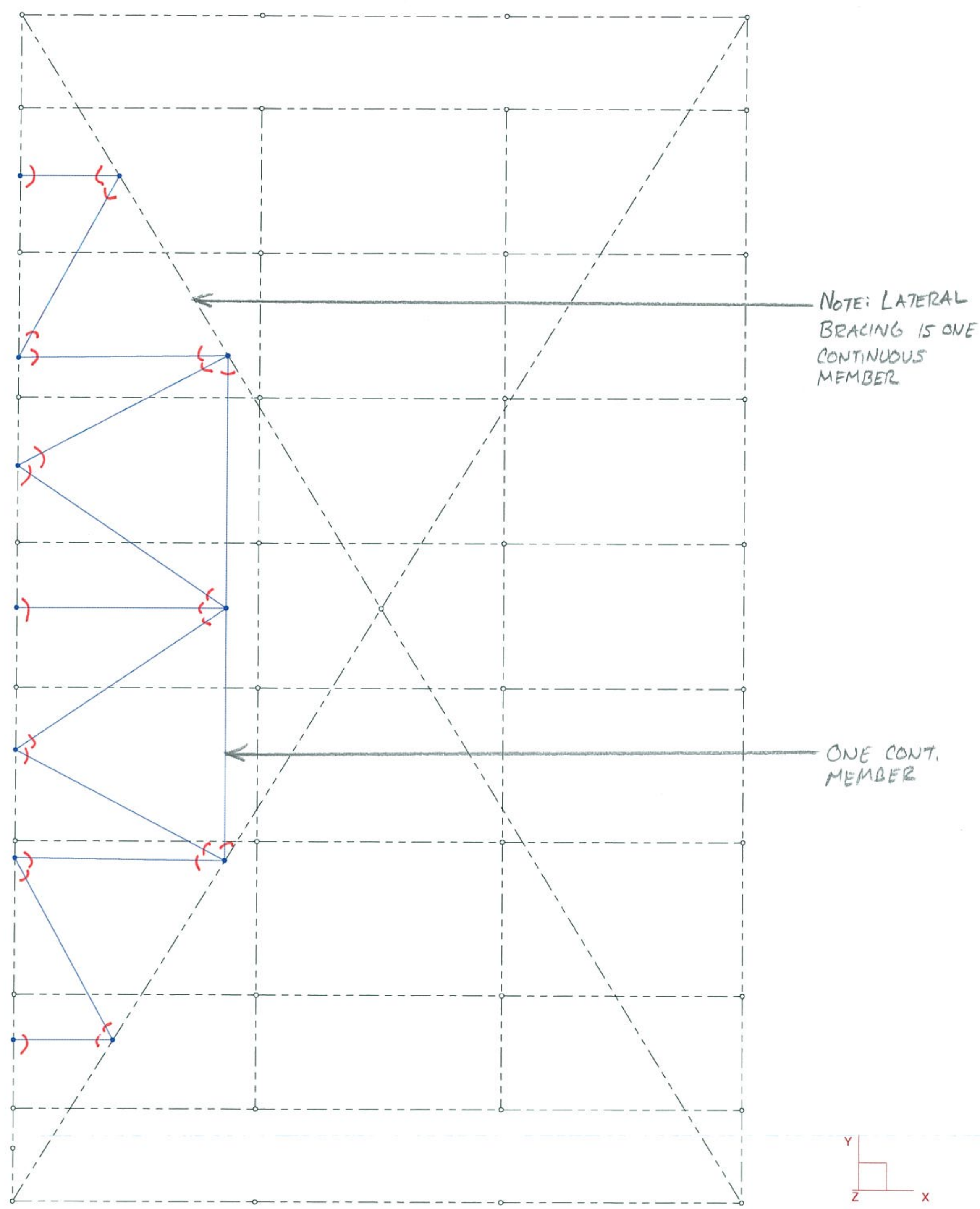
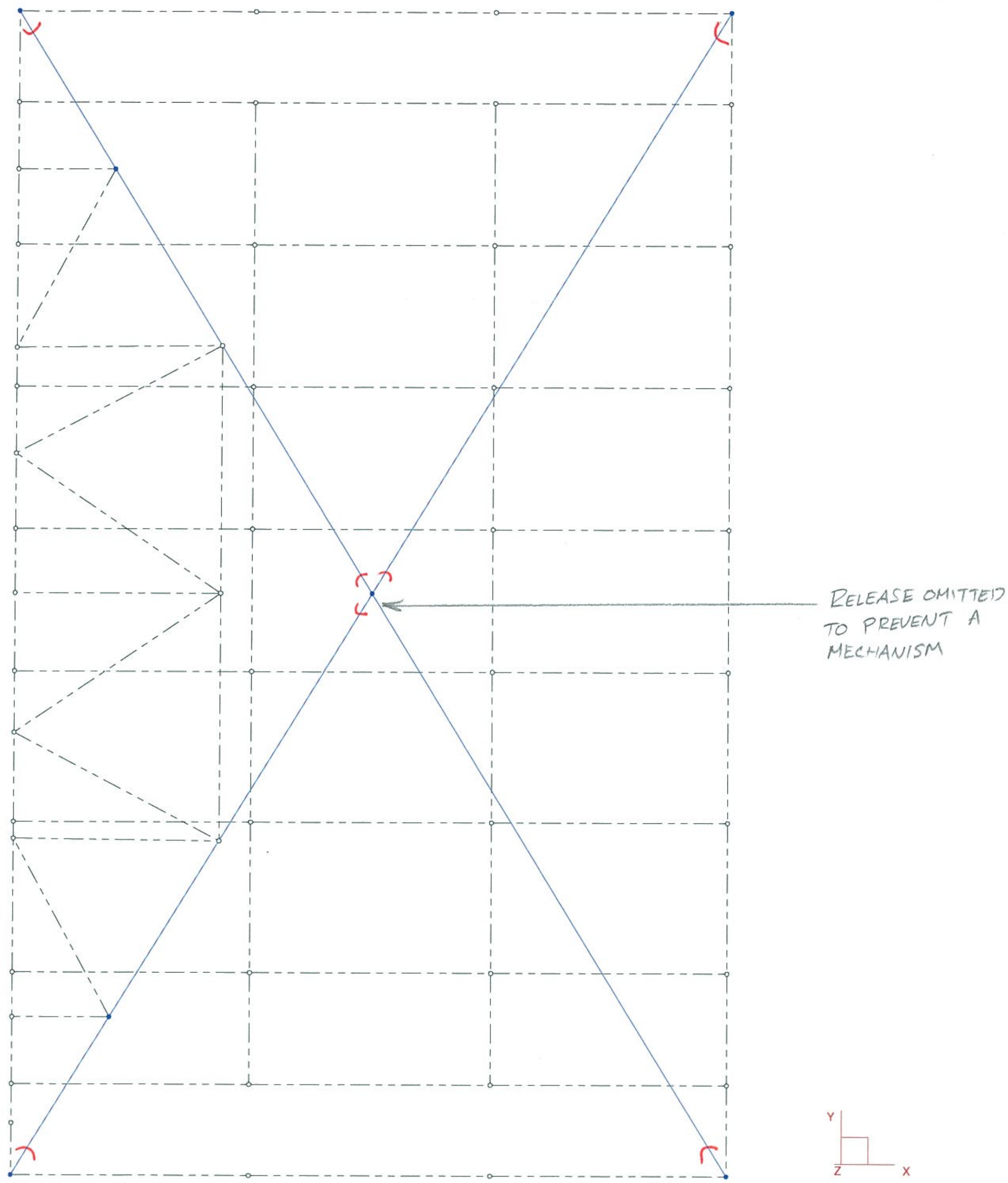
905-823-8500

RS-6 3D Modelling and Structural Analyses
Filename: C:\Users\YusekK\Desktop\3813009 BLB S-Frame Files\23.01.2014\Print Deck.TEL
Description: Burlington Lift Bridge
Engineer: KY



TOWER TRACTION BRACING

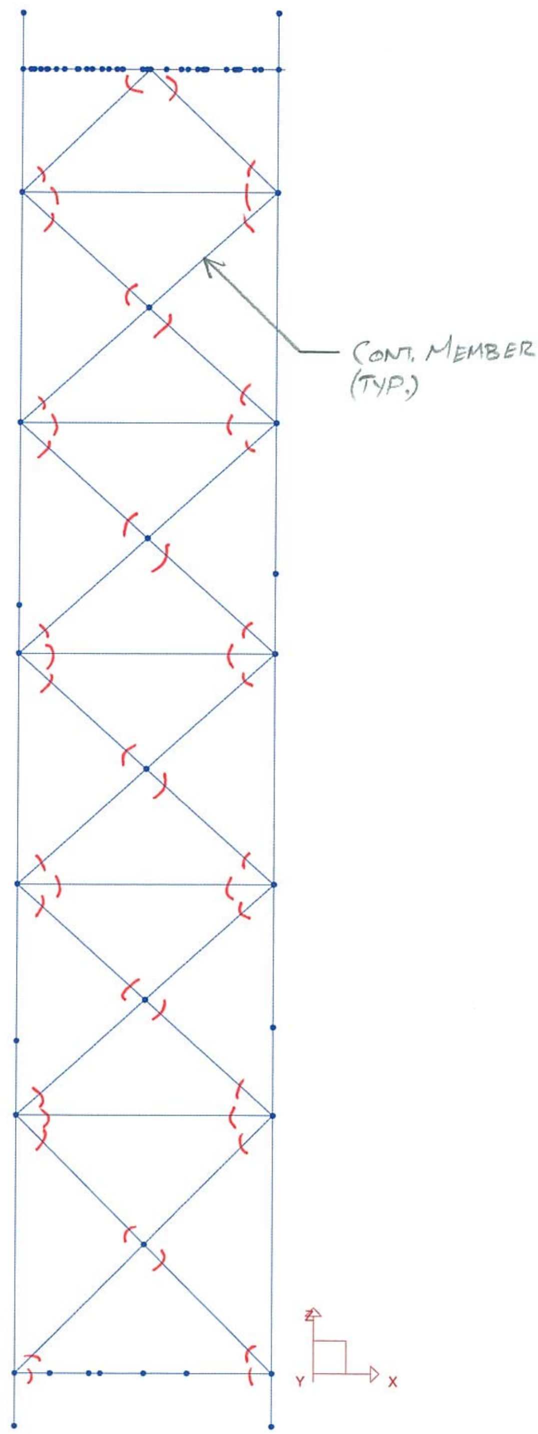


TOWER LATERAL BRACING

MMM Group Ltd.
2655 North Sheridan Way
Mississauga, Ontario
905-823-8500

RS-6 3D Modelling and Structural Analyses
Filename: C:\Users\YusekK\Desktop\3813009 BLB S-Frame Files\23.01.2014\3813009 KY BLB ANALYSIS 23.01.2014.TEL
Description: Burlington Lift Bridge
Engineer: KY

APPROACH SPAN
"REAR"



LIFT SPAN
"FRONT"

BRACING - SIDE

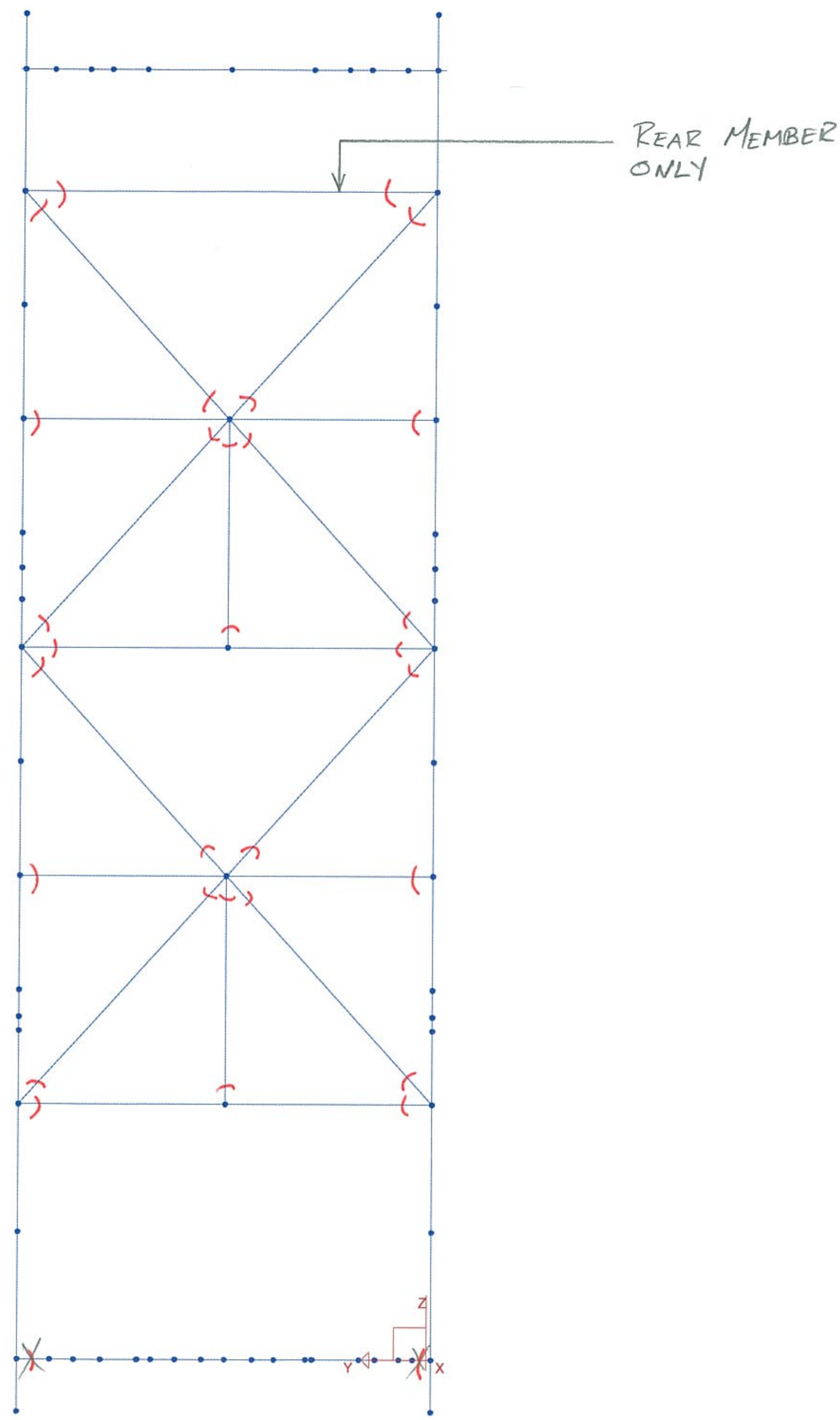
MMM Group Ltd.
2655 North Sheridan Way
Mississauga, Ontario
905-823-8500

RS-6 3D Modelling and Structural Analyses

Filename: C:\Users\YusekK\Desktop\3813009 BLB S-Frame Files\23.01.2014\3813009 KY BLB ANALYSIS 23.01.2014.TEL

Description: Burlington Lift Bridge

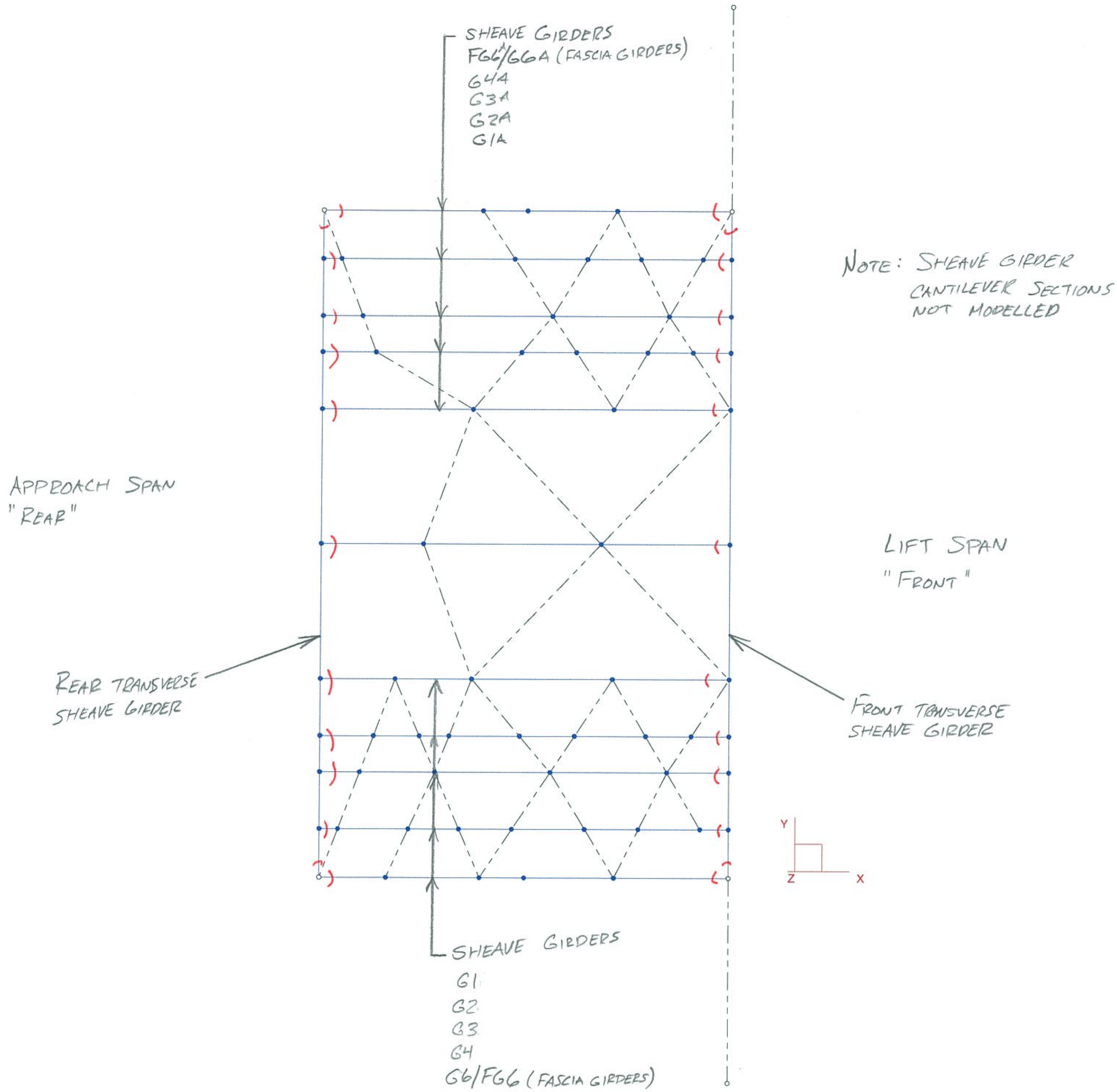
Engineer: KY



BRACING - FRONT
- REAR TYP.

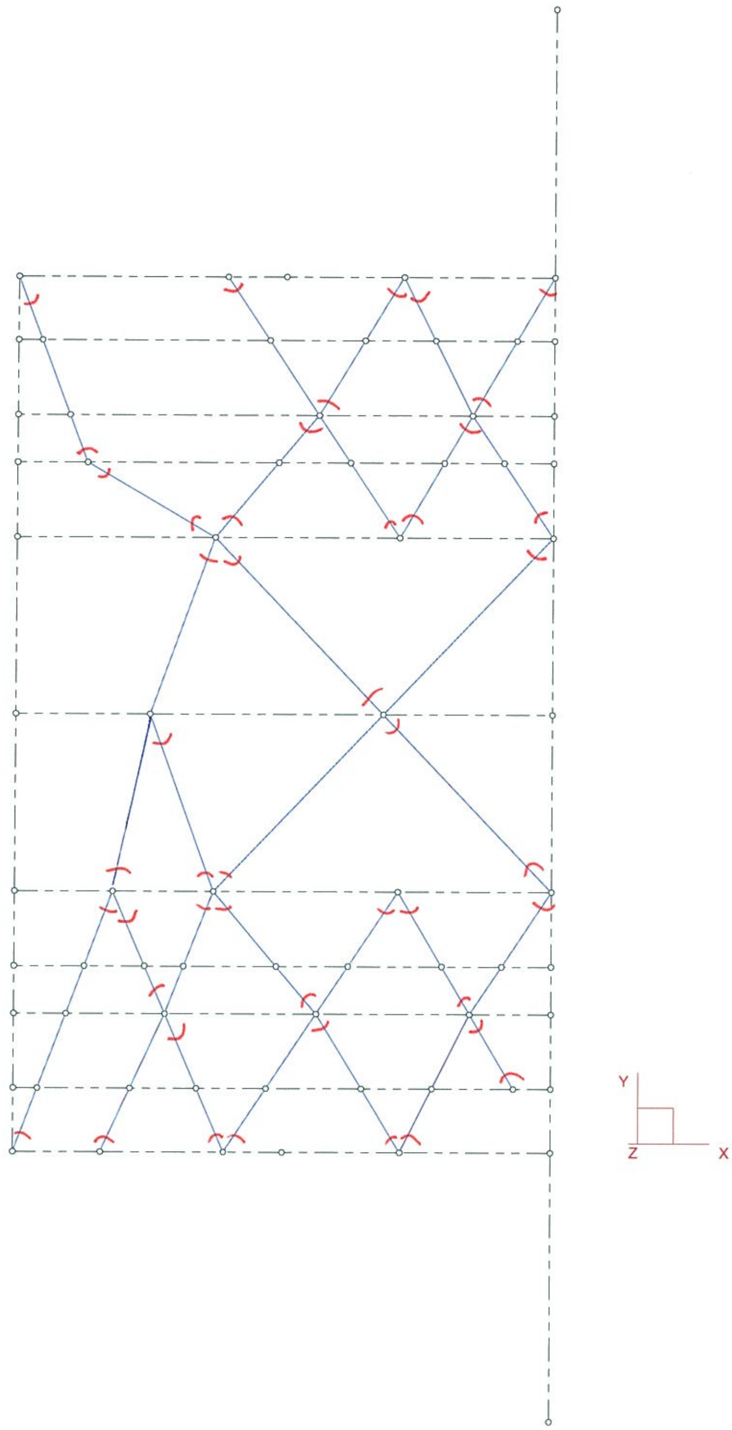
MMM Group Ltd.
2655 North Sheridan Way
Mississauga, Ontario
905-823-8500

RS-6 3D Modelling and Structural Analyses
Filename: C:\Users\YusekK\Desktop\3813009 BLB S-Frame Files\24.01.2014\Print Sheave.TEL
Description: Burlington Lift Bridge
Engineer: KY



SHEAVE GIRDERS

S-FRAME
Enterprise Version 11.00.18



SHEAVE GIRDER BOTTOM CHORD BRACING

APPENDIX C
DESIGN LOAD CALCULATIONS

DEAD LOADS - DECK - APPROACH AND TOWER SPANS

→ NOT SPECIFIED IN MEMO FROM DD JAN 27, 2014:

↳ CONCRETE: $23.5\ kN/m^3$ (190mm)

↳ ASPHALT: $22\ kN/m^3$ (64mm)

$\Rightarrow 23.5\ \frac{kN}{m^3} \times 0.19m = 4.465\ kPa$

$\Rightarrow 22\frac{kN}{m^3} \times 0.064m = 1.408\ kPa$

} 5.873 kPa

DEAD LOADS - TOWER - MACHINE ROOM

$q = 3.6 kPa$ [NBCC TABLE 4.1.5.3]

→ ADD ADDITIONAL DEAD LOAD @ TOP OF TOWERS TO ACCOUNT FOR:
SHEAVES
PLATFORMS
FLOOR/ROOF
CLADDING
LIVE LOAD

→ 450 kN TO BACK COL'S

→ 1600kN TO FRONT COL'S

MRC McCORMICK RANKIN
A member of MMM GROUP

PROJECT BLB - ANALYSIS		W.O. 3213009.304	
DESIGNED KY	DATE FEB 4/14		
CHECKED	DATE April/14	PAGE 1	OF 1

LIFT SPAN SIDEWALK - DEAD LOAD.

• ASSUME SUPPORTED AT TRUSS VERTICALS ONLY

↳ $L = 30'-10'' = 9398mm$

• CONCRETE: $\rho = 23.5 kN/m^3$

$W = 2809mm$ [2006 SHT 101]

$t = 50mm$

$\Rightarrow \rho \times L \times W \times t$

$= 23.5 \times 9.398 \times 2.809 \times 0.05$

$= \underline{31.019\ kN}$

• Steel BRACKETS + FLOOR BEAMS:

↳ ASSUME EQUIVALENT TO THREE "8I23"

$- L = 8.5' = 2591mm$

$- M = 23\ lbs/ft = 0.336\ kN/m$

$\Rightarrow 3 \times 0.336 \times 2.591 = \underline{2.612\ kN}$

• STRINGERS:

$1 \times 21WF62 + 1 \times 8I23 \Rightarrow 62 + 23 = 85\ lbs/f = 1.242\ kN/m$

$1.242\ kN/m \times 9.398m = \underline{11.700\ kN}$

• BRACING $L\ 3\tfrac{1}{2} \times 3 \times \tfrac{3}{8}$, $5'-2 = 1.575m$, $4'-9\tfrac{1}{2}'' = 1.4605$

$L = \sqrt{1.575^2 + 1.4605^2} = 2.148m \times 6\ LEGS = 12.887m$

$11.6\ \frac{kg}{m} \times 12.887m \times \frac{9.81m}{s^2} = \underline{1.466\ kN}$

25kN @ ends

⇑

• RAILING: ASSUME 20 lbs/ft = 0.3 kN/m ⇒ $\underline{2.8kN}$ ⇒ 49.597 = 50kN

MRC McCORMICK RANKIN A member of MMM GROUP

PROJECT	BLB - ANALYSIS	W.O.	3213009.304
DESIGNED	KY	DATE	Feb 6/14
CHECKED	D. DIXON	DATE	April/14
PAGE	1	OF	1

TRAFFIC BARRIER SELF WEIGHT - DEAD LOAD

→ 3x HSS 102x102x6.4 => 0.534 kN/m x 112.776m = 60.2 kN
(RAILS) (PER SIDE)

→ POSTS: W50x37 => 0.366 kN/m x 1.05 m = 0.3843 kN ea.

↳ 50 POSTS PER SIDE = 19.2 kN PER SIDE

=> 60.2 + 19.2 ≃ 80 kN PER SIDE

=> 80/112.776 = 0.709 kN/m LENGTH.

SUMMARY OF LACING WEIGHT INCREASE - DEAD LOAD

→ TOWER:

↳ SINGLE PANEL: "I" → 43% (↳ VERT.)

↳ TWO PANELS: "[ ]" → 33% (↳ HOR + DIAG.)

} DOUBLE LATTICE

→ TRUSS:

↳ SINGLE PANEL, DL: "I" → 15%, 20% [CROSS SWAY BRACING]

↳ DOUBLE PANEL, DL: [ ] → 27% [BOTT STRUTS]

↳ FOUR PANEL, SL+DL: [ ] DL SL → 58% [TOP STRUTS]

⟹ TOWER: 34% [FEW VERTICALS RELATIVE TO DIAG + HOR]

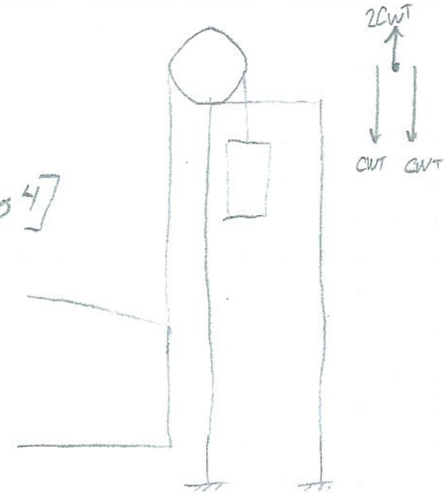
→ 77 x 1.34 = 1.0318E-04

⟹ TRUSS: CROSS + BOT STRUTS = 24% → 9.548E-05
TOP STRUTS = 58% → 1.2166E-04

★ INCREASE STEEL DENSITY FOR THESE MEMBERS.

DEAD

COUNTERWEIGHT LOAD [LIFT SPAN FULLY CLOSED]



→ WEIGHT OF SPAN

1935.17 short tons [Ross Eng, 2004]

= 1755556.693 kg

= 17220.011 kN

→ IMBALANCE

23600 [MEASURED IMBALANCE] + 4500 [SIDEWALK MOD] = 28100 lbs [DELCAN, 2000]

= 124.995 kN ⟹ 17220.011 − 124.995 = 17095.016 kN

→ FORCE PER COUNTERWEIGHT: [TWO COUNTERWEIGHTS]

$\frac{17095.016}{2}$ = 8547.508 kN PER COUNTERWEIGHT

→ FORCE PER SHEAVE: (FOUR PER TOWER)

$\frac{8547.508}{4}$ = 2136.877 kN [DUE TO TENSION FROM CWT ONLY]

→ FORCE PER SHEAVE GIRDER: (TWO PER SHEAVE)

$\frac{2136.877}{2}$ = 1068.439 kN [DUE TO TENSION FROM CWT ONLY]

1068.439 x 2 = 2136.877 kN [DUE TO DOWNWARD FORCE FROM LIFT SPAN]
↳ EQUAL TO FORCE OF COUNTERWEIGHT

→ APPLY AT 2'-6" (0.762m) FROM ℄ FRONT COLUMNS

→ WIND LOAD (FULLY CLOSED) TRUSS

· HORIZONTAL DRAG

↳ $F_H = qC_eC_gC_h$ → ASSUME <u>NO</u> SHIELDING => $K_x = 1.0$

$q = 460\,Pa$ [TABLE A3.1.1]

$C_e = 1.1$ @ 10-16m [TABLE 3.8]

$C_g = 2.0$ [Cl 3.10.1.3]

$C_h = 2.0$ [Cl 3.10.2.2]

=> $F_H = \underline{2.024\,kPa}$ → APPLY TO MAIN TRUSS MEMBERS, NEGLECT BRACINGS.

· WIND ON LIVE LOAD – LENGTH × 3.0m HEIGHT [Cl 3.10.2.4]

· VERTICAL DRAG

↳ $F_V = qC_eC_gC_v$, $C_v = 1.0$ [Cl 3.10.2.3]

$F_V = 1.012\,kPa$ → APPLY AS UDL OVER PLAN AREA OF DECK

↳ USE 85% OF DECK AREA [Cl 13.7.3.5]
(OPEN GRATING)

=> $F_V = \underline{0.8602}\,kPa$

HORIZONTAL WIND LOADING – TRUSS [TRANSVERSE] FULLY CLOSED

→ SURFACE AREA

↳ TRUSS MEMBERS

- VERTICALS: CHOOSE TALLEST (U6:L6)

1'-9" x 55'-0"
= 0.5334m x 16.764m = 8.942 m² x 13 ea. = 116.245 m²
↳ 1.080 kN/m

- DIAGONALS: (U5:L6) – LONGEST

2'-0½" x 63.053 ft
= 0.6223 m x 19.219 m = 11.960 m² x 12 ea = 143.517 m²
↳ 1.260 kN/m

- TOP CHORD

2'-6½" x 370'-0"
0.7747 x 112.776 = 87.368 m²
↳ 1.570 kN/m

- BOT CHORD

[ASSUME SAME AS TOP] = 87.368 m²
↳ 1.570 kN/m

↳ SIDEWALK (LONG. MEMBER)

- 23" x 370'-0"
= 0.584 x 112.776 = 65.884 m² → 1.182 kN/m

3.987 kN/m (Hwy)

↳ STRINGER

24" x 370'
= 0.610 x 112.776 = 68.748 m² → 1.235 kN/m

1.57 + 1.235 = 2.805 (RLY)

⇒ TOTAL = 569.13 m²

HORIZONTAL WIND LOADING – TOWERS [TRANSVERSE]

→ APPLY AS UDL PER UNIT MEMBER LENGTH

→ MEMBER WIDTHS:

FRONT COLUMN: 0.972m
REAR COLUMN: ASSUME 0.972m [CONSERVATIVE]
HORIZONTAL : 0.622m
JACKING GIRDER: 1.8m
DIAGONAL: 0.622m
SHEAVE GIRDER: 2.134m
ELEVATOR SHAFT: 1.829m *

MACHINE ROOM CLADDING: 4.572m

* NOTE: ELEVATOR SHAFT LINE LOAD TO BE SUPERIMPOSED ONTO REAR WEST COLUMNS ONLY.

→ CALCULATE HORIZONTAL DRAG: $F_H = q C_e C_g C_h$, $C_h = 2.0$ [Cl 3.10.2.2]

$q = 460$ Pa [Cl 3.10.1.2]

$C_g = 2.0$ [Cl 3.10.1.3]

LEVELS PER ORIGINAL CONTRACT DWG 19 OF 62

$C_{e,bot} = 1.1$
$C_{e,mid} = 1.3$
$C_{e,top} = 1.5$
[Cl 3.10.1.4]

$\Rightarrow F_{H,BOT} = 2.024$ kPa LEVEL G–K

$F_{H,MID} = 2.392$ kPa LEVEL E–G

$F_{H,TOP} = 2.760$ kPa LEVEL A–E

NOTE, F_H > LOADS SPECIFIED IN [CL 13.7.3.10]

→ UDL LOADS (BASED ON MEMBER WIDTH): [70% LOADS IN BRACKETS]

*

↳ FRONT COL – BOT 0.972 x 2.024 = 1.967 kN/m [1.377]
– MID 0.972 x 2.392 = 2.325 kN/m [1.628]
– TOP 0.972 x 2.760 = 2.683 kN/m [1.878]

↳ REAR COL – BOT, MID, TOP } SAME AS FRONT

↳ HORIZONTALS – BOT = 1.259 kN/m [0.881]
MID = 1.488 kN/m [1.042]
TOP = 1.717 kN/m [1.202]

↳ JACKING GIRDER – BOT = 3.643 kN/m [2.550]

↳ DIAGONAL – BOT 1.259 kN/m [0.881]
MID 1.488 kN/m [1.042]
TOP 1.717 kN/m [1.202]

↳ EXT. SHEAVE GIRDER: TOP 5.890 kN/m

[4.123]

↳ ELEVATOR SHAFT (6ft Wide = 1.829m) – BOT 1.829 x 2.024 = 3.702 kN/m
MID 1.829 x 2.392 = 4.375 kN/m [3.063]
TOP 1.829 x 2.760 = 5.048 kN/m [3.534]
} ADD TO REAR WEST COL. ONLY

* NOTE: THE ABOVE CONVERTS WIND PRESSURE TO FORCE PER UNIT LENGTH OF A MEMBER.

70% LOADS ARE USED TO APPLY A WIND AT AN OBLIQUE ANGLE (45°).

$\Rightarrow \cos 45 = 0.7$

HORIZONTAL WIND LOADING - TOWER - LONGITUDINAL [70% IN BRACKETS]

→ LINE LOAD DUE TO MEMBER WIDTH:

↳ COLUMN: BOT 1.219 x 2.024 = 2.468 kN/m [1.727]
MID 2.916 kN/m [2.041]
TOP 3.365 kN/m [2.355]
} ASSUME FRONT COLUMN

↳ HORIZONTALS: ~~BOT 0.622 x 2.024 = 1.260 kN/m [0.882]~~
MID: 1.489 [1.042]
TOP: 1.718 [1.202]
} SAME FOR DIAGONALS

↳ Fg:Fg': BOT 1.537 x 2.024 = 3.110 [2.177]

↳ TRANSVERSE SHEAVE GIRDER: TOP 4.585 x 2.760 = 12.654 kN/m [8.858] - ASSUME FRONT

↳ ELEVATOR SHAFT: MID: 1.067 x 2.392 = 2.552 [1.786]
TOP: 2.944 [2.061]

↳ MACHINE ROOM CLADDING → APPLY AREA LOAD = 2.760 kPa [1.932]

WIND LOAD ON TRAFFIC

→ LENGTH OF SPAN: 370' = 112.776m → ASSUME ONE LINE OF TRUCKS

→ HEIGHT OF VEHICLE = 3.0m [CHBDC]

⟹ SURFACE AREA = 338.328 m^2

→ WIND LOAD:

2.024 kPa × 338.328 m^2 = 684.776 kN

→ APPLY AS POINT LOAD TO FLOORBEAMS AT CONNECTION TO RAILWAY TRUSS

→ 13 FLOORBEAMS
- 11 INTERIOR, 2 ENDS (EQUIVALENT TO 12)

⟹ 684.776/12 = 57.065 kN

⟹ 11 INT @ 57.065 kN

⟹ 2 END @ 28.532 kN

→ LANE LOADING

- APPLY 9kN/m UDL based on 3m lane [Cl A3.4.1]
  - ↳ APPLY 4.5kN/m line load down each stringer [Conservative] (Represents idealized wheel path)
  - ↳ EIGHT LOAD CASES:

1 - - -	- 2 3 4
1 2 - -	- - 3 4
1 2 3 -	- - - 4
1 2 3 4	1 - - 4

→ ASSUMES NO STIFFNESS FROM THE DECK

Span	Member	Height (m)	Width (m)	Perimeter (m)	Ice Thickness (m)	Ice Density (kN/m^3)	Force (kN/m)
Approach	Stringers (O/S only)	0.612	0.229	0.841	0.031	9.8	0.2554958
Tower	Columns*	0.972	0.800	7.088	0.031	9.8	2.1533344
	Bracing**	0.622	0.829	5.804	0.031	9.8	1.7632552
	Sheave Girder (O./S)	2.134	0.432	2.566	0.031	9.8	0.77949
	Stringers (O/S only)	0.612	0.229	0.841	0.031	9.8	0.2554958
Lift	Truss*	0.775	0.660	5.740	0.031	9.8	1.743812
	Sway**	0.533	0.622	2.310	0.031	9.8	0.701778
	Lateral**	0.775	0.356	4.524	0.031	9.8	1.3743912
	Floor Beam	1.994	0.508	10.008	0.031	9.8	3.0404304
	Stringer	0.612	0.229	3.364	0.031	9.8	1.0219832
	Lifting Girder	4.299	0.914	20.852	0.031	9.8	6.3348376
	Diaphragms	0.305	0.074	1.516	0.031	9.8	0.4605608
	Railway Stringers	0.927	0.418	5.380	0.031	9.8	1.634444

* Assumes inside of member has ice accretion due to holes
** Assume lattice members are solid; treat as box or "I" section

NOTES: Approach/Tower/Lift Span Decks: Assume 31mm radial ice accrection [Cl. 3.12.6.2]
Assume lift span open steel grating deck is 100% solid

Machine House Cladding/Roof: 9.8 kN/m3 x 0.031m = 0.3038 kPa
Apply as area load

Designed: KY Date: 19-Feb-14

Checked: [signature] Date: April /14

TEMPERATURE STRAINS [CLOSED]

→ LOAD CASE 1: BOTTOM CHORD 10°C COOLER THAN TOP CHORD

→ LOAD CASE 2: RAIL TRUSS (LAKE SIDE) 10°C WARMER THAN HWY TRUSS

- ASSUME THE COOLER MEMBER IS AT AMBIENT TEMPERATURE, AND WARMER MEMBER HAS 10°C THERMAL LOAD APPLIED.

WIND DRAG – TRUSS [TRANSVERSE/ LONGITUDINAL/ VERTICAL] – FULLY RAISED (OPEN)

→ HORIZONTAL DRAG:

↳ $F_H = q C_e C_g C_h$ → ASSUME NO SHIELDING ⇒ $K_x = 1.0$

$q = 460$ Pa [TABLE A3.1.1.]

$C_e = 1.4$ @ $120' + (\frac{55}{2})'$ [TABLE 3.8]

$C_g = 2.0$ [Cl 3.10.1.3]

$C_h = 2.0$ [Cl 3.10.2.2]

⇒ $F_H = 2576$ Pa > 1500 Pa → ∴ Use 2576 Pa [TRANSVERSE]

↳ APPLY AS LINE LOAD WRT MEMBER WIDTH
↳ LONG = 50% TRANSVERSE

→ VERTICAL DRAG:

↳ $F_V = q C_e C_g C_v = 460 \times 1.4 \times 2.0 \times 1.0 = 1288$ Pa > 0.25 kPa → ∴ Use 1.288 kPa

↳ APPLY TO 85% OF DECK AREA DUE TO OPEN STEEL GRATING

⇒ $1.288 \times 0.85 = 1.095$ kPa VERTICAL

→ LINE LOADS DUE TO HORIZONTAL DRAG: (50% IN BRACKETS)

- TOP/BOT CHORD = 1.996 kN/m
- VERTICAL = 1.374 kN/m
- DIAGONAL = 1.603 kN/m
- SIDEWALK = 1.504 kN/m
- STRINGER = 1.571 kN/m

} TRANSVERSE HORIZONTAL

- TOP STRUT = 1.602 (0.801) → ASSUME 85% SOLID ⇒ 0.681 kN/m
- VERTICAL = 1.602 (0.801)
- DIAGONAL = 1.602 (0.801)
- BOTTOM STRUT = 1.602 (0.801)
- CROSS BRACING = 0.531 (0.265)
- Int FLRBM = 5.137 (2.568)
- LIFT GRDR = 11.074 (5.537)

} LONGITUDINAL HORIZONTAL

* USE 50%

THERMAL (TEMPERATURE) STRAINS - FULLY RAISED

→ ASSUME ALL SOUTH AND WEST FACES ARE 10°C WARMER.

↳ APPLY TO COLUMNS AND BRACING ONLY [TOWERS ONLY]

IMPACT LOAD AND DEAD LOAD OF LIFT SPAN

→ WEIGHT OF LIFT SPAN:

[ROSS ENG, 2004]

LOC.	TONS	⇒ kN	⇒ DEAD LOAD (PER SHEAVE GIRDER)* ¼ (kN)	⇒ IMPACT LOAD 20%
SE	484.54	4309.958	1077.490	215.498
SW	482.03	4287.632	1071.908	214.382
NE	486.34	4325.969	1081.492	216.299
NW	482.26	4289.678	1072.420	214.484
	1935.17	17213.238		

* FOUR SHEAVE GIRDERS SHALL BE ASSUMED TO EQUALLY SHARE THE LOAD AT EACH CORNER

→ WEIGHT OF COUNTERWEIGHT:

8547.508kN EACH [SEE FEB 11/13 CALC]

FORCE PER SHEAVE GIRDER: 1068.439 kN [DUE TO TENSION FROM CWT ONLY]

⇒ IMPACT (20%) PER SHEAVE GIRDER: 213.688 kN

Lift Span

	DL* (ton)	DL (kg)	DL (kN)	DL Per Shv Gdr (1/4)**	Impact (20%)
SE	484.540	439567.420	4309.959	1077.490	215.498
SW	482.030	437290.386	4287.632	1071.908	214.382
NE	486.340	441200.353	4325.969	1081.492	216.298
NW	482.260	437499.038	4289.678	1072.420	214.484
			17213.238	4303.310	860.662

Counterweight

DL per shv gdr	Impact (20%)
1068.439	213.688

Notes: *DL per shv gdr previously calculated.*
Accounts for an imbalance between lift span and counter weights (slightly span-heavy).

Total

	DL per shv gdr	**Impact (20%)**
SE	**2145.929**	**429.186**
SW	**2140.347**	**428.069**
NE	**2149.931**	**429.986**
NW	**2140.859**	**428.172**

NOTES: * Source: Ross Engineering, *Weighing the Bridge* , May 2004
** Four sheave girders support each corner of the lift span (two sheaves each supported by two girders).

Impact load is 20% the weight of all moving components (lift span + counterweights).

Designed: KY Date: 04-Mar-14

Checked: [signature] Date: April 10/14

APPENDIX D.1
CALCULATION SUMMARIES (PER SECTION)

Section	Max C_f (kN)	Min C_f (kN)	M_a, M_b, M_c, M_{max} (kN.m)						Max Mf (kN.m)	Max V_f (kN)
			Sta. 0	*Sta. 1/4*	*Sta. 1/2*	*Sta. 3.4*	*Sta. End*	*M_{Max} Abs*		
2L3.5X3.5X.375	127	-110	0	1	-1	1	0	1	-1	-1
2L3-1/2x3-1/2x3/8	65	-220	0	0	0	0	0	0	0	0
2L4X4X.375	26	-25	0	0	0	0	0	0	0	1
2L4x4x3/8	143	-304	0	0	1	0	0	1	1	1
2L5X3.5X.375	35	-82	-4	-3	-3	-3	-4	4	-4	-2
2L5X5X.5	7	0	0	4	6	4	0	6	6	-3
2L5x5x3/8	252	-253	0	1	1	1	0	1	1	1
2L6X6X.375	122	-118	-9	-8	8	5	0	9	-9	3
2L6x6x1/2	471	-111	0	12	18	12	0	18	18	5
C12X20.7	644	-137	0	0	0	0	0	0	0	1
C15X33.9	3	-4	0	0	0	0	0	0	0	1
C310X37	618	-89	0	0	0	0	0	0	0	1
C380X50	4	-3	0	0	0	0	0	0	0	1
L4X4X.375	0	0	0	0	0	0	0	0	0	0
L5X5X.375	26	-27	0	0	0	0	0	0	0	0
L5X5X.5	13	-13	0	0	0	0	0	0	0	1
LIFT-BLAT	948	-557	0	70	51	70	0	70	70	15
LIFT-FLRB-END	62	-35	-3493	513	1493	536	-3332	3493	-3493	210
LIFT-FLRB-INT	86	-570	0	4673	6007	4168	0	6007	6007	402
LIFT-HWYT-L0L2	4123	2569	0	85	70	82	0	85	85	-19
LIFT-HWYT-L0U1	-3832	-6920	0	337	417	337	0	417	417	88
LIFT-HWYT-L2L4	7953	5753	0	176	176	171	0	176	176	-19
LIFT-HWYT-L2U3	-2025	-3567	0	115	153	115	0	153	153	33
LIFT-HWYT-L4L6	9753	7255	0	209	242	203	0	242	242	-37
LIFT-HWYT-L4U5	-879	-1506	0	108	143	108	0	143	143	19
LIFT-HWYT-U0L0	-163	-376	0	0	0	0	0	0	0	0
LIFT-HWYT-U0U1	414	-22	0	65	85	65	0	85	85	36
LIFT-HWYT-U1L1	720	257	0	0	0	0	0	0	0	0
LIFT-HWYT-U1L2	4787	2733	0	131	175	131	0	175	175	40
LIFT-HWYT-U1U3	-2636	-6239	0	136	107	132	0	136	136	34
LIFT-HWYT-U2L2	-179	-302	0	0	0	0	0	0	0	0
LIFT-HWYT-U3L3	1058	368	0	0	0	0	0	0	0	15
LIFT-HWYT-U3L4	2667	1491	0	98	131	98	0	131	131	17
LIFT-HWYT-U3U5	-4085	-9214	0	300	373	293	0	373	373	74
LIFT-HWYT-U4L4	89	-195	0	0	0	0	0	0	0	0
LIFT-HWYT-U5L5	906	276	0	0	0	0	0	0	0	0
LIFT-HWYT-U5L6	654	287	0	99	132	99	0	132	132	-6
LIFT-HWYT-U5U6	-4752	-10068	0	312	384	303	0	384	384	-47
LIFT-HWYT-U6L6	-183	-229	0	0	0	0	0	0	0	0
LIFT-LFGR	13	-58	0	602	825	602	0	825	825	-135
LIFT-PORT-BSTR	72	-40	0	38	22	38	0	38	38	12
LIFT-PORT-LATD	66	-77	0	6	8	6	0	8	8	1
LIFT-PORT-LATL	66	-77	0	15	20	15	0	20	20	4
LIFT-PORT-LATT	82	-93	0	1	1	1	0	1	1	2
LIFT-PORT-SWBC	98	-180	0	17	34	17	0	34	34	7
LIFT-PORT-SWBV	45	25	0	3	4	3	0	4	4	3
LIFT-RLYT-L0L2	3980	1521	0	85	71	83	0	85	85	20
LIFT-RLYT-L0U1	-3794	-6741	0	337	417	337	0	417	417	384
LIFT-RLYT-L2L4	8049	3160	0	184	170	177	0	184	184	320
LIFT-RLYT-L2U3	-2043	-3601	0	130	174	130	0	174	174	326
LIFT-RLYT-L4L6	9113	3929	0	241	242	230	0	242	242	1025
LIFT-RLYT-L4U5	-840	-1567	0	118	157	118	0	157	157	257
LIFT-RLYT-U0L0	-282	-406	0	0	0	0	0	0	0	310
LIFT-RLYT-U0U1	1139	-449	0	65	85	65	0	85	85	25

			M_a, M_b, M_c, M_{max} (kN.m)							
Section	**Max C_f (kN)**	**Min C_f (kN)**	*Sta. 0*	*Sta. 1/4*	*Sta. 1/2*	*Sta. 3.4*	*Sta. End*	*M_{Max} Abs*	**Max Mf (kN.m)**	**Max V_f (kN)**
LIFT-RLYT-U1L1	690	283	0	0	0	0	0	0	0	0
LIFT-RLYT-U1L2	4872	2935	0	128	170	128	0	170	170	299
LIFT-RLYT-U1U3	-4730	-6763	0	195	160	187	0	195	195	65
LIFT-RLYT-U2L2	-114	-308	0	0	0	0	0	0	0	0
LIFT-RLYT-U3L3	782	301	0	0	0	0	0	0	0	0
LIFT-RLYT-U3L4	2649	1577	0	109	145	109	0	145	145	299
LIFT-RLYT-U3U5	-6961	-10007	0	305	338	290	0	338	338	62
LIFT-RLYT-U4L4	-118	-315	0	0	0	0	0	0	0	0
LIFT-RLYT-U5L5	775	412	0	0	0	0	0	0	0	0
LIFT-RLYT-U5L6	644	392	0	99	132	99	0	132	132	287
LIFT-RLYT-U5U6	-7693	-10891	0	337	380	319	0	380	380	94
LIFT-RLYT-U6L6	-237	-340	0	0	0	0	0	0	0	0
LIFT-SWAY-BSTR	70	-36	0	9	-15	9	0	15	-15	6
LIFT-SWAY-SWBC	87	-105	0	0	0	0	0	0	0	0
LIFT-SWAY-SWBV	23	-46	0	0	0	0	0	0	0	0
LIFT-SWAY-TSTR	212	-278	-25	27	19	27	0	27	27	11
LIFT-TLAT	538	-536	0	40	44	40	0	44	44	16
TOWR-BBRC-MDIA	1225	-1660	0	43	57	43	0	57	57	19
TOWR-BBRC-RcRc	99	62	0	207	276	207	0	276	276	70
TOWR-BBRC-RdRd	16	-98	0	20	-32	20	0	32	-32	-7
TOWR-BBRC-ReRe	329	88	0	27	-22	27	0	27	27	14
TOWR-BBRC-RfRf	848	12	0	19	-38	19	0	38	-38	14
TOWR-BBRC-RgRg	226	46	0	312	452	312	0	452	452	62
TOWR-BBRC-UDIA	72	-423	0	43	57	43	0	57	57	19
TOWR-BLAT-FRTL	554	-582	29	28	23	14	0	29	29	-7
TOWR-BLAT-HWYL	509	9	0	36	14	-9	0	36	36	17
TOWR-BLAT-RLYL	26	-543	0	37	12	-7	0	37	37	17
TOWR-FBRC-CdCe	63	-140	0	-19	-25	-19	0	25	-25	11
TOWR-FBRC-FdFd	366	107	0	20	-37	20	0	37	-37	8
TOWR-FBRC-FeFe	810	673	0	44	25	44	0	44	44	21
TOWR-FBRC-FfFf	1366	-1140	0	18	-48	18	0	48	-48	15
TOWR-FBRC-FgFg	459	347	0	567	934	567	0	934	934	13
TOWR-FBRC-MDIA	1777	-3139	0	46	61	46	0	61	61	21
TOWR-FBRC-MdMe	69	-31	0	-19	-25	-19	0	25	-25	10
TOWR-FBRC-UDIA	166	-1384	0	43	57	43	0	57	57	19
TOWR-FCOL-BCOL	-10183	-19458	0	-1505	-652	437	351	1505	-1505	-13
TOWR-FCOL-MCOL	-10073	-16596	351	156	-149	153	-171	351	351	25
TOWR-FCOL-UCOL	-11	-14547	-623	-467	-311	-156	216	623	-623	136
TOWR-FLBM-FRNT	44	28	0	941	1273	940	0	1273	1273	-272
TOWR-FLBM-REAR	72	2	0	2909	3930	2912	0	3930	3930	891
TOWR-RCOL-BCOL	-288	-6602	0	-775	-360	245	236	775	-775	257
TOWR-RCOL-MCOL	-176	-3920	236	93	-87	-87	-108	236	236	20
TOWR-RCOL-UCOL	-10	-2578	-126	-120	-160	-137	182	182	182	51
TOWR-SBRC-DIAG	919	-1589	0	15	-35	15	0	35	-35	11
TOWR-SBRC-FgRg	485	276	0	47	62	47	0	62	62	14
TOWR-SBRC-FhRh	568	-72	0	164	218	164	0	218	218	90
TOWR-SBRC-HORZ	452	266	0	43	58	43	0	58	58	24
TOWR-SBRC-SbFc	82	-534	0	15	20	15	0	20	20	12
TOWR-SHVG-G1	37	-34	0	1775	1256	665	0	1775	1775	2750
TOWR-SHVG-G2G3	20	-30	0	1786	1270	674	0	1786	1786	2755
TOWR-SHVG-G4	82	-76	0	1894	1416	786	0	1894	1894	2812
TOWR-SHVG-G6	56	-235	0	-275	-618	-276	0	618	-618	146
TOWR-SHVG-G7	561	221	0	31159	33498	31160	0	33498	33498	10610
TOWR-SHVG-G8	50	-34	0	3660	4000	3654	0	4000	4000	-1274
W10X22	0	-47	0	11	21	30	37	37	37	11
W12X26	0	-136	76	79	80	77	72	80	80	-5

Section		Max C_f (kN)	Min C_f (kN)	M_a, M_b, M_c, M_{max} (kN.m)						Max Mf (kN.m)	Max V_f (kN)
				Sta. 0	*Sta. 1/4*	*Sta. 1/2*	*Sta. 3.4*	*Sta. End*	*M_{Max} Abs*		
W12X35		-2	-136	72	59	47	65	-82	82	-82	13
W16X36		0	0	30	24	19	26	31	31	31	-7
W24X84		0	0	0	503	676	534	0	676	676	29
W27X102		4	-8	-197	125	142	124	-192	197	-197	100
W33X130		0	0	-197	239	294	240	-202	294	294	125
W36X230		1811	-68	0	68	71	67	0	71	71	23
W690X152	*	14	-2	-206	124	136	122	-201	206	-206	73
W840X193	*	0	0	-203	238	286	239	-208	286	286	-130

			M_a, M_b, M_c, M_{max} (kN.m)							
Section	**Max C_f (kN)**	**Min C_f (kN)**	Sta. 0	Sta. 1/4	Sta. 1/2	Sta. 3/4	Sta. End	M_{Max} Abs	**Max Mf (kN.m)**	**Max V_f (kN)**
2L3.5X3.5X.375	403	-387	0	-1	-1	-1	0	1	-1	-1
2L3-1/2x3-1/2x3/8	83	-80	0	0	0	0	0	0	0	0
2L4X4X.375	26	-31	0	0	0	0	0	0	0	-1
2L4x4x3/8	75	-138	0	0	1	0	0	1	1	-1
2L5X3.5X.375	104	-239	0	0	-1	0	0	1	-1	-1
2L5X5X.5	5	-5	0	4	6	4	0	6	6	-3
2L5x5x3/8	70	-70	0	1	1	1	0	1	1	-1
2L6X6X.375	300	-294	0	17	20	14	0	20	20	8
2L6x6x1/2	104	-99	0	13	19	13	0	19	19	-6
C12X20.7	13	-12	0	0	0	0	0	0	0	0
C15X33.9	4	-1	0	0	0	0	0	0	0	-1
C310X37	12	-11	0	0	0	0	0	0	0	0
C380X50	1	-5	0	0	0	0	0	0	0	-1
L4X4X.375	0	0	0	0	0	0	0	0	0	0
L5X5X.375	31	-26	0	0	0	0	0	0	0	0
L5X5X.5	9	-9	0	0	0	0	0	0	0	-1
LIFT-BLAT	857	-732	0	37	39	37	0	39	39	14
LIFT-FLRB-END	610	-12	0	402	533	400	0	533	533	-134
LIFT-FLRB-INT	177	-76	0	1047	1383	987	0	1383	1383	351
LIFT-HWYT-L0L2	-2128	-2574	0	-4	-116	-3	0	116	-116	-35
LIFT-HWYT-L0U1	-4591	-5719	0	313	446	362	0	446	446	-105
LIFT-HWYT-L2L4	1446	1092	0	77	-49	76	0	77	77	-46
LIFT-HWYT-L2U3	-2413	-2936	0	118	158	118	0	158	158	-34
LIFT-HWYT-L4L6	2952	2581	0	94	-12	94	0	94	94	-42
LIFT-HWYT-L4U5	-971	-1215	0	112	149	112	0	149	149	-31
LIFT-HWYT-U0L0	5158	4247	0	-20	-26	-20	0	26	-26	-8
LIFT-HWYT-U0U1	3680	2258	0	49	64	49	0	64	64	-27
LIFT-HWYT-U1L1	536	326	0	-36	-56	-47	0	56	-56	15
LIFT-HWYT-U1L2	3893	3203	0	134	178	134	0	178	178	-41
LIFT-HWYT-U1U3	-980	-1626	0	55	-76	55	0	76	-76	-46
LIFT-HWYT-U2L2	-115	-218	0	-47	-75	-60	0	75	-75	18
LIFT-HWYT-U3L3	550	332	0	-53	-86	-63	0	86	-86	18
LIFT-HWYT-U3L4	2067	1700	0	101	134	101	0	134	134	-29
LIFT-HWYT-U3U5	-2823	-3947	0	168	87	168	0	168	168	-62
LIFT-HWYT-U4L4	-112	-222	0	-55	-90	-64	0	90	-90	18
LIFT-HWYT-U5L5	534	314	0	-57	-94	-66	0	94	-94	18
LIFT-HWYT-U5L6	458	316	0	102	136	102	0	136	136	-28
LIFT-HWYT-U5U6	-3533	-4722	0	176	91	176	0	176	176	-65
LIFT-HWYT-U6L6	-115	-228	0	-57	-94	-66	0	94	-94	18
LIFT-LFGR	530	4	0	456	634	456	0	634	634	153
LIFT-PORT-BSTR	148	-17	0	36	27	36	0	36	36	-15
LIFT-PORT-LATD	91	-71	0	3	4	3	0	4	4	-2
LIFT-PORT-LATL	92	-99	0	8	11	8	0	11	11	-5
LIFT-PORT-LATT	113	-120	0	0	0	0	0	0	0	-1
LIFT-PORT-SWBC	118	-163	0	16	30	16	0	30	30	-7
LIFT-PORT-SWBV	36	25	0	2	3	2	0	3	3	-2
LIFT-RLYT-L0L2	-1137	-1962	0	6	-112	6	0	112	-112	-35
LIFT-RLYT-L0U1	-4677	-5755	0	313	446	362	0	446	446	-105
LIFT-RLYT-L2L4	1484	867	0	82	-66	82	0	82	82	-53
LIFT-RLYT-L2U3	-2521	-3032	0	136	181	136	0	181	181	-39
LIFT-RLYT-L4L6	2942	1992	0	115	-52	115	0	115	115	-61
LIFT-RLYT-L4U5	-1004	-1251	0	123	164	123	0	164	164	-34
LIFT-RLYT-U0L0	5153	4362	0	-20	-26	-20	0	26	-26	-8
LIFT-RLYT-U0U1	3747	3194	0	49	64	49	0	64	64	-27
LIFT-RLYT-U1L1	492	260	0	-36	-56	-47	0	56	-56	15
LIFT-RLYT-U1L2	3974	3375	0	130	173	130	0	173	173	-40

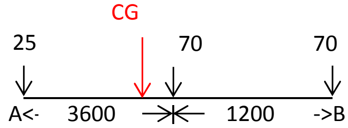
Section	Max C_f (kN)	Min C_f (kN)	M_a, M_b, M_c, M_{max} (kN.m)						Max Mf (kN.m)	Max V_f (kN)
			Sta. 0	Sta. 1/4	Sta. 1/2	Sta. 3/4	Sta. End	M_{Max} Abs		
LIFT-RLYT-U1U3	-1302	-1977	0	102	-57	102	0	102	102	-59
LIFT-RLYT-U2L2	-105	-261	0	-47	-75	-60	0	75	-75	18
LIFT-RLYT-U3L3	551	325	0	-53	-86	-63	0	86	-86	18
LIFT-RLYT-U3L4	2136	1791	0	112	149	112	0	149	149	-32
LIFT-RLYT-U3U5	-4159	-4449	0	183	70	183	0	183	183	-70
LIFT-RLYT-U4L4	-123	-263	0	-55	-90	-64	0	90	-90	18
LIFT-RLYT-U5L5	537	323	0	-57	-94	-66	0	94	-94	18
LIFT-RLYT-U5L6	472	332	0	102	136	102	0	136	136	-28
LIFT-RLYT-U5U6	-5130	-5222	0	201	83	201	0	201	201	-77
LIFT-RLYT-U6L6	-143	-269	0	-57	-94	-66	0	94	-94	18
LIFT-SWAY-BSTR	69	-22	0	5	-11	5	0	11	-11	-6
LIFT-SWAY-SWBC	82	-112	0	7	11	7	0	11	11	-3
LIFT-SWAY-SWBV	17	-20	0	2	3	2	0	3	3	-1
LIFT-SWAY-TSTR	302	-323	-34	9	-35	11	0	35	-35	-10
LIFT-TLAT	694	-688	0	28	33	28	0	33	33	11
TOWR-BBRC-MDIA	658	-1223	0	25	33	25	0	33	33	-11
TOWR-BBRC-RcRc	143	70	0	167	223	167	0	223	223	-56
TOWR-BBRC-RdRd	374	-272	0	12	-17	12	0	17	-17	-12
TOWR-BBRC-ReRe	490	72	0	20	-10	20	0	20	20	-11
TOWR-BBRC-RfRf	609	-509	0	12	-26	12	0	26	-26	-13
TOWR-BBRC-RgRg	329	11	0	367	587	367	0	587	587	-111
TOWR-BBRC-UDIA	452	-803	0	25	33	25	0	33	33	-11
TOWR-BLAT-FRTL	608	-535	32	31	25	15	0	32	32	-7
TOWR-BLAT-HWYL	18	-535	0	39	15	-10	0	39	39	18
TOWR-BLAT-RLYL	608	3	0	40	13	-7	0	40	40	19
TOWR-FBRC-CdCe	23	-190	0	-19	-25	-19	0	25	-25	-11
TOWR-FBRC-FdFd	601	-20	0	11	-23	11	0	23	-23	-14
TOWR-FBRC-FeFe	1031	763	0	39	34	39	0	39	39	-15
TOWR-FBRC-FfFf	1608	-1330	0	10	-37	10	0	37	-37	-17
TOWR-FBRC-FgFg	584	375	0	646	1113	646	0	1113	1113	-185
TOWR-FBRC-MDIA	2371	-4001	0	28	38	28	0	38	38	-13
TOWR-FBRC-MdMe	56	-74	0	-19	-25	-19	0	25	-25	-11
TOWR-FBRC-UDIA	607	-2096	0	25	33	25	0	33	33	-11
TOWR-FCOL-BCOL	-4602	-32221	0	-4522	-1728	1269	961	4522	-4522	-2914
TOWR-FCOL-MCOL	-8339	-24267	961	200	341	819	-408	961	961	-442
TOWR-FCOL-UCOL	-12	-18420	-747	-560	510	-187	393	747	-747	1472
TOWR-FLBM-FRNT	42	12	0	1187	1602	1189	0	1602	1602	365
TOWR-FLBM-REAR	28	-56	0	2678	3627	2673	0	3627	3627	826
TOWR-RCOL-BCOL	9109	-18464	0	-2377	-955	591	624	2377	-2377	-1503
TOWR-RCOL-MCOL	4550	-11008	624	219	-80	-93	-111	624	624	-107
TOWR-RCOL-UCOL	-10	-5703	-131	-149	-235	-252	282	282	282	84
TOWR-SBRC-DIAG	3328	-3914	0	-17	-56	-17	0	56	-56	-14
TOWR-SBRC-FgRg	564	397	0	28	38	28	0	38	38	-16
TOWR-SBRC-FhRh	1259	-717	0	156	208	156	0	208	208	-85
TOWR-SBRC-HORZ	1065	125	0	25	33	25	0	33	33	-14
TOWR-SBRC-SbFc	492	-1190	0	9	12	9	0	12	12	-7
TOWR-SHVG-G1	121	-68	0	2241	1571	825	0	2241	2241	3492
TOWR-SHVG-G2G3	78	-181	0	2254	1590	838	0	2254	2254	3498
TOWR-SHVG-G4	280	-174	0	2369	1743	954	0	2369	2369	3560
TOWR-SHVG-G6	662	-1230	0	-462	-999	-463	0	999	-999	-235
TOWR-SHVG-G7	884	156	0	39356	42238	39285	0	42238	42238	14236
TOWR-SHVG-G8	113	-22	0	4422	4819	4413	0	4819	4819	1567
W10X22	35	-75	0	7	13	19	25	25	25	7
W12X26	35	-163	44	44	44	43	42	44	44	-6
W12X35	-1	-163	28	23	17	-27	-39	39	-39	-10
W16X36	0	0	30	25	22	30	37	37	37	8

Section		Max C_f (kN)	Min C_f (kN)	M_a, M_b, M_c, M_{max} (kN.m)						Max Mf (kN.m)	Max V_f (kN)
				Sta. 0	Sta. 1/4	Sta. 1/2	Sta. 3/4	Sta. End	M_{Max} Abs		
W24X84		308	-234	-45	23	23	20	-45	45	-45	-22
W27X102		27	-5	0	170	226	170	0	226	226	-92
W33X130		0	0	-21	290	386	290	-21	386	386	-124
W36X230		167	-130	0	65	70	64	0	70	70	33
W690X152	*	5	-18	0	174	232	174	0	232	232	-95
W840X193	*	0	0	-21	299	399	299	-21	399	399	-128

APPENDIX D.2
FLOOR BEAM AND STRINGER DEMAND CHECK

1.0 Check Live Load for wheels 1, 2, and 3 of CL-625-ONT *[All references herein to CAN/CSA-S6-06 except where specified]*

1.1 Determine centre of gravity of wheel loads



Wheel Loads (kN)

Spacing (mm)

Note: Not to scale.

Total Length b/w Wheels 1 and 3, L_t = 4,800 mm

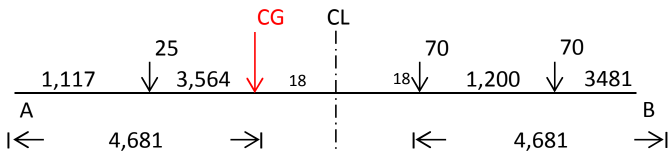
Centre of Gravity, Cg = $\Sigma(F_i$ x $d_i)$ / ΣFi *Sum of moments about point A*
= 588,000 / 165
= 3,564 mm

Dist. to nearest wheel = 36 mm

Maximum bending moment occurs when the midpoint between the centre of gravity and the axle nearest is centred at mid-span.

1.2 Determine position of wheels causing maximum moment

Span Length, L = 9,398 mm *Note: Not to scale.*



Check: L= 9,398 OK

Check: OK

1.3 Determine support reactions

ΣM_A=0 -> F_B = ((25 x 1117) + (70 x 4717) + (70 x 5917)) / 9,398
= 82 kN

F_A = 83 kN

1.4 Determine maximum bending moment

M_{Truck} = F_A x 4,717 - 25 x 3,600
= 83 x 4,717 - 25 x 3,600
= 301 kN·m

Check: M_{Truck} = FB x 4,681 - 70 x 1,200
= 82 x 4,681 - 70 x 1,200
= 301 kN·m OK

1.5 Apply Dynamic Load Allowance (DLA)

DLA = 0.3 *Note: Assume no multi-lane reduction* *[CL 3.8.4.5.3]*

M_{max} = (1 +DLA) x 301
= 1.3 x 301
= 391 kN·m @ d = 4,717 => 4,717 / L = 0.502 ** Say midspan (conservative)*

2.0 Check other live load wheel configurations

Note: It has been determined that wheel combinations 1 & 2, 2 & 3, 2 & 3 & 4, 4 & 5 do not govern.

3.0 Check Lane Live Loading for Moment

M_{Lane} = w x L^2 / 8 *[Can/CSA S16-01 PP 6-44]*
= 9 x 88 / 8
= 99 kN·m

M_{Max} = M_{Lane} + 0.8 x M_{Truck}
= 99 + 0.8 x 301
= 340 kN·m *Does Not Govern*

4.0 Check Dead Load Maximum Moment

Self-Weight = 1.23 kN/m
L = 9.398 m

$M_{max, SW}$ = w x L^2 / 8
= 1.23 x 88 / 8
= 13.58 kN·m

Grating = 1.24 kN/m *Assume 0.96kPa x 1.2954m wide*
L = 9.398 m

$M_{max, Grate}$ = w x L^2 / 8
= 1.24 x 88 / 8
= 13.73 kN·m

$M_{max, DL}$ = $M_{max, SW}$ + $M_{max, Grate}$
= 13.58 + 13.73
= 27 kN·m

5.0 Factored Maximum Moments ***** Note: See also 9.0 for Ma, Mb, Mc***

ULS1 = 1.10 x $M_{max, DL}$ + 1.70 x $M_{max, LL}$
= 1.10 x 27 + 1.70 x 391
= 695 kN·m

FLS1 = 1.00 x $M_{max, DL}$ + 1.00 x $M_{max, LL}$
= 1.00 x 27 + 1.00 x 391
= 418 kN·m

6.0 Maximum Shear

6.1 Unfactored Support Reactions due to Dead Loads

$V_{self-weight}$ = w x L / 2 *Assume simply supported*
= 1.23 x 9.398 / 2
= 6 kN

$V_{grating}$ = w x L / 2
= 1.24 x 9.398 / 2
= 6 kN

$V_{Max, DL}$ = $R_{self-weight}$ + $R_{grating}$ $V_{F,Max, DL}$ = 1.1 x $V_{Max, DL}$

= 6 + 6 = 1.1 x 12
= 12 kN = 13 kN

6.2 Unfactored Support Reactions due to Live Load (Truck)

6.2.1 Wheels 1, 2, and 3

Note: Not to scale.

25	70	70	
↓ 3600	↓ 1200	↓	4,598
A <--		9,398	--> B

$\Sigma M_A = 0 \rightarrow R_B$ = ((70 x 3600) + (70 x 4800)) / 9,398
= 63 kN

R_A = 102 kN *Does Not Govern*

6.2.2 Wheels 2, 3, and 4

Note: Not to scale.

70	70	87.5	
↓ 1200	↓ 6600	↓	1,598
A <--		9,398	--> B

$\Sigma M_A = 0 \rightarrow R_B$ = ((70 x 1200) + (87.5 x 7800)) / 9,398
= 82 kN

R_A = 146 kN *<-- Governs*

6.2.3 Wheels 3 and 4

Note: Not to scale.

70	87.5	
↓ 6600	↓ 2798	0
A <--	9,398	--> B

$\Sigma M_A = 0 \rightarrow R_B$ = ((88 x 6600)) / 9,398
= 61 kN

R_A = 96 kN *Does Not Govern*

6.2.4 Wheels 4 and 5

Note: Not to scale.

87.5	60	
↓ 6600	↓ 2798	0
A <--	9,398	--> B

$\Sigma M_A = 0 \rightarrow R_B$ = ((60 x 6600)) / 9,398 / 9,398
= 42 kN

R_A = 105 kN *Does Not Govern*

6.2.5 Wheels 2, 3, and 4; Reverse Direction

Note: Not to scale.

87.5	70	70	
↓ 6600	↓ 1200	↓	1,598
A <--		9,398	--> B

$\Sigma M_A=0 \rightarrow R_B$	=	((70	x	6600)	+	(70	x	7800))	/	9,398	
	=	107	kN								
R_A	=	120	kN		*Does Not Govern*						

6.3 Apply DLA

V_{Truck}	=	146	kN			
DLA	=	0.3			*Note: Assume no multi-lane reduction*	*[CL 3.8.4.5.3]*
$V_{Max, Truck}$	=	(1 +DLA)	x	V_{Truck}		
	=	1.3	x	146		
	=	190	kN·m		*<-- Governs*	

7.0 Check Lane Live Loading for Shear

V_{Lane}	=	w	x	L	/	2		
	=	9	x	9	/	2		
	=	42	kN					
$V_{Max, Lane}$	=	V_{Lane}	+	0.8	x	V_{Truck}		*Note: Assume no multi-lane reduction*
	=	42	+	0.8	x	146		
	=	159	kN				*Does Not Govern*	

8.0 Factored Maximum Shear

ULS1	=	1.10	x	$V_{Max, DL}$	+	1.70	x	$V_{max, LL}$	*Combined Load Factor:*	*1.67*
	=	1.10	x	12	+	1.70	x	190		
	=	335	kN							
FLS1	=	1.00	x	$V_{Max, DL}$	+	1.00	x	$V_{max, LL}$		
	=	1.00	x	12	+	1.00	x	190		
	=	201	kN							

9.0 Factored Maximum Shear

1.0 One Truck 1,-,-,-

[All references herein to CAN/CSA-S6-06 except where specified]

1.1 Stringer Factored Loads *Assume each floor beam supports twice the maximum stringer reaction*
Includes DLA + Multi-Lane Reduction Factor

Lanes = 1 -> R_L = 1.0 *[CL 3.8.4.2]*

						ULS									ULS	
S1	=	335	x	2	=	671	kN		S7	=	13	x	2	=	26	kN
S2	=	13	x	2	=	26	kN		S8	=	13	x	2	=	26	kN
S3	=	335	x	2	=	671	kN		S9	=	13	x	2	=	26	kN
S4	=	13	x	2	=	26	kN		S10	=	13	x	2	=	26	kN
S5	=	13	x	2	=	26	kN		S11	=	13	x	2	=	26	kN
S6	=	13	x	2	=	26	kN		S12	=	13	x	2	=	26	kN

1.2 Stringer Spacing

				Cumulative						Cumulative	
A - S1	=	1.0668	m	1.0668	m	S6 - S7	=	1.2954	m	8.8392	m
S1 - S2	=	1.2954	m	2.3622	m	S7 - S8	=	1.1176	m	9.9568	m
S2 - S3	=	1.2954	m	3.6576	m	S8 - S9	=	1.1303	m	11.0871	m
S3 - S4	=	1.2954	m	4.953	m	S9 - S10	=	1.1303	m	12.2174	m
S4 - S5	=	1.2954	m	6.2484	m	S10 - S11	=	1.1303	m	13.3477	m
S5 - S6	=	1.2954	m	7.5438	m	S11 - S12	=	1.1303	m	14.478	m
						S12 - B	=	1.0668	m	15.5448	m

1.3 Support Reactions

		ULS	
ΣM_A=0 -> F_B	=	354	kN
=> F_A	=	1243	kN

1.4 Factored Shear (ULS1)

		ULS				ULS	
A	=	1243	kN	S7	=	-226	kN
S1	=	573	kN	S8	=	-251	kN
S2	=	547	kN	S9	=	-277	kN
S3	=	-123	kN	S10	=	-302	kN
S4	=	-149	kN	S11	=	-328	kN
S5	=	-175	kN	S12	=	-354	kN
S6	=	-200	kN	B	=	354	kN

Check: OK

1.5 Factored Moments (ULS1)

		ULS			x/L			ULS			x/L
A	=	0	kN·m	@	0.00	S7	=	1939	kN·m	@	0.57
S1	=	1326	kN·m	@	0.07	S8	=	1687	kN·m	@	0.64
S2	=	2068	kN·m	@	0.15	S9	=	1403	kN·m	@	0.71
S3	=	2777	kN·m	@	0.24	S10	=	1148	kN·m	@	0.79
S4	=	2617	kN·m	@	0.32	S11	=	748	kN·m	@	0.86
S5	=	2424	kN·m	@	0.40	S12	=	435	kN·m	@	0.93
S6	=	2198	kN·m	@	0.49	B	=	0	kN·m	@	1.00

1.6 Factored Demands:

ULS1: M_f = 2777 kN·m V_f = 1243 kN

2.0 Two Trucks 1,2,-,-

[All references herein to CAN/CSA-S6-06 except where specified]

2.1 Stringer Factored Loads *Assume each floor beam supports twice the maximum stringer reaction*
Includes DLA + Multi-Lane Reduction Factor

Lanes = 2 -> R_L = 0.9 *[CL 3.8.4.2]*

						ULS	
S1	=	303	x	2	=	606	kN
S2	=	13	x	2	=	26	kN
S3	=	303	x	2	=	606	kN
S4	=	303	x	2	=	606	kN
S5	=	13	x	2	=	26	kN
S6	=	303	x	2	=	606	kN
S7	=	13	x	2	=	26	kN
S8	=	13	x	2	=	26	kN
S9	=	13	x	2	=	26	kN
S10	=	13	x	2	=	26	kN
S11	=	13	x	2	=	26	kN
S12	=	13	x	2	=	26	kN

2.2 Stringer Spacing

				Cumulative	
A - S1	=	1.0668	m	1.0668	m
S1 - S2	=	1.2954	m	2.3622	m
S2 - S3	=	1.2954	m	3.6576	m
S3 - S4	=	1.2954	m	4.953	m
S4 - S5	=	1.2954	m	6.2484	m
S5 - S6	=	1.2954	m	7.5438	m
S6 - S7	=	1.2954	m	8.8392	m
S7 - S8	=	1.1176	m	9.9568	m
S8 - S9	=	1.1303	m	11.0871	m
S9 - S10	=	1.1303	m	12.2174	m
S10 - S11	=	1.1303	m	13.3477	m
S11 - S12	=	1.1303	m	14.478	m
S12 - B	=	1.0668	m	15.5448	m

2.3 Support Reactions

		ULS		
$\Sigma M_A=0 \rightarrow F_B$	=	801	kN	kN
$\Rightarrow F_A$	=	1828	kN	kN

2.4 Factored Shear (ULS1)

		ULS	
A	=	1828	kN
S1	=	1222	kN
S2	=	1197	kN
S3	=	591	kN
S4	=	-16	kN
S5	=	-41	kN
S6	=	-647	kN
S7	=	-673	kN
S8	=	-698	kN
S9	=	-724	kN
S10	=	-750	kN
S11	=	-775	kN
S12	=	-801	kN
B	=	801	kN

Check: OK

2.5 Factored Moments (ULS1)

		ULS			x/L
A	=	0	kN·m	@	0.00
S1	=	1951	kN·m	@	0.07
S2	=	3534	kN·m	@	0.15
S3	=	5084	kN·m	@	0.24
S4	=	5849	kN·m	@	0.32
S5	=	5829	kN·m	@	0.40
S6	=	5776	kN·m	@	0.49
S7	=	4937	kN·m	@	0.57
S8	=	4185	kN·m	@	0.64
S9	=	3396	kN·m	@	0.71
S10	=	2635	kN·m	@	0.79
S11	=	1730	kN·m	@	0.86
S12	=	912	kN·m	@	0.93
B	=	0	kN·m	@	1.00

2.6 Factored Demands:

ULS1: M_f = 5849 kN·m V_f = 1828 kN

3.0 Three Trucks 1,2,3,-

[All references herein to CAN/CSA-S6-06 except where specified]

3.1 Stringer Factored Loads *Assume each floor beam supports twice the maximum stringer reaction*
Includes DLA + Multi-Lane Reduction Factor

Lanes = 3 -> R_L = 0.8 *[CL 3.8.4.2]*

						ULS								ULS	
S1	=	271	x	2	=	542	kN	S7	=	271	x	2	=	542	kN
S2	=	13	x	2	=	26	kN	S8	=	13	x	2	=	26	kN
S3	=	271	x	2	=	542	kN	S9	=	271	x	2	=	542	kN
S4	=	271	x	2	=	542	kN	S10	=	13	x	2	=	26	kN
S5	=	13	x	2	=	26	kN	S11	=	13	x	2	=	26	kN
S6	=	271	x	2	=	542	kN	S12	=	13	x	2	=	26	kN

3.2 Stringer Spacing

				Cumulative						Cumulative	
A - S1	=	1.0668	m	1.0668	m	S6 - S7	=	1.2954	m	8.8392	m
S1 - S2	=	1.2954	m	2.3622	m	S7 - S8	=	1.1176	m	9.9568	m
S2 - S3	=	1.2954	m	3.6576	m	S8 - S9	=	1.1303	m	11.0871	m
S3 - S4	=	1.2954	m	4.953	m	S9 - S10	=	1.1303	m	12.2174	m
S4 - S5	=	1.2954	m	6.2484	m	S10 - S11	=	1.1303	m	13.3477	m
S5 - S6	=	1.2954	m	7.5438	m	S11 - S12	=	1.1303	m	14.478	m
						S12 - B	=	1.0668	m	15.5448	m

3.3 Support Reactions

		ULS	
$\Sigma M_A=0 \rightarrow F_B$	=	1391	kN
$\Rightarrow F_A$	=	2012	kN

3.4 Factored Shear (ULS1)

		ULS				ULS	
A	=	2012	kN	S7	=	-747	kN
S1	=	1471	kN	S8	=	-772	kN
S2	=	1445	kN	S9	=	-1314	kN
S3	=	904	kN	S10	=	-1340	kN
S4	=	362	kN	S11	=	-1365	kN
S5	=	336	kN	S12	=	-1391	kN
S6	=	-205	kN	B	=	1391	kN

Check: OK

3.5 Factored Moments (ULS1)

		ULS			x/L			ULS			x/L
A	=	0	kN·m	@	0.00	S7	=	7734	kN·m	@	0.57
S1	=	2147	kN·m	@	0.07	S8	=	6899	kN·m	@	0.64
S2	=	4052	kN·m	@	0.15	S9	=	6026	kN·m	@	0.71
S3	=	5924	kN·m	@	0.24	S10	=	5765	kN·m	@	0.79
S4	=	7095	kN·m	@	0.32	S11	=	3027	kN·m	@	0.86
S5	=	7564	kN·m	@	0.40	S12	=	1541	kN·m	@	0.93
S6	=	7999	kN·m	@	0.49	B	=	0	kN·m	@	1.00

3.6 Factored Demands:

ULS1: M_f = 7999 kN·m V_f = 2012 kN

4.0 Four Trucks 1,2,3,4

[All references herein to CAN/CSA-S6-06 except where specified]

4.1 Stringer Factored Loads *Assume each floor beam supports twice the maximum stringer reaction*
Includes DLA + Multi-Lane Reduction Factor

Lanes = 4 -> R_L = 0.7 *[CL 3.8.4.2]*

						ULS								ULS	
S1	=	239	x	2	=	477	kN	S7	=	239	x	2	=	477	kN
S2	=	13	x	2	=	26	kN	S8	=	13	x	2	=	26	kN
S3	=	239	x	2	=	477	kN	S9	=	239	x	2	=	477	kN
S4	=	239	x	2	=	477	kN	S10	=	239	x	2	=	477	kN
S5	=	13	x	2	=	26	kN	S11	=	13	x	2	=	26	kN
S6	=	239	x	2	=	477	kN	S12	=	239	x	2	=	477	kN

4.2 Stringer Spacing

				Cumulative						Cumulative	
A - S1	=	1.0668	m	1.0668	m	S6 - S7	=	1.2954	m	8.8392	m
S1 - S2	=	1.2954	m	2.3622	m	S7 - S8	=	1.1176	m	9.9568	m
S2 - S3	=	1.2954	m	3.6576	m	S8 - S9	=	1.1303	m	11.0871	m
S3 - S4	=	1.2954	m	4.953	m	S9 - S10	=	1.1303	m	12.2174	m
S4 - S5	=	1.2954	m	6.2484	m	S10 - S11	=	1.1303	m	13.3477	m
S5 - S6	=	1.2954	m	7.5438	m	S11 - S12	=	1.1303	m	14.478	m
						S12 - B	=	1.0668	m	15.5448	m

4.3 Support Reactions

		ULS	
$\Sigma M_A=0 \rightarrow F_B$	=	2012	kN
=> F_A	=	1907	kN

4.4 Factored Shear (ULS1)

		ULS				ULS	
A	=	1907	kN	S7	=	-530	kN
S1	=	1430	kN	S8	=	-555	kN
S2	=	1404	kN	S9	=	-1032	kN
S3	=	927	kN	S10	=	-1509	kN
S4	=	450	kN	S11	=	-1535	kN
S5	=	425	kN	S12	=	-2012	kN
S6	=	-52	kN	B	=	2012	kN

Check: OK

4.5 Factored Moments (ULS1)

		ULS			x/L			ULS			x/L
A	=	0	kN·m	@	0.00	S7	=	7973	kN·m	@	0.57
S1	=	2035	kN·m	@	0.07	S8	=	7381	kN·m	@	0.64
S2	=	3887	kN·m	@	0.15	S9	=	6754	kN·m	@	0.71
S3	=	5706	kN·m	@	0.24	S10	=	6666	kN·m	@	0.79
S4	=	6908	kN·m	@	0.32	S11	=	3881	kN·m	@	0.86
S5	=	7491	kN·m	@	0.40	S12	=	2204	kN·m	@	0.93
S6	=	8041	kN·m	@	0.49	B	=	0	kN·m	@	1.00

4.6 Factored Demands:

ULS1: M_f = 8041 kN·m V_f = -2012 kN

1.0 One Truck 1,-,-,-

[All references herein to CAN/CSA-S6-06 except where specified]

1.1 Stringer Factored Loads

Includes DLA + Multi-Lane Reduction Factor

Lanes = 1 -> R_L = 1.0 *[CL 3.8.4.2]*

						ULS								ULS	
S1	=	335	x	1	=	335	kN	S7	=	13	x	1	=	13	kN
S2	=	13	x	1	=	13	kN	S8	=	13	x	1	=	13	kN
S3	=	335	x	1	=	335	kN	S9	=	13	x	1	=	13	kN
S4	=	13	x	1	=	13	kN	S10	=	13	x	1	=	13	kN
S5	=	13	x	1	=	13	kN	S11	=	13	x	1	=	13	kN
S6	=	13	x	1	=	13	kN	S12	=	13	x	1	=	13	kN

1.2 Stringer Spacing

				Cumulative						Cumulative	
A - S1	=	1.0668	m	1.0668	m	S6 - S7	=	1.2954	m	8.8392	m
S1 - S2	=	1.2954	m	2.3622	m	S7 - S8	=	1.1176	m	9.9568	m
S2 - S3	=	1.2954	m	3.6576	m	S8 - S9	=	1.1303	m	11.0871	m
S3 - S4	=	1.2954	m	4.953	m	S9 - S10	=	1.1303	m	12.2174	m
S4 - S5	=	1.2954	m	6.2484	m	S10 - S11	=	1.1303	m	13.3477	m
S5 - S6	=	1.2954	m	7.5438	m	S11 - S12	=	1.1303	m	14.478	m
						S12 - B	=	1.0668	m	15.5448	m

1.3 Support Reactions

		ULS	
ΣM_A=0 -> F_B	=	177	kN
=> F_A	=	622	kN

1.4 Factored Shear (ULS1)

		ULS				ULS	
A	=	622	kN	S7	=	-113	kN
S1	=	286	kN	S8	=	-126	kN
S2	=	274	kN	S9	=	-138	kN
S3	=	-62	kN	S10	=	-151	kN
S4	=	-74	kN	S11	=	-164	kN
S5	=	-87	kN	S12	=	-177	kN
S6	=	-100	kN	B	=	177	kN

Check: OK

1.5 Factored Moments (ULS1)

		ULS			x/L			ULS			x/L
A	=	0	kN·m	@	0.00	S7	=	969	kN·m	@	0.57
S1	=	663	kN·m	@	0.07	S8	=	843	kN·m	@	0.64
S2	=	1034	kN·m	@	0.15	S9	=	701	kN·m	@	0.71
S3	=	1389	kN·m	@	0.24	S10	=	574	kN·m	@	0.79
S4	=	1309	kN·m	@	0.32	S11	=	374	kN·m	@	0.86
S5	=	1212	kN·m	@	0.40	S12	=	217	kN·m	@	0.93
S6	=	1099	kN·m	@	0.49	B	=	0	kN·m	@	1.00

1.6 Factored Demands:

ULS1: M_f = 1389 kN·m V_f = 622 kN

2.0 Two Trucks 1,2,-,-

[All references herein to CAN/CSA-S6-06 except where specified]

2.1 Stringer Factored Loads *Includes DLA + Multi-Lane Reduction Factor*

Lanes = 2 -> R_L = 0.9 *[CL 3.8.4.2]*

						ULS									ULS	
S1	=	303	x	1	=	303	kN		S7	=	13	x	1	=	13	kN
S2	=	13	x	1	=	13	kN		S8	=	13	x	1	=	13	kN
S3	=	303	x	1	=	303	kN		S9	=	13	x	1	=	13	kN
S4	=	303	x	1	=	303	kN		S10	=	13	x	1	=	13	kN
S5	=	13	x	1	=	13	kN		S11	=	13	x	1	=	13	kN
S6	=	303	x	1	=	303	kN		S12	=	13	x	1	=	13	kN

2.2 Stringer Spacing

				Cumulative							Cumulative	
A - S1	=	1.0668	m	1.0668	m		S6 - S7	=	1.2954	m	8.8392	m
S1 - S2	=	1.2954	m	2.3622	m		S7 - S8	=	1.1176	m	9.9568	m
S2 - S3	=	1.2954	m	3.6576	m		S8 - S9	=	1.1303	m	11.0871	m
S3 - S4	=	1.2954	m	4.953	m		S9 - S10	=	1.1303	m	12.2174	m
S4 - S5	=	1.2954	m	6.2484	m		S10 - S11	=	1.1303	m	13.3477	m
S5 - S6	=	1.2954	m	7.5438	m		S11 - S12	=	1.1303	m	14.478	m
							S12 - B	=	1.0668	m	15.5448	m

2.3 Support Reactions

		ULS		
$\Sigma M_A=0 \rightarrow F_B$	=	400	kN	kN
$\Rightarrow F_A$	=	914	kN	kN

2.4 Factored Shear (ULS1)

		ULS					ULS	
A	=	914	kN		S7	=	-336	kN
S1	=	611	kN		S8	=	-349	kN
S2	=	598	kN		S9	=	-362	kN
S3	=	295	kN		S10	=	-375	kN
S4	=	-8	kN		S11	=	-388	kN
S5	=	-21	kN		S12	=	-400	kN
S6	=	-324	kN		B	=	400	kN

Check: OK

2.5 Factored Moments (ULS1)

		ULS			x/L				ULS			x/L
A	=	0	kN·m	@	0.00		S7	=	2469	kN·m	@	0.57
S1	=	975	kN·m	@	0.07		S8	=	2093	kN·m	@	0.64
S2	=	1767	kN·m	@	0.15		S9	=	1698	kN·m	@	0.71
S3	=	2542	kN·m	@	0.24		S10	=	1318	kN·m	@	0.79
S4	=	2925	kN·m	@	0.32		S11	=	865	kN·m	@	0.86
S5	=	2914	kN·m	@	0.40		S12	=	456	kN·m	@	0.93
S6	=	2888	kN·m	@	0.49		B	=	0	kN·m	@	1.00

2.6 Factored Demands:

ULS1: M_f = 2925 kN·m V_f = 914 kN

3.0 Three Trucks 1,2,3,-

[All references herein to CAN/CSA-S6-06 except where specified]

3.1 Stringer Factored Loads *Includes DLA + Multi-Lane Reduction Factor*

Lanes = 3 -> R_L = 0.8 *[CL 3.8.4.2]*

						ULS									ULS	
S1	=	271	x	1	=	271	kN		S7	=	271	x	1	=	271	kN
S2	=	13	x	1	=	13	kN		S8	=	13	x	1	=	13	kN
S3	=	271	x	1	=	271	kN		S9	=	271	x	1	=	271	kN
S4	=	271	x	1	=	271	kN		S10	=	13	x	1	=	13	kN
S5	=	13	x	1	=	13	kN		S11	=	13	x	1	=	13	kN
S6	=	271	x	1	=	271	kN		S12	=	13	x	1	=	13	kN

3.2 Stringer Spacing

				Cumulative							Cumulative	
A - S1	=	1.0668	m	1.0668	m		S6 - S7	=	1.2954	m	8.8392	m
S1 - S2	=	1.2954	m	2.3622	m		S7 - S8	=	1.1176	m	9.9568	m
S2 - S3	=	1.2954	m	3.6576	m		S8 - S9	=	1.1303	m	11.0871	m
S3 - S4	=	1.2954	m	4.953	m		S9 - S10	=	1.1303	m	12.2174	m
S4 - S5	=	1.2954	m	6.2484	m		S10 - S11	=	1.1303	m	13.3477	m
S5 - S6	=	1.2954	m	7.5438	m		S11 - S12	=	1.1303	m	14.478	m
							S12 - B	=	1.0668	m	15.5448	m

3.3 Support Reactions

		ULS	
ΣM_A=0 -> F_B	=	695	kN
=> F_A	=	1006	kN

3.4 Factored Shear (ULS1)

		ULS					ULS	
A	=	1006	kN		S7	=	-373	kN
S1	=	735	kN		S8	=	-386	kN
S2	=	723	kN		S9	=	-657	kN
S3	=	452	kN		S10	=	-670	kN
S4	=	181	kN		S11	=	-683	kN
S5	=	168	kN		S12	=	-695	kN
S6	=	-103	kN		B	=	695	kN

Check: OK

3.5 Factored Moments (ULS1)

		ULS			x/L				ULS			x/L
A	=	0	kN·m	@	0.00		S7	=	3867	kN·m	@	0.57
S1	=	1073	kN·m	@	0.07		S8	=	3450	kN·m	@	0.64
S2	=	2026	kN·m	@	0.15		S9	=	3013	kN·m	@	0.71
S3	=	2962	kN·m	@	0.24		S10	=	2883	kN·m	@	0.79
S4	=	3547	kN·m	@	0.32		S11	=	1513	kN·m	@	0.86
S5	=	3782	kN·m	@	0.40		S12	=	771	kN·m	@	0.93
S6	=	4000	kN·m	@	0.49		B	=	0	kN·m	@	1.00

3.6 Factored Demands:

ULS1: M_f = 4000 kN·m V_f = 1006 kN

4.0 Four Trucks 1,2,3,4

[All references herein to CAN/CSA-S6-06 except where specified]

4.1 Stringer Factored Loads *Includes DLA + Multi-Lane Reduction Factor*

Lanes = 4 -> R_L = 0.7 *[CL 3.8.4.2]*

						ULS									ULS	
S1	=	239	x	1	=	239	kN		S7	=	239	x	1	=	239	kN
S2	=	13	x	1	=	13	kN		S8	=	13	x	1	=	13	kN
S3	=	239	x	1	=	239	kN		S9	=	239	x	1	=	239	kN
S4	=	239	x	1	=	239	kN		S10	=	239	x	1	=	239	kN
S5	=	13	x	1	=	13	kN		S11	=	13	x	1	=	13	kN
S6	=	239	x	1	=	239	kN		S12	=	239	x	1	=	239	kN

4.2 Stringer Spacing

				Cumulative							Cumulative	
A - S1	=	1.0668	m	1.0668	m		S6 - S7	=	1.2954	m	8.8392	m
S1 - S2	=	1.2954	m	2.3622	m		S7 - S8	=	1.1176	m	9.9568	m
S2 - S3	=	1.2954	m	3.6576	m		S8 - S9	=	1.1303	m	11.0871	m
S3 - S4	=	1.2954	m	4.953	m		S9 - S10	=	1.1303	m	12.2174	m
S4 - S5	=	1.2954	m	6.2484	m		S10 - S11	=	1.1303	m	13.3477	m
S5 - S6	=	1.2954	m	7.5438	m		S11 - S12	=	1.1303	m	14.478	m
							S12 - B	=	1.0668	m	15.5448	m

4.3 Support Reactions

		ULS	
ΣM_A=0 -> F_B	=	1006	kN
=> F_A	=	954	kN

4.4 Factored Shear (ULS1)

		ULS					ULS	
A	=	954	kN		S7	=	-265	kN
S1	=	715	kN		S8	=	-278	kN
S2	=	702	kN		S9	=	-516	kN
S3	=	464	kN		S10	=	-755	kN
S4	=	225	kN		S11	=	-767	kN
S5	=	212	kN		S12	=	-1006	kN
S6	=	-26	kN		B	=	1006	kN

Check: OK

4.5 Factored Moments (ULS1)

		ULS			x/L				ULS			x/L
A	=	0	kN·m	@	0.00		S7	=	3987	kN·m	@	0.57
S1	=	1017	kN·m	@	0.07		S8	=	3691	kN·m	@	0.64
S2	=	1944	kN·m	@	0.15		S9	=	3377	kN·m	@	0.71
S3	=	2853	kN·m	@	0.24		S10	=	3333	kN·m	@	0.79
S4	=	3454	kN·m	@	0.32		S11	=	1941	kN·m	@	0.86
S5	=	3745	kN·m	@	0.40		S12	=	1102	kN·m	@	0.93
S6	=	4021	kN·m	@	0.49		B	=	0	kN·m	@	1.00

4.6 Factored Demands:

ULS1: M_f = 4021 kN·m V_f = -1006 kN

1.0 One Truck

[All references herein to CAN/CSA-S6-06 except where specified]

1.1 Stringer Factored Loads

Assume each floor beam supports 1.25x maximum stringer reaction (account for other axles)
Includes DLA + Multi-Lane Reduction Factor
Assume lane is down centre of structure (wheel path = S5, S7)

Lanes = 1 -> R_L = 1.0 *[CL 3.8.4.2]*

						FLS								FLS	
S1	=	13	x	1.25	=	16	kN	S7	=	201	x	1.25	=	252	kN
S2	=	13	x	1.25	=	16	kN	S8	=	13	x	1.25	=	16	kN
S3	=	13	x	1.25	=	16	kN	S9	=	13	x	1.25	=	16	kN
S4	=	13	x	1.25	=	16	kN	S10	=	13	x	1.25	=	16	kN
S5	=	201	x	1.25	=	252	kN	S11	=	13	x	1.25	=	16	kN
S6	=	13	x	1.25	=	16	kN	S12	=	13	x	1.25	=	16	kN

1.2 Stringer Spacing

				Cumulative						Cumulative	
A - S1	=	1.0668	m	1.0668	m	S6 - S7	=	1.2954	m	8.8392	m
S1 - S2	=	1.2954	m	2.3622	m	S7 - S8	=	1.1176	m	9.9568	m
S2 - S3	=	1.2954	m	3.6576	m	S8 - S9	=	1.1303	m	11.0871	m
S3 - S4	=	1.2954	m	4.953	m	S9 - S10	=	1.1303	m	12.2174	m
S4 - S5	=	1.2954	m	6.2484	m	S10 - S11	=	1.1303	m	13.3477	m
S5 - S6	=	1.2954	m	7.5438	m	S11 - S12	=	1.1303	m	14.478	m
						S12 - B	=	1.0668	m	15.5448	m

1.3 Support Reactions

		FLS	
$\Sigma M_A=0 \rightarrow F_B$	=	327	kN
$\Rightarrow F_A$	=	336	kN

1.4 Factored Shear (ULS1)

		FLS				FLS	
A	=	336	kN	S7	=	-247	kN
S1	=	320	kN	S8	=	-263	kN
S2	=	304	kN	S9	=	-279	kN
S3	=	288	kN	S10	=	-295	kN
S4	=	272	kN	S11	=	-311	kN
S5	=	20	kN	S12	=	-327	kN
S6	=	4	kN	B	=	327	kN

Check: OK

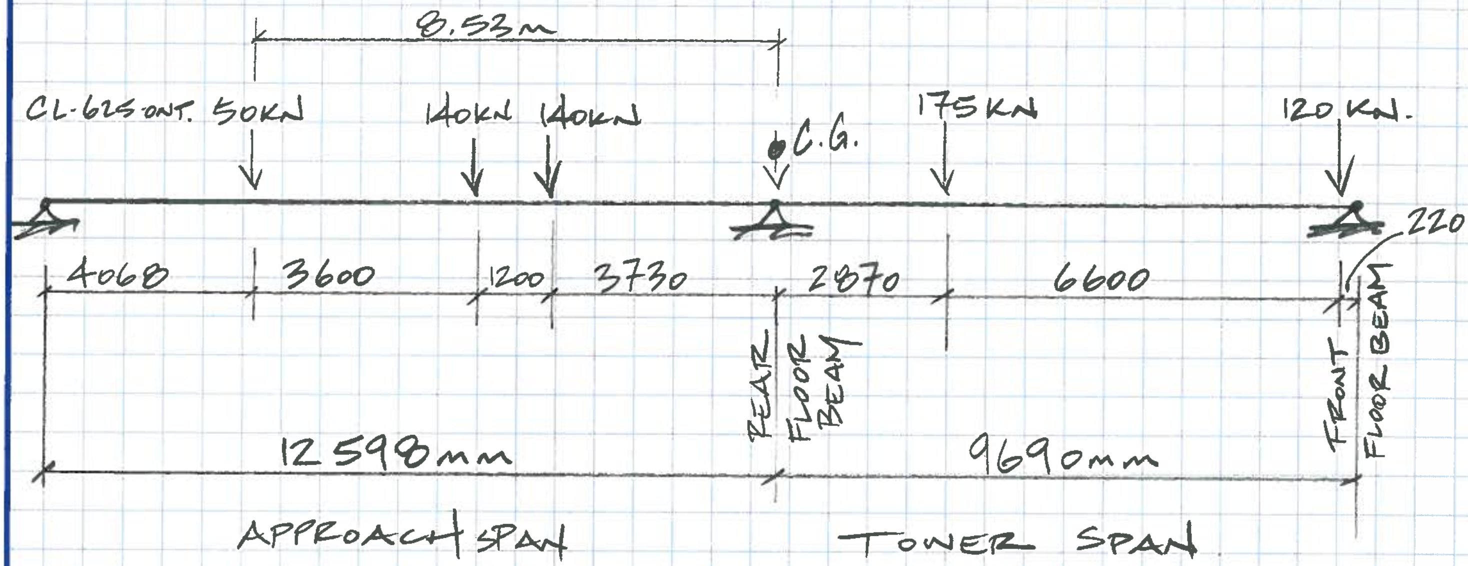
1.5 Factored Moments (ULS1)

		FLS			x/L			FLS			x/L
A	=	0	kN·m	@	0.00	S7	=	1924	kN·m	@	0.57
S1	=	358	kN·m	@	0.07	S8	=	1648	kN·m	@	0.64
S2	=	773	kN·m	@	0.15	S9	=	1350	kN·m	@	0.71
S3	=	1167	kN·m	@	0.24	S10	=	1071	kN·m	@	0.79
S4	=	1540	kN·m	@	0.32	S11	=	701	kN·m	@	0.86
S5	=	1892	kN·m	@	0.40	S12	=	385	kN·m	@	0.93
S6	=	1919	kN·m	@	0.49	B	=	0	kN·m	@	1.00

1.6 Factored Demands:

FLS1: M_f = 1924 kN·m V_f = 336 kN

TOWER SPAN REAR FLOOR BEAM:



Σ MOMENTS TO FIND MAX POINT LOAD TO REAR FLOOR BEAM

∴ MAX LIVE LOAD TO REAR GIRDER FROM CL-625-ONT IS 325.8kN.

ASSUME FOUR LANES LOADED;

MAX UN-FACTORED LIVE LOAD AT EACH STRINGER:

$$\frac{325.8\text{kN} \times 4 \text{ LANES}}{8 \text{ STRINGERS}} = 162.9 \text{ kN} \quad \text{UN-FACTORED}$$

APPLY DLA = 0.25 [CL. 3.8.4.5.3]

162.9kN × 1.25 = 203.6 kN UN-FACTORED

203.6kN × 1.7 = 346.1 kN FACTORED ULS #1

DEAD LOAD:

	UN-FACTORED	α	FACTORED
STRINGERS	1.49 kN/m	x1.10	1.64 kN/m
MISC. STEEL - 15%	0.22 kN/m	x1.10	0.24 kN/m
DECK CONC. (7½")	9.40 kN/m	x1.20	11.28 kN/m
ASPHALT (2½")	3.07 kN/m	x1.50	4.61 kN/m
			17.77 kN/m

DEAD LOAD PER STRINGER TO REAR FLOOR BEAM:

$$17.77 \frac{kN}{m} \times \left(\frac{1}{2}\right)(12.598m + 9.690m)$$

DEAD LOAD = 198.0 kN FACTORED ULS #1

TOTAL FACTORED LOAD PER STRINGER TO REAR FLOOR BEAM:

	198.0 kN	DEAD
+	346.1 kN	LIVE
	544.1 kN	ULS #1

MULTI-LANE LOAD REDUCTION FACTORS

REAR FLOOR BEAM

LOADED LANES	MODIFICATION FACTOR (CL. 3.8.4.2)		LIVE LOAD ULS#1		REDUCED LIVE LOAD		DEAD LOAD ULS#1		TOTAL ULS#1
1	1.0	x	346kN	=	346kN	+	198 kN	=	544kN
2	0.9	x	346kN	=	311 kN	+	198kN	=	509kN
3	0.8	x	346kN	=	277kN	+	198kN	=	475kN
4	0.7	x	346kN	=	242 kN	+	198kN	=	440kN.

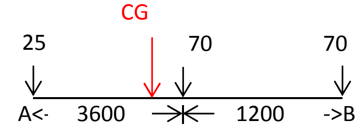
FRONT FLOOR BEAM

1	1.0	x	205 kN	=	205kN	+	86 kN	=	291 kN
2	0.9	x	205 kN	=	185 kN	+	86kN	=	271 kN
3	0.8	x	205kN	=	164 kN	+	86kN	=	250kN
4	0.7	x	205 kN	=	144 kN	+	86 kN		230 kN

1.0 Check Live Load for wheels 1, 2, and 3 of CL-625-ONT

[All references herein to CAN/CSA-S6-06 except where specified]

1.1 Determine centre of gravity of wheel loads



Wheel Loads (kN)

Spacing (mm)

Note: Not to scale.

Total Length b/w Wheels 1 and 3, L_t = 4,800 mm

Centre of Gravity, Cg = $\Sigma(F_i \times d_i) / \Sigma Fi$ *Sum of moments about point A*

= 588,000 / 165

= 3,564 mm

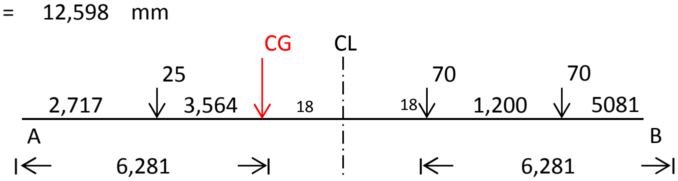
Dist. to nearest wheel = 36 mm

Maximum bending moment occurs when the midpoint between the centre of gravity and the axle nearest is centred at mid-span.

1.2 Determine position of wheels causing maximum moment

Span Length, L = 12,598 mm

Note: Not to scale.



Check: L= 12,598 OK

Check: OK

1.3 Determine support reactions

ΣM_A=0 -> F_B = ((25 x 2717) + (70 x 6317) + (70 x 7517)) / 12,598

= 82 kN

F_A = 83 kN

1.4 Determine maximum bending moment

M_{Truck} = F_A x 6,317 - 25 x 3,600

= 83 x 6,317 - 25 x 3,600

= 433 kN·m

Check: M_{Truck} = FB x 6,281 - 70 x 1,200

= 82 x 6,281 - 70 x 1,200

= 433 kN·m OK

1.5 Apply Dynamic Load Allowance (DLA)

DLA = 0.3 *Note: Assume no multi-lane reduction* *[CL 3.8.4.5.3]*

M_{max} = (1 +DLA) x 433

= 1.3 x 433

= 562 kN·m @ d = 6,317 => 6,317 / L = 0.501 ** Say midspan (conservative)*

2.0 Check other live load wheel configurations

Note: It has been determined that wheel combinations 1 & 2, 2 & 3, 2 & 3 & 4, 4 & 5 do not govern.

3.0 Check Lane Live Loading for Moment

[Can/CSA S16-01 PP 6-44]

M_{Lane} = w x L^2 / 8
= 9 x 159 / 8
= 179 kN·m

M_{Max} = M_{Lane} + 0.8 x M_{Truck}
= 179 + 0.8 x 433
= 525 kN·m *Does Not Govern*

4.0 Check Dead Load Maximum Moment

Self-Weight = 1.88 kN/m
L = 12.598 m

$M_{max, SW}$ = w x L^2 / 8
= 1.88 x 159 / 8
= 37.30 kN·m

$M_{max, deck}$ = w x L^2 / 8
= 15.89 x 159 / 8
= 315.24 kN·m

Deck = 15.89 kN/m *Assume 0.96kPa x 1.2954m wide*
L = 12.598 m

$M_{max, DL}$ = $M_{max, SW}$ + $M_{max, Grate}$
= 37.30 + 315.24
= 353 kN·m

5.0 Factored Maximum Moments

ULS1 = 1.10 x $M_{max, DL}$ + 1.70 x $M_{max, LL}$
= 1.10 x 353 + 1.70 x 562
= 1344 kN·m

FLS1 = 1.00 x $M_{max, DL}$ + 1.00 x $M_{max, LL}$
= 1.00 x 353 + 1.00 x 562
= 915 kN·m

6.0 Maximum Shear

6.1 Unfactored Support Reactions due to Dead Loads

$V_{self\text{-}weight}$ = w x L / 2 *Assume simply supported*
= 1.88 x 12.598 / 2
= 12 kN

V_{deck} = w x L / 2
= 15.89 x 12.598 / 2
= 100 kN

$V_{Max, DL}$ = $R_{self\text{-}weight}$ + $R_{decking}$
= 12 + 100
= 112 kN

$V_{F,Max, DL}$ = 1.1 x $V_{Max, DL}$
= 1.1 x 112
= 123 kN

6.2 Unfactored Support Reactions due to Live Load (Truck)

6.2.1 Wheels 1, 2, and 3

Note: Not to scale.

25 ↓ 3600 | 70 ↓ 1200 | 70 ↓ 7,798

A <-- 12,598 --> B

$\Sigma M_A=0 \rightarrow R_B$ = ((70 x 3600) + (70 x 4800)) / 12,598
= 47 kN

R_A = 118 kN *Does Not Govern*

6.2.2 Wheels 2, 3, and 4

Note: Not to scale.

70 ↓ 1200 | 70 ↓ 6600 | 87.5 ↓ 4,798

A <-- 12,598 --> B

$\Sigma M_A=0 \rightarrow R_B$ = ((70 x 1200) + (87.5 x 7800)) / 12,598
= 61 kN

R_A = 167 kN *<-- Governs*

6.2.3 Wheels 3 and 4

Note: Not to scale.

70 ↓ 6600 | 87.5 ↓ 2798 | 3,200

A <-- 12,598 --> B

$\Sigma M_A=0 \rightarrow R_B$ = ((88 x 6600)) / 12,598
= 46 kN

R_A = 112 kN *Does Not Govern*

6.2.4 Wheels 4 and 5

Note: Not to scale.

87.5 ↓ 6600 | 60 ↓ 2798 | 3,200

A <-- 12,598 --> B

$\Sigma M_A=0 \rightarrow R_B$ = ((60 x 6600)) / 12,598 / 12,598
= 31 kN

R_A = 116 kN *Does Not Govern*

6.2.5 Wheels 2, 3, and 4; Reverse Direction

Note: Not to scale.

87.5 ↓ 6600 | 70 ↓ 1200 | 70 ↓ 4,798

A <-- 12,598 --> B

$\Sigma M_A=0 \rightarrow R_B$ = ((70 x 6600) + (70 x 7800)) / 12,598
= 80 kN

R_A = 147 kN *Does Not Govern*

6.3 Apply DLA

V_{Truck} = 167 kN

DLA = 0.3 *Note: Assume no multi-lane reduction* *[CL 3.8.4.5.3]*

$V_{Max, Truck}$ = (1 +DLA) x V_{Truck}
= 1.3 x 167
= 217 kN·m *<-- Governs*

7.0 Check Lane Live Loading for Shear

V_{Lane} = w x L / 2
= 9 x 13 / 2
= 57 kN

$V_{Max, Lane}$ = V_{Lane} + 0.8 x V_{Truck} *Note: Assume no multi-lane reduction*
= 57 + 0.8 x 167
= 190 kN *Does Not Govern*

8.0 Factored Maximum Shear

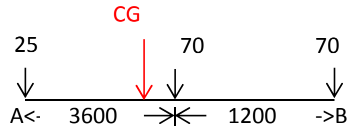
ULS1 = 1.10 x $V_{Max, DL}$ + 1.70 x $V_{max, LL}$ *Combined Load Factor: 1.50*
= 1.10 x 112 + 1.70 x 217
= 491 kN

FLS1 = 1.00 x $V_{Max, DL}$ + 1.00 x $V_{max, LL}$
= 1.00 x 112 + 1.00 x 217
= 329 kN

1.0 Check Live Load for wheels 1, 2, and 3 of CL-625-ONT

[All references herein to CAN/CSA-S6-06 except where specified]

1.1 Determine centre of gravity of wheel loads



Wheel Loads (kN)

Spacing (mm)

Note: Not to scale.

Total Length b/w Wheels 1 and 3, L_t = 4,800 mm

Centre of Gravity, Cg = Σ(F_i x d_i) / ΣFi *Sum of moments about point A*
= 588,000 / 165
= 3,564 mm

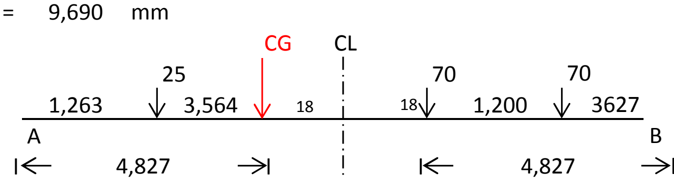
Dist. to nearest wheel = 36 mm

Maximum bending moment occurs when the midpoint between the centre of gravity and the axle nearest is centred at mid-span.

1.2 Determine position of wheels causing maximum moment

Span Length, L = 9,690 mm

Note: Not to scale.



Check: L= 9,690 OK

Check: OK

1.3 Determine support reactions

ΣM_A=0 -> F_B = ((25 x 1263) + (70 x 4863) + (70 x 6063)) / 9,690
= 82 kN

F_A = 83 kN

1.4 Determine maximum bending moment

M_{Truck} = F_A x 4,863 - 25 x 3,600
= 83 x 4,863 - 25 x 3,600
= 313 kN·m

Check: M_{Truck} = FB x 4,827 - 70 x 1,200
= 82 x 4,827 - 70 x 1,200
= 313 kN·m OK

1.5 Apply Dynamic Load Allowance (DLA)

DLA = 0.3 *Note: Assume no multi-lane reduction* *[CL 3.8.4.5.3]*

M_{max} = (1 +DLA) x 313
= 1.3 x 313
= 407 kN·m @ d = 4,863 => 4,863 / L = 0.502 ** Say midspan (conservative)*

2.0 Check other live load wheel configurations

Note: It has been determined that wheel combinations 1 & 2, 2 & 3, 2 & 3 & 4, 4 & 5 do not govern.

3.0 Check Lane Live Loading for Moment

$M_{Lane} = w \times L^2 / 8$ *[Can/CSA S16-01 PP 6-44]*
$= 9 \times 94 / 8$
$= 106$ kN·m

$M_{Max} = M_{Lane} + 0.8 \times M_{Truck}$
$= 106 + 0.8 \times 313$
$= 356$ kN·m *Does Not Govern*

4.0 Check Dead Load Maximum Moment

Self-Weight = 1.88 kN/m
L = 9.690 m

$M_{max, SW} = w \times L^2 / 8$
$= 1.88 \times 94 / 8$
$= 22.07$ kN·m

$M_{max, deck} = w \times L^2 / 8$
$= 15.89 \times 94 / 8$
$= 186.50$ kN·m

Deck = 15.89 kN/m *Assume 0.96kPa x 1.2954m wide*
L = 9.690 m

$M_{max, DL} = M_{max, SW} + M_{max, Grate}$
$= 22.07 + 186.50$
$= 209$ kN·m

5.0 Factored Maximum Moments

$ULS1 = 1.10 \times M_{max, DL} + 1.70 \times M_{max, LL}$
$= 1.10 \times 209 + 1.70 \times 407$
$= 921$ kN·m

$FLS1 = 1.00 \times M_{max, DL} + 1.00 \times M_{max, LL}$
$= 1.00 \times 209 + 1.00 \times 407$
$= 615$ kN·m

6.0 Maximum Shear

6.1 Unfactored Support Reactions due to Dead Loads

$V_{self-weight} = w \times L / 2$ *Assume simply supported*
$= 1.88 \times 9.690 / 2$
$= 9$ kN

$V_{deck} = w \times L / 2$
$= 15.89 \times 9.690 / 2$
$= 77$ kN

$V_{Max, DL} = R_{self-weight} + R_{grating}$
$= 9 + 77$
$= 86$ kN

$V_{F,Max, DL} = 1.1 \times V_{Max, DL}$
$= 1.1 \times 86$
$= 95$ kN

6.2 Unfactored Support Reactions due to Live Load (Truck)

6.2.1 Wheels 1, 2, and 3

Note: Not to scale.

25 ↓ 3600 | 70 ↓ 1200 | 70 ↓ 4,890
A <-- 9,690 --> B

$\Sigma M_A=0 \rightarrow R_B$ = ((70 x 3600) + (70 x 4800)) / 9,690
= 61 kN

R_A = 104 kN *Does Not Govern*

6.2.2 Wheels 2, 3, and 4

Note: Not to scale.

70 ↓ 1200 | 70 ↓ 6600 | 87.5 ↓ 1,890
A <-- 9,690 --> B

$\Sigma M_A=0 \rightarrow R_B$ = ((70 x 1200) + (87.5 x 7800)) / 9,690
= 79 kN

R_A = 148 kN *<-- Governs*

6.2.3 Wheels 3 and 4

Note: Not to scale.

70 ↓ 6600 | 87.5 ↓ 2798 | 292
A <-- 9,690 --> B

$\Sigma M_A=0 \rightarrow R_B$ = ((88 x 6600)) / 9,690
= 60 kN

R_A = 98 kN *Does Not Govern*

6.2.4 Wheels 4 and 5

Note: Not to scale.

87.5 ↓ 6600 | 60 ↓ 2798 | 292
A <-- 9,690 --> B

$\Sigma M_A=0 \rightarrow R_B$ = ((60 x 6600)) / 9,690 / 9,690
= 41 kN

R_A = 107 kN *Does Not Govern*

6.2.5 Wheels 2, 3, and 4; Reverse Direction

Note: Not to scale.

87.5 ↓ 6600 | 70 ↓ 1200 | 70 ↓ 1,890
A <-- 9,690 --> B

$\Sigma M_A=0 \rightarrow R_B$ = ((70 x 6600) + (70 x 7800)) / 9,690
= 104 kN

R_A = 123 kN *Does Not Govern*

6.3 Apply DLA

V_{Truck} = 148 kN

DLA = 0.3 *Note: Assume no multi-lane reduction* *[CL 3.8.4.5.3]*

$V_{Max, Truck}$ = (1 +DLA) x V_{Truck}
= 1.3 x 148
= 193 kN·m *<-- Governs*

7.0 Check Lane Live Loading for Shear

V_{Lane} = w x L / 2
= 9 x 10 / 2
= 44 kN

$V_{Max, Lane}$ = V_{Lane} + 0.8 x V_{Truck} *Note: Assume no multi-lane reduction*
= 44 + 0.8 x 148
= 162 kN *Does Not Govern*

8.0 Factored Maximum Shear

ULS1 = 1.10 x $V_{Max, DL}$ + 1.70 x $V_{max, LL}$ *Combined Load Factor:* *1.51*
= 1.10 x 86 + 1.70 x 193
= 423 kN

FLS1 = 1.00 x $V_{Max, DL}$ + 1.00 x $V_{max, LL}$
= 1.00 x 86 + 1.00 x 193
= 279 kN

1.0 One Truck 1,-,-,-

[All references herein to CAN/CSA-S6-06 except where specified]

1.1 Stringer Factored Loads *Includes DLA + Multi-Lane Reduction Factor*

Lanes = 1 -> R_L = 1.0 *[CL 3.8.4.2]*

		ULS				ULS	
S1	=	544	kN	S7	=	198	kN
S2	=	544	kN	S8	=	198	kN
S3	=	198	kN				
S4	=	198	kN				
S5	=	198	kN				
S6	=	198	kN				

1.2 Stringer Spacing

				Cumulative						Cumulative	
A - S1	=	1.245	m	1.245	m	S6 - S7	=	1.943	m	12.712	m
S1 - S2	=	1.524	m	2.769	m	S7 - S8	=	1.943	m	14.655	m
S2 - S3	=	2.057	m	4.826	m	S8 - B	=	1.245	m	15.900	m
S3 - S4	=	2.057	m	6.883	m						
S4 - S5	=	1.943	m	8.826	m						
S5 - S6	=	1.943	m	10.769	m						

1.3 Support Reactions

		ULS	
$\Sigma M_A=0 \rightarrow F_B$	=	868	kN
$\Rightarrow F_A$	=	1408	kN

1.4 Factored Shear (ULS1)

		ULS				ULS	
A	=	1408	kN	S7	=	-670	kN
S1	=	864	kN	S8	=	-868	kN
S2	=	320	kN	B	=	-868	kN
S3	=	122	kN				
S4	=	-76	kN				
S5	=	-274	kN				
S6	=	-472	kN				

Check: OK

1.5 Factored Moments (ULS1)

		ULS			x/L			ULS			x/L
A	=	0	kN·m	@	0.00	S7	=	2382	kN·m	@	0.80
S1	=	1753	kN·m	@	0.08	S8	=	1081	kN·m	@	0.92
S2	=	3070	kN·m	@	0.17	B	=	0	kN·m	@	1.00
S3	=	3728	kN·m	@	0.30						
S4	=	3979	kN·m	@	0.43						
S5	=	3832	kN·m	@	0.56						
S6	=	3299	kN·m	@	0.68						

1.6 Factored Demands:

Applied Loads:	M_f	=	3979	kN·m	V_f	=	1408	kN
Girder Self Weight:	M_f	=	165	kN·m	V_f	=	41	kN
ULS1:	M_f		4144	kN·m	V_f	=	1449	kN

1.0 Two Trucks 1,2,-,-

[All references herein to CAN/CSA-S6-06 except where specified]

1.1 Stringer Factored Loads *Includes DLA + Multi-Lane Reduction Factor*

Lanes = 2 -> R_L = 0.9 *[CL 3.8.4.2]*

		ULS				*ULS*	
S1	=	509	kN	S7	=	198	kN
S2	=	509	kN	S8	=	198	kN
S3	=	509	kN				
S4	=	509	kN				
S5	=	198	kN				
S6	=	198	kN				

1.2 Stringer Spacing

				Cumulative						*Cumulative*	
A - S1	=	1.245	m	1.245	m	S6 - S7	=	1.943	m	12.712	m
S1 - S2	=	1.524	m	2.769	m	S7 - S8	=	1.943	m	14.655	m
S2 - S3	=	2.057	m	4.826	m	S8 - B	=	1.245	m	15.900	m
S3 - S4	=	2.057	m	6.883	m						
S4 - S5	=	1.943	m	8.826	m						
S5 - S6	=	1.943	m	10.769	m						

1.3 Support Reactions

		ULS	
ΣM_A=0 -> F_B	=	1088	kN
=> F_A	=	1740	kN

1.4 Factored Shear (ULS1)

		ULS				*ULS*	
A	=	1740	kN	S7	=	-890	kN
S1	=	1231	kN	S8	=	-1088	kN
S2	=	722	kN	B	=	-1088	kN
S3	=	213	kN				
S4	=	-296	kN				
S5	=	-494	kN				
S6	=	-692	kN				

Check: OK

1.5 Factored Moments (ULS1)

		ULS			x/L			*ULS*			x/L
A	=	0	kN·m	@	0.00	S7	=	3084	kN·m	@	0.80
S1	=	2166	kN·m	@	0.08	S8	=	1355	kN·m	@	0.92
S2	=	4042	kN·m	@	0.17	B	=	0	kN·m	@	1.00
S3	=	5527	kN·m	@	0.30						
S4	=	5965	kN·m	@	0.43						
S5	=	5389	kN·m	@	0.56						
S6	=	4429	kN·m	@	0.68						

1.6 Factored Demands:

Applied Loads:	M_f	=	5965	kN·m	V_f	=	1740	kN
Girder Self Weight:	M_f	=	165	kN·m	V_f	=	41	kN
ULS1:	M_f		6130	kN·m	V_f	=	1781	kN

1.0 Three Trucks 1,2,3,-

[All references herein to CAN/CSA-S6-06 except where specified]

1.1 Stringer Factored Loads *Includes DLA + Multi-Lane Reduction Factor*

Lanes = 3 -> R_L = 0.8 *[CL 3.8.4.2]*

		ULS				*ULS*	
S1	=	475	kN	S7	=	198	kN
S2	=	475	kN	S8	=	198	kN
S3	=	475	kN				
S4	=	475	kN				
S5	=	475	kN				
S6	=	475	kN				

1.2 Stringer Spacing

				Cumulative						*Cumulative*	
A - S1	=	1.245	m	1.245	m	S6 - S7	=	1.943	m	12.712	m
S1 - S2	=	1.524	m	2.769	m	S7 - S8	=	1.943	m	14.655	m
S2 - S3	=	2.057	m	4.826	m	S8 - B	=	1.245	m	15.900	m
S3 - S4	=	2.057	m	6.883	m						
S4 - S5	=	1.943	m	8.826	m						
S5 - S6	=	1.943	m	10.769	m						

1.3 Support Reactions

		ULS	
$\Sigma M_A=0 \rightarrow F_B$	=	1396	kN
$\Rightarrow F_A$	=	1850	kN

1.4 Factored Shear (ULS1)

		ULS				*ULS*	
A	=	1850	kN	S7	=	-1198	kN
S1	=	1375	kN	S8	=	-1396	kN
S2	=	900	kN	B	=	-1396	kN
S3	=	425	kN				
S4	=	-50	kN				
S5	=	-525	kN				
S6	=	-1000	kN				

Check: OK

1.5 Factored Moments (ULS1)

		ULS			x/L			*ULS*			x/L
A	=	0	kN·m	@	0.00	S7	=	4065	kN·m	@	0.80
S1	=	2303	kN·m	@	0.08	S8	=	1738	kN·m	@	0.92
S2	=	4399	kN·m	@	0.17	B	=	0	kN·m	@	1.00
S3	=	6251	kN·m	@	0.30						
S4	=	7125	kN·m	@	0.43						
S5	=	7028	kN·m	@	0.56						
S6	=	6008	kN·m	@	0.68						

1.6 Factored Demands:

Applied Loads:	M_f	=	7125	kN·m	V_f	=	1850	kN
Girder Self Weight:	M_f	=	165	kN·m	V_f	=	41	kN
ULS1:	M_f		7290	kN·m	V_f	=	1891	kN

1.0 Four Trucks 1,2,3,4

[All references herein to CAN/CSA-S6-06 except where specified]

1.1 Stringer Factored Loads *Includes DLA + Multi-Lane Reduction Factor*

Lanes = 4 -> R_L = 0.7 *[CL 3.8.4.2]*

		ULS				*ULS*	
S1	=	440	kN	S7	=	440	kN
S2	=	440	kN	S8	=	440	kN
S3	=	440	kN				
S4	=	440	kN				
S5	=	440	kN				
S6	=	440	kN				

1.2 Stringer Spacing

				Cumulative						*Cumulative*	
A - S1	=	1.245	m	1.245	m	S6 - S7	=	1.943	m	12.712	m
S1 - S2	=	1.524	m	2.769	m	S7 - S8	=	1.943	m	14.655	m
S2 - S3	=	2.057	m	4.826	m	S8 - B	=	1.245	m	15.900	m
S3 - S4	=	2.057	m	6.883	m						
S4 - S5	=	1.943	m	8.826	m						
S5 - S6	=	1.943	m	10.769	m						

1.3 Support Reactions

		ULS	
ΣM_A=0 -> F_B	=	1735	kN
=> F_A	=	1785	kN

1.4 Factored Shear (ULS1)

		ULS				*ULS*	
A	=	1785	kN	S7	=	-1295	kN
S1	=	1345	kN	S8	=	-1735	kN
S2	=	905	kN	B	=	-1735	kN
S3	=	465	kN				
S4	=	25	kN				
S5	=	-415	kN				
S6	=	-855	kN				

Check: OK

1.5 Factored Moments (ULS1)

		ULS			x/L			*ULS*			x/L
A	=	0	kN·m	@	0.00	S7	=	4675	kN·m	@	0.80
S1	=	2223	kN·m	@	0.08	S8	=	2160	kN·m	@	0.92
S2	=	4273	kN·m	@	0.17	B	=	0	kN·m	@	1.00
S3	=	6135	kN·m	@	0.30						
S4	=	7092	kN·m	@	0.43						
S5	=	7142	kN·m	@	0.56						
S6	=	6336	kN·m	@	0.68						

1.6 Factored Demands:

Applied Loads:	M_f	=	7142	kN·m	V_f	=	1785	kN
Girder Self Weight:	M_f	=	165	kN·m	V_f	=	41	kN
ULS1:	M_f		7307	kN·m	V_f	=	1826	kN

1.0 One Truck 1,-,-,-

[All references herein to CAN/CSA-S6-06 except where specified]

1.1 Stringer Factored Loads *Includes DLA + Multi-Lane Reduction Factor*

Lanes = 1 -> R_L = 1.0 *[CL 3.8.4.2]*

		ULS				ULS	
S1	=	291	kN	S7	=	86	kN
S2	=	291	kN	S8	=	86	kN
S3	=	86	kN				
S4	=	86	kN				
S5	=	86	kN				
S6	=	86	kN				

1.2 Stringer Spacing

				Cumulative						Cumulative	
A - S1	=	1.245	m	1.245	m	S6 - S7	=	1.943	m	12.712	m
S1 - S2	=	1.524	m	2.769	m	S7 - S8	=	1.943	m	14.655	m
S2 - S3	=	2.057	m	4.826	m	S8 - B	=	1.245	m	15.900	m
S3 - S4	=	2.057	m	6.883	m						
S4 - S5	=	1.943	m	8.826	m						
S5 - S6	=	1.943	m	10.769	m						

1.3 Support Reactions

		ULS	
$\Sigma M_A=0 \rightarrow F_B$	=	391	kN
$\Rightarrow F_A$	=	707	kN

1.4 Factored Shear (ULS1)

		ULS				ULS	
A	=	707	kN	S7	=	-305	kN
S1	=	416	kN	S8	=	-391	kN
S2	=	125	kN	B	=	-391	kN
S3	=	39	kN				
S4	=	-47	kN				
S5	=	-133	kN				
S6	=	-219	kN				

Check: OK

1.5 Factored Moments (ULS1)

		ULS			x/L			ULS			x/L
A	=	0	kN·m	@	0.00	S7	=	1079	kN·m	@	0.80
S1	=	880	kN·m	@	0.08	S8	=	487	kN·m	@	0.92
S2	=	1515	kN·m	@	0.17	B	=	0	kN·m	@	1.00
S3	=	1772	kN·m	@	0.30						
S4	=	1853	kN·m	@	0.43						
S5	=	1762	kN·m	@	0.56						
S6	=	1504	kN·m	@	0.68						

1.6 Factored Demands:

Applied Loads:	M_f	=	1853	kN·m	V_f	=	707	kN
Girder Self Weight:	M_f	=	164	kN·m	V_f	=	38	kN
ULS1:	M_f		2017	kN·m	V_f	=	745	kN

1.0 Two Trucks 1,2,-,-

[All references herein to CAN/CSA-S6-06 except where specified]

1.1 Stringer Factored Loads *Includes DLA + Multi-Lane Reduction Factor*

Lanes = 2 -> R_L = 0.9 *[CL 3.8.4.2]*

		ULS				ULS	
S1	=	271	kN	S7	=	86	kN
S2	=	271	kN	S8	=	86	kN
S3	=	271	kN				
S4	=	271	kN				
S5	=	86	kN				
S6	=	86	kN				

1.2 Stringer Spacing

				Cumulative						*Cumulative*	
A - S1	=	1.245	m	1.245	m	S6 - S7	=	1.943	m	12.712	m
S1 - S2	=	1.524	m	2.769	m	S7 - S8	=	1.943	m	14.655	m
S2 - S3	=	2.057	m	4.826	m	S8 - B	=	1.245	m	15.900	m
S3 - S4	=	2.057	m	6.883	m						
S4 - S5	=	1.943	m	8.826	m						
S5 - S6	=	1.943	m	10.769	m						

1.3 Support Reactions

		ULS	
ΣM_A=0 -> F_B	=	522	kN
=> F_A	=	906	kN

1.4 Factored Shear (ULS1)

		ULS				ULS	
A	=	906	kN	S7	=	-436	kN
S1	=	635	kN	S8	=	-522	kN
S2	=	364	kN	B	=	-522	kN
S3	=	93	kN				
S4	=	-178	kN				
S5	=	-264	kN				
S6	=	-350	kN				

Check: OK

1.5 Factored Moments (ULS1)

		ULS			x/L			ULS			x/L
A	=	0	kN·m	@	0.00	S7	=	1497	kN·m	@	0.80
S1	=	1128	kN·m	@	0.08	S8	=	650	kN·m	@	0.92
S2	=	2096	kN·m	@	0.17	B	=	0	kN·m	@	1.00
S3	=	2844	kN·m	@	0.30						
S4	=	3036	kN·m	@	0.43						
S5	=	2690	kN·m	@	0.56						
S6	=	2177	kN·m	@	0.68						

1.6 Factored Demands:

Applied Loads:	M_f	=	3036	kN·m	V_f	=	906	kN
Girder Self Weight:	M_f	=	164	kN·m	V_f	=	38	kN
ULS1:	M_f		3200	kN·m	V_f	=	944	kN

1.0 Three Trucks 1,2,3,-

[All references herein to CAN/CSA-S6-06 except where specified]

1.1 Stringer Factored Loads

Includes DLA + Multi-Lane Reduction Factor

Lanes = 3 -> R_L = 0.8 *[CL 3.8.4.2]*

		ULS				*ULS*	
S1	=	250	kN	S7	=	86	kN
S2	=	250	kN	S8	=	86	kN
S3	=	250	kN				
S4	=	250	kN				
S5	=	250	kN				
S6	=	250	kN				

1.2 Stringer Spacing

				Cumulative						*Cumulative*	
A - S1	=	1.245	m	1.245	m	S6 - S7	=	1.943	m	12.712	m
S1 - S2	=	1.524	m	2.769	m	S7 - S8	=	1.943	m	14.655	m
S2 - S3	=	2.057	m	4.826	m	S8 - B	=	1.245	m	15.900	m
S3 - S4	=	2.057	m	6.883	m						
S4 - S5	=	1.943	m	8.826	m						
S5 - S6	=	1.943	m	10.769	m						

1.3 Support Reactions

		ULS	
$\Sigma M_A=0 \rightarrow F_B$	=	703	kN
$\Rightarrow F_A$	=	969	kN

1.4 Factored Shear (ULS1)

		ULS				*ULS*	
A	=	969	kN	S7	=	-617	kN
S1	=	719	kN	S8	=	-703	kN
S2	=	469	kN	B	=	-703	kN
S3	=	219	kN				
S4	=	-31	kN				
S5	=	-281	kN				
S6	=	-531	kN				

Check: OK

1.5 Factored Moments (ULS1)

		ULS			x/L			*ULS*			x/L
A	=	0	kN·m	@	0.00	S7	=	2075	kN·m	@	0.80
S1	=	1206	kN·m	@	0.08	S8	=	876	kN·m	@	0.92
S2	=	2301	kN·m	@	0.17	B	=	0	kN·m	@	1.00
S3	=	3265	kN·m	@	0.30						
S4	=	3715	kN·m	@	0.43						
S5	=	3654	kN·m	@	0.56						
S6	=	3108	kN·m	@	0.68						

1.6 Factored Demands:

Applied Loads:	M_f	=	3715	kN·m	V_f	=	969	kN
Girder Self Weight:	M_f	=	164	kN·m	V_f	=	38	kN
ULS1:	M_f		3879	kN·m	V_f	=	1007	kN

1.0 Four Trucks 1,2,3,4

[All references herein to CAN/CSA-S6-06 except where specified]

1.1 Stringer Factored Loads

Includes DLA + Multi-Lane Reduction Factor

Lanes = 4 -> R_L = 0.7 *[CL 3.8.4.2]*

		ULS				ULS	
S1	=	230	kN	S7	=	230	kN
S2	=	230	kN	S8	=	230	kN
S3	=	230	kN				
S4	=	230	kN				
S5	=	230	kN				
S6	=	230	kN				

1.2 Stringer Spacing

				Cumulative						Cumulative	
A - S1	=	1.245	m	1.245	m	S6 - S7	=	1.943	m	12.712	m
S1 - S2	=	1.524	m	2.769	m	S7 - S8	=	1.943	m	14.655	m
S2 - S3	=	2.057	m	4.826	m	S8 - B	=	1.245	m	15.900	m
S3 - S4	=	2.057	m	6.883	m						
S4 - S5	=	1.943	m	8.826	m						
S5 - S6	=	1.943	m	10.769	m						

1.3 Support Reactions

		ULS	
$\Sigma M_A=0 \rightarrow F_B$	=	907	kN
$\Rightarrow F_A$	=	933	kN

1.4 Factored Shear (ULS1)

		ULS				ULS	
A	=	933	kN	S7	=	-677	kN
S1	=	703	kN	S8	=	-907	kN
S2	=	473	kN	B	=	-907	kN
S3	=	243	kN				
S4	=	13	kN				
S5	=	-217	kN				
S6	=	-447	kN				

Check: OK

1.5 Factored Moments (ULS1)

		ULS			x/L			ULS			x/L
A	=	0	kN·m	@	0.00	S7	=	2444	kN·m	@	0.80
S1	=	1162	kN·m	@	0.08	S8	=	1129	kN·m	@	0.92
S2	=	2234	kN·m	@	0.17	B	=	0	kN·m	@	1.00
S3	=	3207	kN·m	@	0.30						
S4	=	3707	kN·m	@	0.43						
S5	=	3733	kN·m	@	0.56						
S6	=	3312	kN·m	@	0.68						

1.6 Factored Demands:

Applied Loads:	M_f	=	3733	kN·m	V_f	=	933	kN
Girder Self Weight:	M_f	=	164	kN·m	V_f	=	38	kN
ULS1:	M_f		3897	kN·m	V_f	=	971	kN

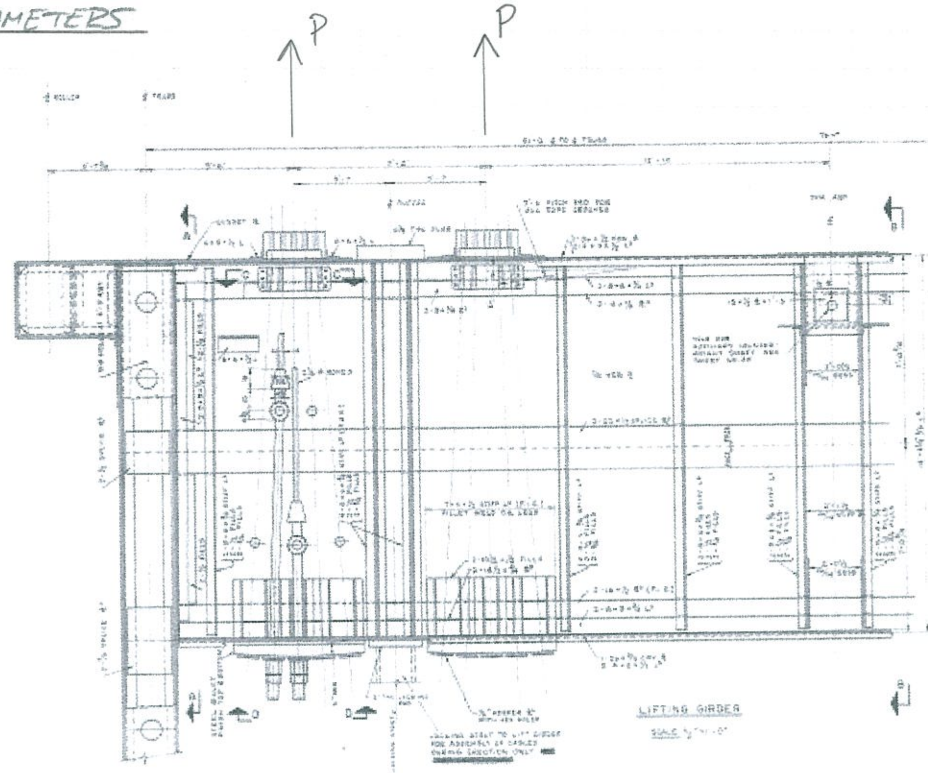
APPENDIX D.3
LIFTING GIRDER DEMAND CHECK

MMM GROUP

Project No.: 3213009	File:	
By: KY	Date: May 15/14	
Checked by: [signature]	Page: 1 of 2	

Subject: BLB ANALYSIS – LIFTING GIRDER HAND CHECK (DEMAND)

① PARAMETERS



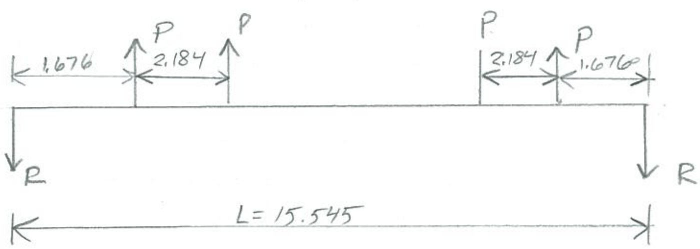
② LOADING (RAISED POSITION)

- DUE TO IMBALANCE, SLIGHTLY DIFFERENT LOADS EXIST AT EACH OF THE FOUR CORNERS. FOR THIS CHECK, USE MAXIMUM FACTORED LOAD WHICH IS CONSERVATIVE.

- USE ULS V.3 LOAD COMBINATION FOR LIFT SPAN IN RAISED POSITION TO PRODUCE THE MAXIMUM FACTORED LOAD. (DEAD + WIND + IMPACT *)

  → FROM ANALYSIS: $R_f = 6376\ kN$ PER "CORNER" (FACTORED)
  4 ∴ $P = R/2 = 3188\ kN$ PER ROPE

- ASSUME BEAM IS FIXED AT ENDS.



NOTE: SELF WEIGHT CALCULATED TO BE $0.169943 m^2 \times 77 kN/m^3 = 13\ kN/m$

* IMPACT LOAD SHALL BE 20% OF LIFT SPAN DEAD LOAD.

MMM GROUP

Project No. : 3213009	File :	
By : KY	Date : May 15/14	
Checked by : [signature]	Page : 2 of 2	

Subject : BLB - Lifting Girder Demand Check

③ Forces (Raised Position)

Max Moment = 13779 kN·m
Max Shear = 6304 kN
} Output from analysis software

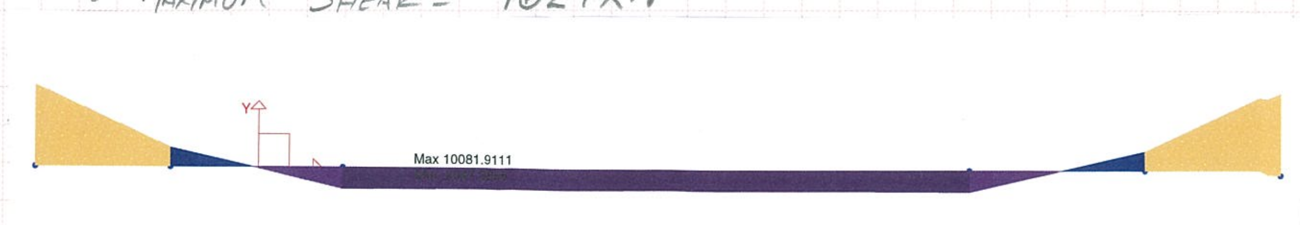
④ Closed Position

- Only dead load from counterweight is assumed to be acting on the lifting girder. [Use ULS 1]

  ⇒ $\alpha_D \times W = 1.1 \times 8547 = 9402$ kN per counterweight.

  ⇒ Four ropes per counterweight ⇒ P = 2350 kN

- Maximum Moment = 10081 kN·m
- Maximum Shear = 4624 kN



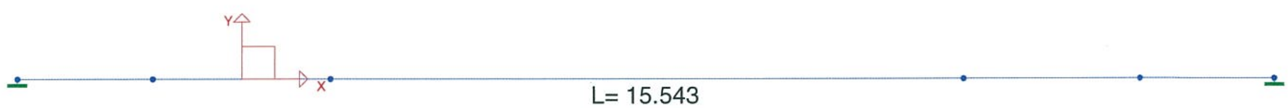
Metric - 5mm Grid

MMM Group Ltd.
2655 North Sheridan Way
Mississauga, Ontario
905-823-8500

RS-6 3D Modelling and Structural Analyses
Filename: C:\Users\YusekK\Desktop\3813009 BLB S-Frame Files\5 - May 2014\May 14, 2014\Test\Test2.TEL
Description: Burlington Lift Bridge
Engineer: KY

SUPPORT REACTIONS

NOTE: FIXED AT BOTH ENDS.



FORCES - RAISED POSITION (FACTORED ULSV3)

NOTE: SELF WEIGHT APPLIED BY SOFTWARE (AND FACTORED PER ULS V3)

APPENDIX D.4
DEFLECTIONS

TRUSS MID-SPAN DEFLECTION APPROXIMATION:

① PARAMETERS:

LENGTH OF LIFT SPAN: $L = 370'-0'' = 112\,776\,mm$

HEIGHT OF TRUSS (AVERAGE) $d = \frac{45.5 + 55}{2} = 50.25' = 15\,316\,mm$

TOP CHORD: AREA → SINCE DEFLECTION IS GOVERNED MORE BY MID-SPAN, USE AVERAGE AREA OF INNER CHORD SECTIONS (IE U_3U_5, U_5U_6)

$$A_{TOP} = \tfrac{1}{2}(104\,028 + 108\,905) = 106\,467\,mm^2$$

SECOND MOMENT OF AREA, I_{TOP} = AVG OF U_3U_5, U_5U_6

$= 11.534 \times 10^9\,mm^4$

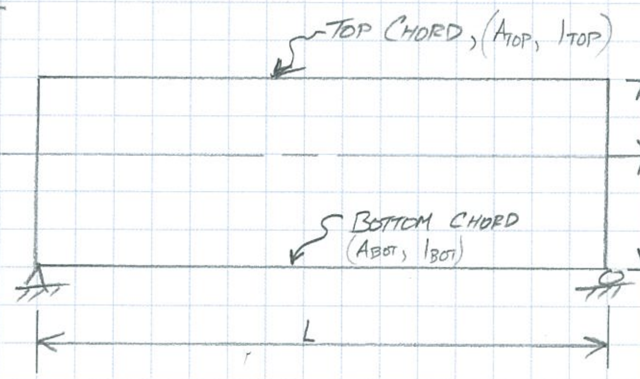
BOTTOM CHORD: AREA (AVG OF L_2L_4, L_4L_6) $= 79\,919\,mm^2 = A_{BOT}$

SECOND MOMENT OF AREA, $I_{BOT} = 5.628 \times 10^9\,mm^4$ (AVG OF L_2L_4, L_4L_6)

ELASTIC MODULUS, $E = 200\,GPa$

② IDEALIZATION:

• AS A BEAM:



→ LOC. OF NEUTRAL AXIS:

$A\bar{y} = \Sigma A_i y_i$

$\Rightarrow d_2 = \frac{A_{TOP} \times (d_1 + d_2) + A_{BOT} \times 0}{(A_{TOP} + A_{BOT})}$

$= 8749\,mm$

$\Rightarrow d_1 = 6567\,mm$

• $I = [I_{TOP} + A_{TOP} d_1^2] + [I_{BOT} + A_{BOT} d_2^2]$ ★ NOTE: I_{TOP}, I_{BOT} ARE VERY SMALL, RELATIVELY.

$= \cancel{I_{TOP}}^{0}\,★ + 4.591 \times 10^{12} + \cancel{I_{BOT}}^{0}\,★ + 6.117 \times 10^{12} = 10.709 \times 10^{12}\,mm^4$

③ LOADING:

→ DEAD LOAD: TOTAL = 17 213.238 kN [ROSS ENG, 2004]

→ ASSUME DEAD LOAD IS EVENLY SHARED BETWEEN THE TWO TRUSSES

↳ 8 606.619 kN

→ APPLY DL AS UDL ALONG LENGTH OF IDEALIZED TRUSS (BEAM)

↳ $8606.619 / 112.766 = 76.316$ kN/m LENGTH = W

$= 76.316 \frac{kN}{m} \times \frac{m}{1000mm} \times \frac{1000N}{kN} = 76.316$ N/mm

④ DEFLECTIONS:

$$\Delta_{DL} = \frac{5WL^4}{384EI} = 5 \times 76.316 \left(\frac{N}{mm}\right) \times 112776^4 (mm^4) \times \frac{1}{384} \times \frac{1}{200000} \left(\frac{mm^2}{N}\right) \times \frac{1}{10.709 \times 10^{12} mm^4}$$

$= 75\,mm$ [ASSUMES NO WEB STIFFENING]

↳ $L/\Delta_{DL} \equiv 1500$

⑤ COMPARISON TO S-FRAME RESULTS:

- DEAD LOAD DEFLECTIONS:

↳ HIGHWAY TRUSS RESULT = 69mm ($L/\Delta_{DL} = 1634$)

$75/69 \simeq 1.1 \rightarrow \therefore \sim 10\%$ WEB STIFFENING

↳ RAILWAY TRUSS RESULT = 63mm ($\frac{L}{\Delta_{DL}} = 1790$)

$75/63 \simeq 1.2 \rightarrow \therefore \sim 20\%$ WEB STIFFENING

Tower Deflection Approximation:

① Parameters:

→ Height of tower: 169'-2 3/8" = 51.572 m (to top of 'B' level)

→ Depth (longitudinal): 32'-0" = 9.754 m

→ Front Column: A_{FCOL} = Avg of mid + top sections
$= \frac{1}{2}(190\,460 + 128\,534)$
$= 159\,497\ mm^2$

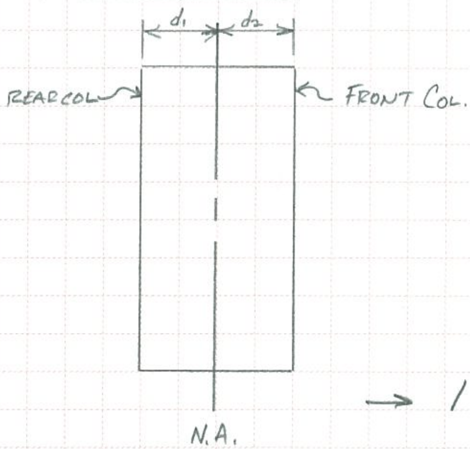
I_{FCOL} = Avg of mid + top
$= 20.730 \times 10^9\ mm^4$

→ Rear Column: $A_{RCOL} = 114\,125\ mm^2$

$I_{RCOL} = 13.516 \times 10^9\ mm^4$

→ Elastic Modulus: 200 000 MPa = 200 000 N/mm^2

② Idealization:



→ Loc. of N.A.: $Ay = \Sigma_i A_i y_i$

$\Rightarrow d_1 = \frac{A_{FCOL} \times (d_1 + d_2) + A_{RCOL} \times 0}{(A_{FCOL} + A_{RCOL})}$

$= 5\,686\ mm$

$\Rightarrow d_2 = 4068\ mm$

→ $I = I_{FCOL} + A_{FCOL} d_2^2 + I_{RCOL} + A_{RCOL} d_1^2$

$= I_{FCOL} (\nearrow 0) + 2.639 \times 10^{12} + I_{RCOL} (\nearrow 0) + 3.690 \times 10^{12}$

$= 6.329 \times 10^{12}\ mm^4$

③ LOADING

→ WIND LOAD: COLUMNS: TAKE AVERAGE OF MID AND TOP

$$W = \frac{1}{2}(2.916 + 3.365) = 3.141 \text{ kN/m PER COL}$$

(ASSUME TWO COLUMNS)

$$= 2 \times 3.141 = 6.282 \text{ kN/m height}$$

↳ QUADRUPLE TO ACCOUNT FOR HORIZONTALS AND DIAGONALS = 25.128 kN/m (TWO FACES) [CONSERVATIVE] [1] (SEE BELOW)

↳ POINT LOAD AT TOP OF EACH TRUSS:
- TRANSVERSE SHEAVE GIRDER: 12.654 kN/m x 15.9m = 201.204 kN
- CLADDING: 2.76 kN/m^2 x 15.9m x 4.572m = 200.638 kN

P => 401.842 kN

NOTES: 1) CALCULATION OF EFFECT OF HORIZONTALS AND DIAGONALS:

HORIZONTAL LENGTH: 52'-2" (15 900mm) EA.
QTY. HORIZONTALS : 5 EA.
0.5 x LENGTH x 2 FACES (FRONT, BACK)
↳ SHARED B/W TWO COLUMS

=> LENGTH OF HORIZONTALS = 79 500 mm

DIAGONAL LENGTH: 11 837mm EA.
QTY 8 EA.
0.5 x L x 2 FACES

=> LENGTH = 94 696mm

=> TOTAL L = 174.196m @ 6.282 kN/m

= 1094 kN (CONVERT TO TOTAL FORCE)

=> 1094 kN / 51.5m = 21 kN/m (EQUIVALENT FORCE PER m HEIGHT)

=> 21+6 ≅ 25 → ASSUMPTION VALID.

④ DEFLECTIONS

$\Delta_{WIND,UDL} = \frac{WL^4}{8EI} = 17mm^*$ (UDL ONLY)

$\Delta_{WIND,PT.} = \frac{PL^3}{3EI} = 15mm^*$ (Pt ONLY)

} = 32mm [NO WEB STIFFENING] (Combined)

↳ $L/\Delta_W \approx 1600$

* Combine deflections due to wind UDL and wind point load

⑤ COMPARISON:

↳ S-FRAME RESULT: 26mm VS CALCULATED 32mm

↳ $32/26 = 1.2 \longrightarrow \therefore$ 20% WEB STIFFENING

↳ NOTE: S-FRAME $L/\Delta \approx 1984$

Panel Point	Dead Load		Live Load (2 Lanes)		D + L	
	Δ (mm)	L / Δ	Δ (mm)	L / Δ	Δ (mm)	L / Δ
0 (S)	0		0		0	
1 (S)	-19	-6050	-2	46712	-21	5356
2 (S)	-36	-3167	-5	24975	-40	2811
3 (S)	-51	-2204	-7	17292	-58	1954
4 (S)	-62	-1805	-8	14258	-70	1602
5 (S)	-68	-1659	-9	12669	-77	1467
6	-69	-1634	-9	12384	-78	1444
5 (N)	-68	-1659	-9	12670	-77	1467
4 (N)	-62	-1807	-8	14263	-70	1604
3 (N)	-51	-2207	-7	17303	-58	1957
2 (N)	-36	-3170	-5	24999	-40	2814
1 (N)	-19	-6058	-2	46823	-21	5364
0 (N)	0		0		0	

Notes: Lift span deflections are provided along the Z-axis (i.e. vertical direction). Positive is "up"
Live loading assumes two outside lanes loaded.

Prepared By: Kyle Yusek

Date: 22/05/2014

Level	Closed, x		Closed, y		Raised, x		Raised, y	
	Δ (mm)	L / Δ	Δ (mm)	L / Δ	Δ (mm)	L / Δ	Δ (mm)	L / Δ
0	0		0		0		0	
1	7	7244	-0.4	-122412	24	2158	13	3878
2	11	4661	-0.4	-116784	37	1381	14	3661
3	16	3324	-0.5	-104928	54	959	13	4100
4	20	2582	-0.4	-135502	70	737	11	4557
5	24	2122	-0.4	-123142	82	626	11	4800
6	26	1984	-0.5	-105615	89	580	15	3499

Note: Level 0 is at the bearing elevation, level 6 is at the sheave girder elevation.
Load case considered is longitudinal wind only.
Deflection based on northeast column of south tower
Tower span deflections are provided along the X-axis (north is positive) and the Y-axis (west is positive).