West Seattle High Level Bridge

Technical Assessment Memo

SDOT

Project Number 221-498

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Prepared by

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1 Introduction

1.1 Authorization

This assessment is submitted in accordance with the request of John Buswell, Roadway Structures Manager, Seattle Department of Transportation (SDOT) and the agreement between HDR and John H. Clark, Consulting Engineer dated 30 October 2013.

1.2 Background

An under bridge inspection (UBIT) in August 2013 by SDOT revealed cracking in the soffit on the main span box girders at four similar locations, approximately 112 feet shoreward from the centerline of the main span. (See Fig 1, Segment 11 between Joints 37 & 38.) At one location, NE, the cracking showed evidence on relative movement and some spalling of the concrete. (See Fig 2.)

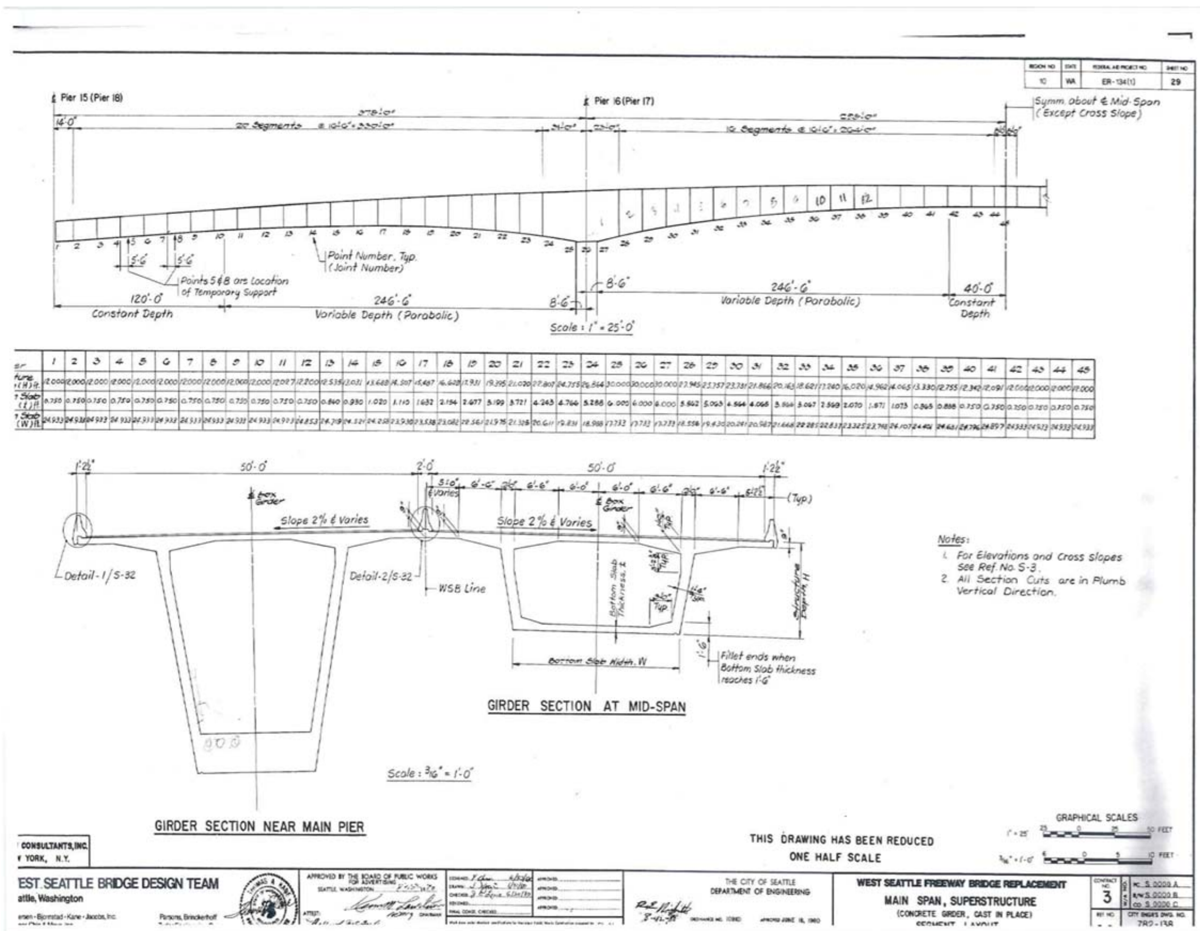


Figure 1. Crack Locations (between Joints 37 & 38)

Figure 2. Spalling at NE crack location

1.3 Purpose

The purpose of this assessment is to assist SDOT in determining 1) the cause of the cracking; and 2) an appropriate repair of the cracking

1.4 Physical Investigations

See Buswell (2013) for report of inspection discovering cracks.

SDOT is planning to conduct the following further physical inspections of the cracked areas:

- UBIT visual re-inspection and crack measurement;
- Coring of slab at crack locations to determine depth of cracking;
- Installation of crack gages to monitor movement.

2 Possible Causes

Possible causes of the cracking are listed below with discussion as to probable magnitude of stresses at the locations where cracks have been observed. The observed fact that cracking has occurred in four similar locations indicates that the cause may be something related to design assumptions or procedures assumed in design being different from what has actually occurred. Determination of stresses required to produce cracking is a difficult task since there are many variables of unknown magnitude. Menn (1990) states the following:

> *It is impossible to know the steel stresses under service conditions. Stresses in the steel are a function of many different factors, some of which are subject to considerable variability. The most important of these include prestressing losses, the redistribution pf sectional forces, self-equilibrating states of stress, and restrained deformations.*
>
> *It thus follows that whatever accuracy promised by an "exact" calculation of steel stresses under service conditions is illusory. Simplifications based on rational models of structural behavior should therefore be used to calculate steel stresses, crack widths, and deformations. It also follows that the criteria used to evaluate cracking behavior and deformations need not be regarded as "exact" values but rather as rough, conservative estimates.*

The statements above with regard to steel stresses also apply to concrete stresses.

2.1 Dead Load

Unit weight of the concrete assumed in design was 160 pounds per cubic foot (pcf). This is consistent with local practice. Cylinder weights of 152 pcf are common for concrete in this area. Reinforcing steel weight from the plan quantities adds another 4 pcf and prestressing steel 2 pcf. Thus the design assumption was adequate. Another source of additional dead load is variations from plan dimensions. The section is made up of relatively thin, wide members. A variation of 1/8 inch of deck and soffit thickness (within normal tolerance) could add 0.7% to the unit weight of the mid-span section. An allowance was made in the design calculations for a deck overly of 2" of asphalt or latex modified concrete, median and side barriers, and miscellaneous utilities. The overlay was applied at the end of construction.

The design plans (Sheet S-16, 782-138) indicate that the structural dead load moment (DL1) at the location of the cracking after PT losses, creep and shrinkage is very nearly zero. This sheet also indicates a superimposed dead load (dead load added after completion of construction of the girder) of 3.75 kip per foot (klf). The median and edge barriers and the allowance for future overlay only account for 2.05 klf. An allowance of 800 plf (for the full width bridge) was specified in the design criteria to cover utilities, drains, and light standards.

2.2 PT Losses

Prestressing losses include elastic shortening, relaxation, anchor set, friction, creep, and shrinkage. Elastic shortening in post-tensioned structures only effects tendons previously anchored since the tendon is elongated as the concrete shortens (at least for the tendon being jacked). Relaxation is the reduction in stress for a tendon held at a constant elongation. Relaxation occurs relatively quickly, (in a few hours) and was estimated in the design to be 3% of the jacking stress. Anchor set influences only a short distance from the anchor.

Friction in essentially straight tendons such as used here is small and most of it occurs at the curvature near the anchorages. Relaxation, anchor set, and friction were accounted for in the design as shown on the VSL shop drawing for cantilever tendons. VSL elected to provide 19 strand tendons using 0.5” diameter strands (As = 0.153 square inches per strand) in lieu of the 12 strand tendon using 0.6” diameter strands. The total number of tendons was adjusted to meet the design plan requirements.

2.3 Creep

Creep is the plastic deformation of concrete under sustained load. It is a function of atmospheric humidity, fineness of cement, cement content of the mix, water/cement ratio, concrete dimensions, concrete age at loading, and time since load application. Many of these variables are not known by the designer at the time of preparation of the plans, therefore an estimate is made. Creep influences prestress losses, deformations and moment redistribution due to a change in the structural system (i.e. closure at mid-span). Creep is usually expressed as an ultimate (time = infinity) value dependent upon material properties and environmental conditions. This value is then modified by a correction factor for the concrete age at the time of load application and by a function describing the time rate of development of the creep. The function for the time rate of development is primarily a function of the dimensions of the section or the effective thickness, h_e.

Various codifications of creep are available for use, including AASHTO LRFD Specifications for Bridge Design and other European codes. The AASHTO formulation is based primarily on experience with prestressed girders of modest dimensions. Most of the research has been done on 6” diameter cylinders (h_e = 3”). The dimensions of the box girders are such that the effective thickness varies from 16.4” at the midspan section to 28.6” at the pier section. Bazant (1982) states the time rate of development of creep varies as the square of the effective thickness since creep is essentially a diffusion process. This means that creep develops much more slowly in a thick section than in a thin section. The design criteria specified an ultimate (at time infinity) creep factor of 2.0. A typical design assumption is that this is reached after 10 to 20 years.

Each segment in the box girder is of a different age and the load application is a series of events. Thus it is impossible to characterize the creep with a single number as was done in the design.

2.4 Shrinkage

Shrinkage is the reduction in size due to the chemical reaction of the cement and to drying shrinkage as the concrete cures. It is influenced by the same factors as is creep. A value of 160 microstrain ($160*10^{-6}$ inches/inch) was used in the design. The time rate of development is similar to creep

2.5 Live Load

Live load in the main span produces positive moment (tension in the bottom slab) at this location. The design live load was based on 5 lanes of HS20 loading reduced for the improbability of multiple lane loading. It is conceivable that two fully loaded trucks (36 tons each) could be on the bridge simultaneously.

2.6 Seismic Displacement

Longitudinal seismic displacement produces both positive and negative moment and a tensile or compressive axial load at the locations of concern. Magnitude of the displacement is dependent upon the seismic event and upon the extent to which the foundations are softened by liquefaction. The 28 February 2001 Nisqually event produced longitudinal displacements estimated to be on the order of 3" according SDOT's post-earthquake inspection. This displacement would produce tensile stresses of approximately 2.0 ksi at this location.

2.7 Differential Temperature

Temperature differences through the depth of the section create restraint stresses in statically determinate structures. These differences occur because of the lag in the response to external temperature differences due to change in the air temperature and solar radiation. Clear summer days following a period of cloudy weather create the most severe differences. On August 11, 2013 the maximum temperature at SEATAC was 27.3 ^{o}F above the running three day mean. This indicates a day with strong solar radiation.

A deck temperature of 20 ^{o}F above the average ambient temperature was used in the analytical studies. This temperature was assumed to decrease according to a 5th order parabola over a depth of 40 inches. This is similar to the differential temperature distribution recommended in the AASHTO LRFD Bridge Design Specifications.

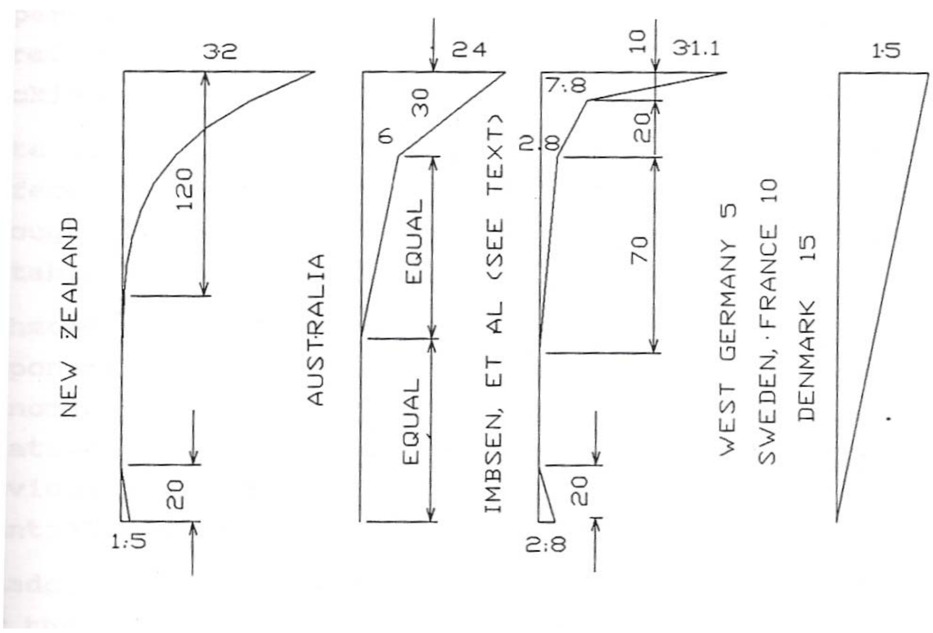


Figure 3. Recommended Temperature Distributions (Dimensions °C, cm)

The design criteria specified a differential temperature situation where the deck slab was 18 ^{o}F hotter than the remainder of the section. This is more extreme than current design recommendations.

The assumed temperature profile was integrated over the section and then a uniform increase was calculated by dividing this integral by the area of the section. Similarly the temperature and width times the depth from the neutral axis was integrated over the section. Dividing this integral by the moment of inertia and multiplying by the coefficient of thermal expansion yields the curvature which would exist in a simply supported section. These two integrations are necessary for plane sections to remain plane. The expansion due to the uniform increase of temperature and the curvature are restrained in this structure leading to forces and moments which produce stresses.

The curvature is applied as a uniform distortion of each member of the superstructure and the temperature at the neutral axis is applied as a temperature load. These loads yield the restraint moments and forces on the continuous structure.

The calculation procedure described above is only an indication of the moments that could be produced by differential temperature effects but it is sufficient to show that these are significant.

2.8 Local Effects

Local effects are present at this location in addition to the global effects discussed above. These include the termination of reinforcing in the bottom slab near the positive moment post-tensioning and transmission of the effect of the cantilever post-tensioning to the bottom slab. (See Section A-A Plan Sheet S13 and Figure 3.) These local effects were not quantified in this assessment. A detailed finite element model beyond the scope of this study would be required to do so.

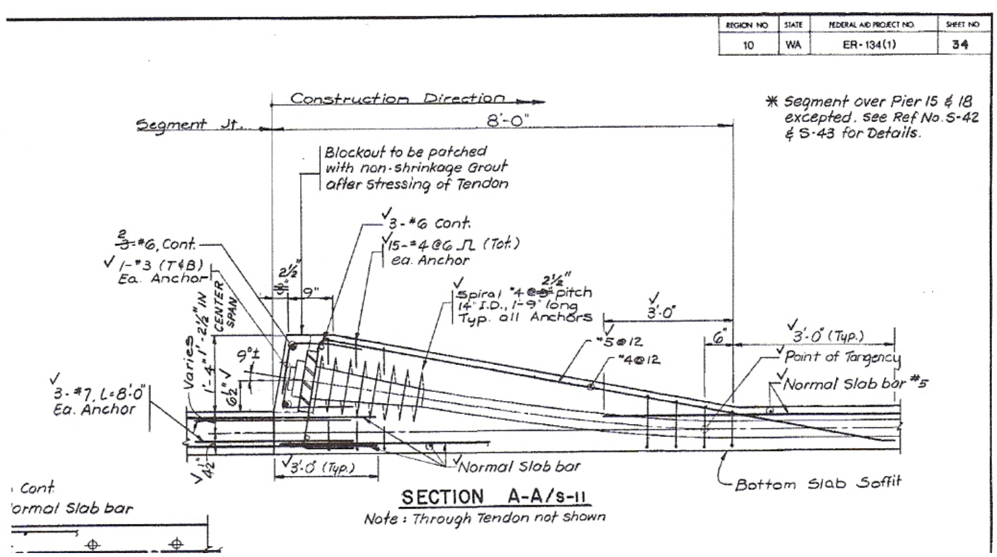


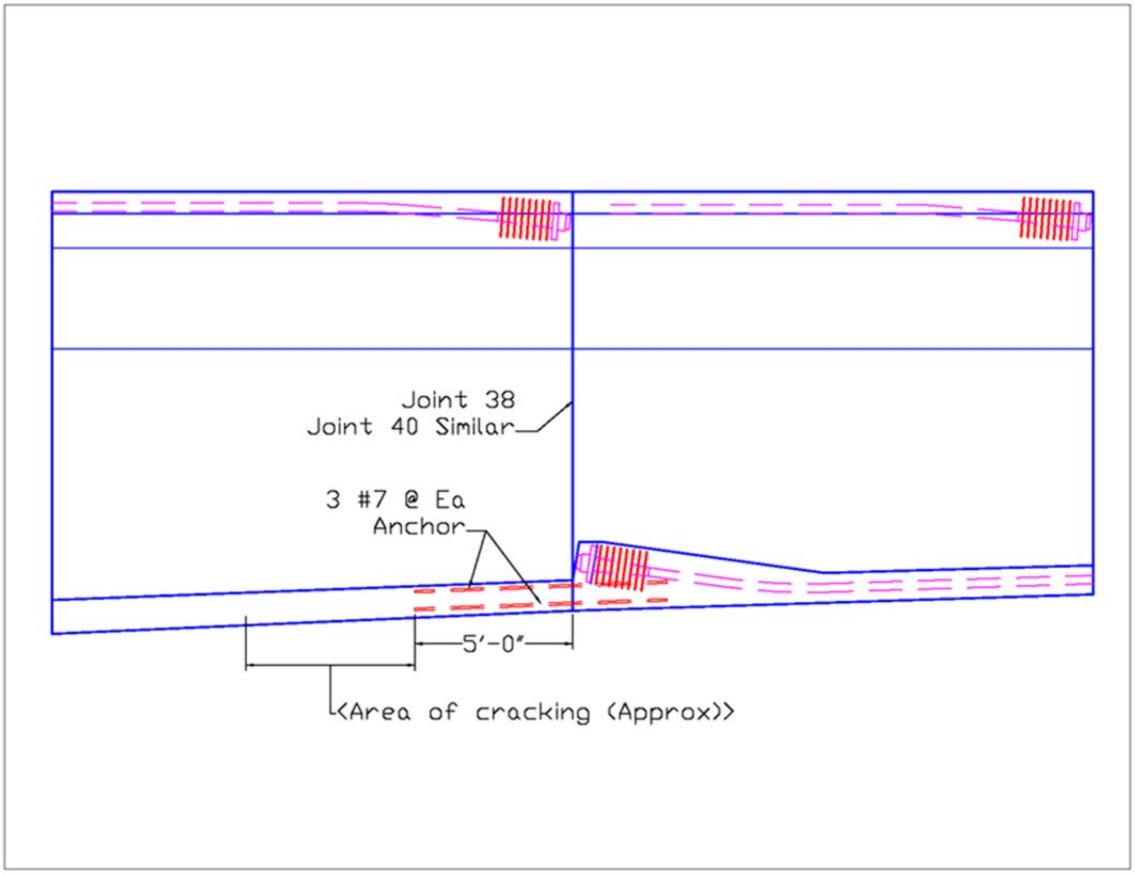
Figure 4. Section A-A Detail at Positive Moment Post-tensioning Buttress

2.9 Termination of Reinforcing at Intermediate Anchorages

The positive moment post-tensioning in the main span is terminated in the blisters at Joints 38 and 40. Additional reinforcing is required in the slab beyond these blisters to prevent cracking. The design called for 6 #7 bars at each anchorage (spaced 14” cc) and extending 5’-0” beyond the segment joint. Normal slab reinforcing is two layers of #5 at 12” cc. Leonhardt (1964) recommends provision of for a force of one-half of the tendon force in such reinforcing. In this case the required tendon force before losses is 478 kips. The corresponding stress in this reinforcing and the normal bottom slab reinforcing would be approximately 48 ksi and the stress on the concrete approximately 0.62 ksi. This local effect tension acts simultaneously with any global stresses. Again a detailed finite element model would be required to definitively quantify these stresses.

2.10 Location of Cantilever Moment Post-tensioning

The anchorages for the cantilever moment post-tensioning in each segment are located as high in the section as possible. The force from these tendons cannot be assumed to be distributed over the whole section closer than about the depth of the section. (Bernoulli’s principle.) Thus, it is conservative to assume that the axial force from each group of tendons is not effective until the next joint is reached. It is also conservative to assume that the induced moment acts at the section where the tendon is anchored. (See Figure 4 below.) The net effect is an increase of tension of 0.227 ksi at the location of the observed cracking.



Note: Not all reinforcing is shown.

Figure 5. Detail between Joints 37 and 38

3 Analytical Studies

A two dimensional GTSTRUDL model of the structure was created to attempt to define the state of stress at the location of the cracking. (See Appendix A.) One quarter of the structure (one box from Pier 15 to the centerline of the main span) was modeled including the structure as it existed after completion of the cantilever construction and both a symmetrical and asymmetrical model of the final structure. Loads applied included self weight of the structure, superimposed dead loads, live load, shrinkage, post-tensioning, differential temperature, uniform live load, HS20 truck, and longitudinal lateral loads.

Redistribution of the loads from the cantilever condition to the final condition was estimated according to Menn (1990) as:

$\sigma^{inf} = \sigma^{A} + 0.8*(\sigma^{E} - \sigma^{A})$ where

σ^{inf} = stress (force or moment) at time = infinity

σ^{A} = stress in cantilever condition

σ^{E} = stress as if all loads applied to the final continuous structure.

This formulation gives results similar to Leonhardt's (1964) method that combines the two load sets according to:

$\sigma^{inf} = \sigma^{A} e^{-\phi} + \sigma^{E} (1-e^{-\phi})$ where ϕ is the creep factor at time infinity less the creep factor when the structure was made continuous.

Both of these are simplifications that are not realized in practice since it is impossible to characterize creep by a single number. Each segment is of a slightly different age and the east portion of the structure was completed a few months before the west half. Age at loading is different for each segment. These differences tend to disappear with increasing time but the difference due to the age at loading can be significant in the ultimate creep.

The results from the analytical studies indicate tension in the area of the observed cracks. Local effects not accounted for in the model or more severe differential temperature or earthquake events would increase this indicated tension, possibly to the point of rupture. The most severe tension resulted from the longitudinal earthquake loading.

The tensile stress at cracking can be estimated as $f_r = 6\sqrt{f'c}$ where f_r is the tensile stress at rupture and $f`_c$ is the characteristic concrete compressive stress. The minimum design concrete compressive stress was 5000 psi. The increase of strength with age and normal distribution of strengths could make this 25% higher than the minimum. Thus the rupture strength could be estimated to be between 420 and 530 psi. The design criteria specified no tension in the box girders except for loads combined with temperature. In this case a tension of 3 times the square root of $f`_c$ (212 psi) was allowed provided that mild steel was provided to carry the total tensile force at a stress of 24 ksi. The stresses at the location of the observed cracking for the case of permanent loads (all dead loads, post-tensioning, creep and shrinkage) plus differential temperature indicated by this study result in tensile stresses of 0.226 ksi at the top of the bottom slab and 0.375 ksi at the soffit. This is a total tension of 43.2 kips to be resisted by 4 #5 bars or about 35 ksi. It should be noted that the differential temperature load case used in this analysis was significantly less that called for by the design criteria. It is possible that differential temperature stresses could have been higher.

4 Conclusions

The analytical studies did not reveal a definitive cause for the cracking although the longitudinal earthquake (2001 Nisqually) could have produce tensile stresses sufficient to cause cracking in the region of the observed cracks. The cracks were not reported in the post-earthquake inspection. The resultant stresses for all load combinations deemed likely were tensile at the location of the observed cracking but less than the probable tensile strength of the concrete. Therefore it must be concluded that the principal cause of the cracking is due to the combination of global loads covered by the analytical studies and local effects not quantified here or the result of the 2001 Nisqually earthquake.

The cracking does not influence the ultimate load capacity of the bridge. The load capacity would be very nearly the same if a hinge were inserted at the location of the observed cracking. Stresses due to restrained strain are relieved by the cracking.

5 Potential Repairs

5.1 Epoxy Grouting

Epoxy grout can be used to seal open cracks and restore most of the tensile capacity. Sealing the cracks is essential to protection of the reinforcing from corrosion.

5.2 Carbon Fiber Reinforcement

Placement of carbon fiber strips, glued to the slab could be used to increase the stiffness and strength of the slab in the cracked regions. Ideally this would be applied to the exterior but constructability issues may make it necessary to do this in the interior of the cell.

5.3 Post-tensioning

The bridge as designed included provision for additional tendons at the Pier 16 and 17 diaphragms. Tendons anchored here would need to have deviation blocks near Section 37. These tendons would be encased in plastic ducts and greased for corrosion protection. It is assumed that these anchorages could accommodate a total of four 12 0.6” diameter strands or four 19 0.5” diameter strands in each box. (See Sheet S-33.)

6 Recommendation

6.1 Epoxy Grouting

Cracks over 0.006” wide should be injected with low viscosity epoxy to restore the tensile capacity of the section. Cracks finer than 0.006” should be sealed with a surface applied sealant.

6.2 Crack Monitoring

The cracks should be monitored by placing crack movement gages across them. The principal purpose of this is to determine if the cracking potential is still active or whether the cracks have relieved the tensile stresses caused by local effects.

U-BIT inspections should be continued at frequent intervals.

6.3 Additional Post-tensioning

If it is determined that the cracks are active, consideration should be given to addition of additional post-tensioning. This would be the most expensive approach; but a permanent remedy for the cracking.

7 References

Menn, C., 1990. *Prestressed Concrete Bridges*, Birkhauser Verlag, Basel

Bazant, Z.P. and F.H. Wittman (Ed.). 1982 *Creep and Shrinkage in Concrete Structures*, John Wiley & Sons, New York

Leonhardt, F. 1964. *Prestressed Concrete, Design and Construction*, Wilhelm Ernst & Sohn, Berlin

Buswell, J. 2013. *Special Bridge Inspection 8-26-13.* Internal SDOT Report

Anon. 1980. *Structural Design Criteria for West Seattle Freeway Bridge Replacement*, West Seattle Bridge Design Team

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APPENDIX A. GTSTRUDL MODEL

The structure model used for the analytical studies is a 2 dimensional “stick” model of one box including the column and foundation. The model extends from the bearing at Pier 15 to the centerline of mid span. The boundary conditions at the centerline of mid-span are changed to represent the symmetrically loaded structure, the asymmetrically loaded structure and the cantilever structure. Members and joints not present in the cantilever structure are inactivated. The cantilever post-tensioning is represented by truss members offset from the box girder center of gravity by a rigid link. The positive moment post-tensioning and coupling post-tensioning are represented by beam members with eccentric ends (offset from the box girder center of gravity) with a minimal moment of inertia.

Loading applied are described in the input files (see below) and various combinations thereof are included. Output is in the form of Excel files for sorting and combination.

A. 1. Cantilever Construction Model

```
STRUDL 'WSB I'  'WSB I High Level Bridge 1 Box'
$ Created 10 Oct 2013 JH Clark'
$ 2D model of one box modelled along cg of section
$ Coordinates are station and elevation
$ Final condition, complete structure, all PT
$ PT as per VSL shop drawings
$ Cantilever PT modelled as truss members between offset joints
$ Continuity  (+M) PT modelled as eccentric beam members
$ Revised 20 October  Added column at Pier 16, seismic response
spectra (WSB design and AASHTO 2009 D)
$ Revised 25 Nov 2013 Corrected cantilever PT added creep for
cantilever PT
UNIT FEET KIPS FAHRENHEIT
JOINT COORDINATES
$ Box section cgc
 1    9302.5     128.890   S     $ CL brg Pier 15
 2    9315.5     129.670
 3    9332.0     130.660
 4    9348.5     131.650
 5    9354.0     131.980
 6    9365.0     132.640
 7    9377.0     133.360
 8    9385.5     133.870
 9    9396.5     134.530
10    9413.0     135.520
11    9429.5     136.500
12    9446.0     137.428
13    9462.5     137.181
14    9479.0     138.839
15    9495.5     139.401
16    9512.0     139.864
17    9528.5     139.687
18    9545.0     139.458
19    9561.5     139.184
20    9578.0     138.844
```

```
21   9594.5     138.425
22   9611.0     137.938
23   9627.5     137.322
24   9644.0     136.637
25   9666.5     135.568          $ Face column Pier 16
26   9675.0     135.858          $ CL    column Pier 16
261  9675.0      -5.000   S      $ CL Footing Pier 16
262  9675.0      18.000          $ End of bottom plastic hinge
263  9675.0      47.741
264  9675.0      77.482
265  9675.0     107.223          $ Start of upper plastic hinge
266  9675.0     122.477          $ Soffit of box girder
27   9683.5     136.141          $ Face column Pier 16
28   9698.0     137.813
29   9714.5     139.638
30   9731.0     141.375
31   9747.5     143.019
32   9764.0     144.571
33   9780.5     146.034
34   9797.0     147.414
35   9813.5     148.726
36   9830.0     149.990
37   9846.5     151.191
38   9863.0     151.811
39   9879.5     152.330
40   9896.0     152.755
41   9912.5     152.969
42   9929.0     153.094
43   9945.5     153.156
44   9962.0     153.186
45   9970.0     153.190   S     $ CL Span 16
$ Cantilever PT cgs
307  9377.0     137.120
308  9385.5     137.630
309  9396.5     138.290
310  9413.0     139.280
311  9429.5     140.270
312  9446.0     141.260
313  9462.5     142.233
314  9479.0     143.174
315  9495.5     144.084
316  9512.0     144.963
317  9528.5     145.812
318  9545.0     146.629
319  9561.5     147.414
320  9578.0     148.169
321  9594.5     148.893
322  9611.0     149.585
323  9627.5     150.247
324  9644.0     150.877
325  9666.5     151.686
326  9675.0     151.977     $ CL Pier 16
327  9683.5     152.260
```

```
328  9698.0     152.722
329  9714.5     153.220
330  9731.0     153.686
331  9747.5     154.121
332  9764.0     154.525
333  9780.5     154.898
334  9797.0     155.420
335  9813.5     155.550
336  9830.0     155.830
337  9846.5     156.078
338  9863.0     156.296
339  9879.5     156.482
340  9896.0     156.637
341  9912.5     156.761
342  9929.0     156.854
343  9945.5     156.916
344  9962.0     156.946
345  9970.0     156.950      $ CL Span 16
$
JOINT RELEASES
   1   FOR X  MOM Z KFY 1.544E06  $ 1/2 Pier 15 (32 24" Octagonal
Hollow PSC 38.5' eff length)
  261   KFX 565.9E03 KFY 3.640E06 KMZ 878.2E06  $ 1/2 Pier 16 (28
36"x3/4"wall Conc filled steel 50' eff length)
$
TYPE PLANE TRUSS
MEMBER INCIDENCES
$ Cantilever PT
GENERATE 38 MEMBERS ID 307 INC 1 FROM 307 INC 1 TO 308 INC 1
DEFINE GROUP 'PT1' ADD MEMBERS 307 TO 344
$
TYPE PLANE FRAME
MEMBER INCIDENCES
$ Span 16 Column
  1601 261 262
  1602 262 263
  1603 263 264
  1604 264 265
  1605 265 266
  1606 266  25
  1607 266  27
$
$ Rigid links from cgc to cgs cantilever
GENERATE 39 MEMBERS ID 407 INC 1 FROM 7 INC 1 TO 307 INC 1
$
GENERATE 44 MEMBERS ID 201 INC 1 FROM 1 INC 1 TO 2 INC 1
$
DEFINE GROUP 'CONST' ADD MEMBERS 201 TO 209  242 TO 244
DEFINE GROUP 'PIER'  ADD MEMBERS 225 226
DEFINE GROUP 'VAR'   ADD MEMBERS 210 TO 224  227 TO 241
DEFINE GROUP 'PT_LINK' ADD MEMBERS 407 TO 445 1606 1607
DEFINE GROUP 'COLUMN_PH' ADD MEMBERS 1601 1605
DEFINE GROUP 'COLUMN'    ADD MEMBERS 1602 TO 1604
```

```
$
MEMBER ECCENTRICITIES
$ Column 16 ends
  1601 START Y 8.000
$
MEMBER PROPERTIES PRISMATIC
  GROUP 'CONST' AX 106.185 AY 32.634 IZ  2217.8  YC  4.260  YD  12.000
  210        AX  106.322  AY 32.670  IZ  2228.6  YC  4.265  YD  12.013
  211        AX  106.564  AY 32.942  IZ  2270.9  YC  4.301  YD  12.113
  212        AX  107.929  AY 33.634  IZ  2416.5  YC  4.442  YD  12.368
  213        AX  110.452  AY 34.763  IZ  2684.3  YC  4.630  YD  12.783
  214        AX  113.388  AY 36.332  IZ  3051.3  YC  5.009  YD  13.360
  215        AX  116.721  AY 38.339  IZ  3537.3  YC  5.391  YD  14.098
  216        AX  124.872  AY 40.785  IZ  4374.4  YC  6.112  YD  14.997
  217        AX  137.951  AY 43.669  IZ  5722.0  YC  7.148  YD  16.058
  218        AX  151.294  AY 46.993  IZ  7303.2  YC  8.201  YD  17.280
  219        AX  168.484  AY 50.754  IZ  9178.4  YC  9.278  YD  18.663
  220        AX  177.411  AY 54.955  IZ 11429.7  YC 10.397  YD  20.208
  221        AX  189.689  AY 59.594  IZ 14134.0  YC 11.558  YD  21.914
  222        AX  201.816  AY 64.672  IZ 17396.5  YC 12.786  YD  23.781
  223        AX  213.679  AY 70.188  IZ 21327.2  YC 14.083  YD  25.809
  224        AX  226.404  AY 77.320  IZ 26801.4  YC 15.685  YD  28.432
  GROUP 'PIER' AX 233.531 AY 81.584  IZ 30856.1  YC 16.618  YD  30.000
  227        AX  227.197  AY 78.790  IZ 28262.6  YC 16.014  YD  28.972
  228        AX  219.654  AY 73.021  IZ 23517.7  YC 14.745  YD  26.851
  229        AX  208.858  AY 67.292  IZ 19270.0  YC 13.446  YD  24.744
  230        AX  197.481  AY 62.001  IZ 15718.0  YC 12.206  YD  22.799
  231        AX  185.260  AY 57.149  IZ 12766.0  YC 11.028  YD  21.015
  232        AX  173.370  AY 52.736  IZ 10323.1  YC  9.909  YD  19.392
  233        AX  160.840  AY 48.762  IZ  8304.2  YC  8.845  YD  17.931
  234        AX  148.115  AY 45.226  IZ  6627.9  YC  7.826  YD  16.630
  235        AX  135.282  AY 42.129  IZ  5216.6  YC  6.832  YD  15.491
  236        AX  122.822  AY 39.470  IZ  4019.8  YC  5.864  YD  14.514
  237        AX  114.964  AY 37.250  IZ  3270.1  YC  5.186  YD  13.698
  238        AX  111.527  AY 35.469  IZ  2832.0  YC  4.819  YD  13.043
  239        AX  108.517  AY 34.127  IZ  2504.1  YC  4.517  YD  12.549
  240        AX  106.813  AY 33.223  IZ  2314.8  YC  4.337  YD  12.217
  241        AX  106.399  AY 32.757  IZ  2242.1  YC  4.276  YD  12.045
$
  GROUP 'COLUMN_PH' AX 150.25 AY 85.0 IZ 3277. YC 8.5 YD 17.0
     $  60% I gross
  GROUP 'COLUMN'  AX 150.25 AY 85.000  IZ 5462. YC 8.5 YD 17.0
     $ 100% I gross 17.0' x 17.75', 2.5' Walls
  GROUP 'PT_LINK' AX 100.0 AY 100.0 IZ 1E04
     $ Rigid link cgc to cgs cantilever PT
$
UNITS INCH
MEMBER PROPERTIES PRISMATIC
  307 308  AX  11.628  $   4 tendons 19x0.5" diam
  309  AX  23.256  $   8 tendons 19x0.5" diam
  310  AX  34.884  $  12 tendons 19x0.5" diam
  311  AX  52.326  $  18 tendons 19x0.5" diam
  312  AX  69.768  $  24 tendons 19x0.5" diam
```

```
  313  AX  87.210  $  30 tendons 19x0.5" diam
  314  AX  98.838  $  34 tendons 19x0.5" diam
  315  AX 116.280  $  40 tendons 19x0.5" diam
  316  AX 133.722  $  46 te36ons 19x0.5" diam
  317  AX 151.164  $  52 tendons 19x0.5" diam
  318  AX 168.606  $  58 tendons 19x0.5" diam
  319  AX 186.048  $  64 tendons 19x0.5" diam
  320  AX 203.490  $  70 tendons 19x0.5" diam
  321  AX 215.118  $  74 tendons 19x0.5" diam
  322  AX 232.560  $  80 tendons 19x0.5" diam
  323  AX 250.002  $  86 tendons 19x0.5" diam
  324 TO 328 AX 273.258  $  94 tendons 19x0.5" diam
  $
  329  AX 255.816  $  88 tendons 19x0.5" diam
  330  AX 238.374  $  82 tendons 19x0.5" diam
  331  AX 220.932  $  76 tendons 19x0.5" diam
  332  AX 209.304  $  72 tendons 19x0.5" diam
  333  AX 191.862  $  66 tendons 19x0.5" diam
  334  AX 174.420  $  60 tendons 19x0.5" diam
  335  AX 156.978  $  54 tendons 19x0.5" diam
  336  AX 139.528  $  48 tendons 19x0.5" diam
  337  AX 122.094  $  42 tendons 19x0.5" diam
  338  AX 104.652  $  36 tendons 19x0.5" diam
  339  AX  93.024  $  32 tendons 19x0.5" diam
  340  AX  75.582  $  26 tendons 19x0.5" diam
  341  AX  58.140  $  20 tendons 19x0.5" diam
  342  AX  40.698  $  14 tendons 19x0.5" diam
  343  AX  29.070  $  10 tendons 19x0.5" diam
  344  AX  17.442  $   6 tendons 19x0.5" diam
$
UNITS FEET
CONSTANTS
$ 5000 psi concrete
  E  580000   GROUP LIST 'CONST'  'PIER'  'VAR'
  G  217000   GROUP LIST 'CONST'  'PIER'  'VAR'
  DEN 0.160   GROUP LIST 'CONST'  'PIER'  'VAR'
  CTE 5.5E-06 GROUP LIST 'CONST'  'PIER'  'VAR'
$ 4000 psi concrete
  E  508000   GROUP LIST 'COLUMN_PH' 'COLUMN'
  G  215000   GROUP LIST 'COLUMN_PH' 'COLUMN'
  DEN 0.160   GROUP LIST 'COLUMN_PH' 'COLUMN'
  CTE 5.5E-06 GROUP LIST 'COLUMN_PH' 'COLUMN'
$ 0.5" Diam Lo-lax strand
  E  3888000   GROUP LIST 'PT1'
  DEN 0.335    GROUP LIST 'PT1'  $ Density difference between steel &
concrete
  CTE 6.5E-06  GROUP LIST 'PT1'
$ Rigid link cgc to cgs cantilever PT
  E 4E07    GROUP 'PT_LINK'
  DEN 1E-06 GROUP 'PT_LINK'
  G 4E07    GROUP 'PT_LINK'
  CTE 1E-09 GROUP 'PT_LINK'
$
```

```
$
$
SELF WEIGHT LOAD 'DC1' 'Member weight' DIR -Y FACTOR 1.00 ALL MEMBERS
$
LOAD 'DC2' 'Blister & diaphragm dead load'
  JOINT LOADS
    1  FOR Y -216.3    $ End  diaphragm 5.5' thick
 MEMBER LOADS
    225 226 FOR Y GLO UNIF W -41.0 LA 0.0 LB 8.5   $ Thickened top
slab and webs
    225     FOR Y GLO UNIF W -85.0 LA 3.5 LB 8.5   $ Diaphragm + pier
strut
    226     FOR Y GLO UNIF W -85.0 LA 3.5 LB 8.5   $ Diaphragm + pier
strut
    225     FOR Y GLO UNIF W -25.6 LA 0.0 LB 2.5   $ Diaphragm between
piers
    226     FOR Y GLO UNIF W -25.6 LA 6.0 LB 8.5   $ Diaphragm between
piers
    201     FOR Y GLO CONC P -39.3 L 8.25  $ Bottom EQ blister
    211 213 FOR Y GLO CONC P -26.5 L 2.76  $ Bottom blister
    238 240 FOR Y GLO CONC P -21.3 L 2.76  $ Bottom blister
    244     FOR Y GLO CONC P  -6.3 L 4.00  $ Top closure blister
$
$
LOAD 'CANT_PT' 'Cantilever PT'
  MEMBER TEMPERATURE LOAD        $ T seated w/ friction per VSL shop
dwgs and 3% relaxation
      307   FR 0.0 1.0 AXIAL -1293
      308   FR 0.0 1.0 AXIAL -1293
      309   FR 0.0 1.0 AXIAL -1266
      310   FR 0.0 1.0 AXIAL -1261
      311   FR 0.0 1.0 AXIAL -1257
      312   FR 0.0 1.0 AXIAL -1268
      313   FR 0.0 1.0 AXIAL -1273
      314   FR 0.0 1.0 AXIAL -1278
      315   FR 0.0 1.0 AXIAL -1280
      316   FR 0.0 1.0 AXIAL -1283
      317   FR 0.0 1.0 AXIAL -1297
      318   FR 0.0 1.0 AXIAL -1293
      319   FR 0.0 1.0 AXIAL -1299
      320   FR 0.0 1.0 AXIAL -1282
      321   FR 0.0 1.0 AXIAL -1308
      322   FR 0.0 1.0 AXIAL -1310
      323   FR 0.0 1.0 AXIAL -1312
      324   FR 0.0 1.0 AXIAL -1257
      325   FR 0.0 1.0 AXIAL -1317
      326   FR 0.0 1.0 AXIAL -1317
      327   FR 0.0 1.0 AXIAL -1317
      328   FR 0.0 1.0 AXIAL -1317
      329   FR 0.0 1.0 AXIAL -1309
      330   FR 0.0 1.0 AXIAL -1304
      331   FR 0.0 1.0 AXIAL -1299
      332   FR 0.0 1.0 AXIAL -1291
```

```
     333  FR 0.0 1.0 AXIAL -1286
     334  FR 0.0 1.0 AXIAL -1276
     335  FR 0.0 1.0 AXIAL -1268
     336  FR 0.0 1.0 AXIAL -1270
     337  FR 0.0 1.0 AXIAL -1264
     338  FR 0.0 1.0 AXIAL -1260
     339  FR 0.0 1.0 AXIAL -1244
     340  FR 0.0 1.0 AXIAL -1234
     341  FR 0.0 1.0 AXIAL -1228
     342  FR 0.0 1.0 AXIAL -1233
     343  FR 0.0 1.0 AXIAL -1219
     344  FR 0.0 1.0 AXIAL -1259
$
FORM LOAD 'DC'  FROM 'DC1' 1.0 'DC2' 1.0
FORM LOAD 'CNSTRUCT' FROM 'DC' 1.0  'CANT_PT' 1.0
$
$
 ACTIVE JOINTS ALL BUT 1 TO 6 45 345
 ACTIVE MEMBERS ALL BUT 201 TO 206 344 244 445
 LOAD LIST 'DC1' 'DC2' 'DC' 'CANT_PT' 'CNSTRUCT'
$
$
STIFFNESS ANALYSIS
$
OUTPUT DEC 1
LIST REACTIONS
LIST SUM REACTIONS
OUTPUT BY LOAD
OUTPUT DECIMAL 5
LIST DISPLACEMENTS JOINTS  7 10 18 22 26 30 34 38 42 44
OUTPUT DEC 1
OUTPUT BY LOAD
SECTION FR NS 1 0.7 MEMBERS EXISTING   207 TO 243  307 TO 344
OUTPUT FIELD F
LIST SECTION FORCES SUMMARY MEMBERS EXISTING 207 TO 243 307 TO 344
$
OUTPUT DEC 3
UNITS INCH
LOAD LIST 'CNSTRUCT'
SECTION FR NS 1 0.7 MEMBERS EXISTING 237
LIST SECTION STRESSES SUMMARY MEMBERS EXISTING 237
$
LOAD LIST 'DC' 'CANT_PT' 'CNSTRUCT'
OUTPUT BY LOAD
UNITS FEET
OUTPUT DEC 1
WRITE REPLACE JOINT RESULTS JOINTS  EXISTING
WRITE REPLACE MEMBER RESULTS MEMBERS  EXISTING
WRITE REPLACE SECTION FORCES NS 2 MEMBERS  EXISTING
```

A. 2. Symmetrical Continuous Structure

```
STRUDL 'WSB I'  'WSB I High Level Bridge 1 Box'
$ Created 10 Oct 2013 JH Clark'
$ 2D model of one box modelled along cg of section
$ Coordinates are station and elevation
$ Final condition, complete structure, all PT
$ PT as per VSL shop drawings
$ Cantilever PT modelled as truss members between offset joints
$ Continuity  (+M) PT modelled as eccentric beam members
$ Revised 20 October  Added column at Pier 16, seismic response
spectra (WSB design and AASHTO 2009 D)
$ Revised 19 November Added PT Creep Differential Temperature  Changed
support conditions at midspan
$ Revised 21 Nov 2013  Differential Temperature Curvature corrected
UNIT FEET KIPS FAHRENHEIT
JOINT COORDINATES
$ Box section cgc
 1    9302.5     128.890   S     $ CL brg Pier 15
 2    9315.5     129.670
 3    9332.0     130.660
 4    9348.5     131.650
 5    9354.0     131.980
 6    9365.0     132.640
 7    9377.0     133.360
 8    9385.5     133.870
 9    9396.5     134.530
10    9413.0     135.520
11    9429.5     136.500
12    9446.0     137.428
13    9462.5     138.181
14    9479.0     138.839
15    9495.5     139.401
16    9512.0     139.864
17    9528.5     139.687
18    9545.0     139.458
19    9561.5     139.184
20    9578.0     138.844
21    9594.5     138.425
22    9611.0     137.938
23    9627.5     137.322
24    9644.0     136.637
25    9666.5     135.568         $ Face column Pier 16
26    9675.0     135.858         $ CL    column Pier 16
261  9675.0     -10.500   S     $ CL Footing Pier 16
262  9675.0      14.000         $ End of bottom plastic hinge
263  9675.0      45.074
264  9675.0      76.149
265  9675.0     107.223         $ Start of upper plastic hinge
266  9675.0     122.477         $ Soffit of box girder
27   9683.5     136.141
28    9698.0     137.813
29    9714.5     139.638
```

```
30    9731.0     141.375
31    9747.5     143.019
32    9764.0     144.571
33    9780.5     146.034
34    9797.0     147.414
35    9813.5     148.726
36    9830.0     149.990
37    9846.5     151.191
38    9863.0     151.811
39    9879.5     152.330
40    9896.0     152.755
41    9912.5     152.969
42    9929.0     153.094
43    9945.5     153.156
44    9962.0     153.186
45    9970.0     153.190   S    $ CL Span 16
$ Cantilever PT cgs
307  9377.0      137.120
308  9385.5     137.630
309  9396.5     138.290
310  9413.0     139.280
311  9429.5     140.270
312  9446.0     141.260
313  9462.5     142.233
314  9479.0     143.174
315  9495.5     144.084
316  9512.0     144.963
317  9528.5     145.812
318  9545.0     146.629
319  9561.5     147.414
320  9578.0     148.169
321  9594.5     148.893
322  9611.0     149.585
323  9627.5     150.247
324  9644.0     150.877
325  9666.5     151.686
326  9675.0     151.977      $ CL Pier 16
327  9683.5     152.260
328  9698.0     152.722
329  9714.5     153.220
330  9731.0     153.686
331  9747.5     154.121
332  9764.0     154.525
333  9780.5     154.898
334  9797.0     155.420
335  9813.5     155.550
336  9830.0     155.830
337  9846.5     156.078
338  9863.0     156.296
339  9879.5     156.482
340  9896.0     156.637
341  9912.5     156.761
342  9929.0     156.854
```

```
343  9945.5     156.916
344  9962.0     156.946
345  9970.0     156.950    S  $ CL Span 16
$
JOINT RELEASES
   1       FOR X  MOM Z  KFY 1.544E06              $ 1/2 Pier 15 (32
Piles 24" Hollow PSC 38.5 ft effective length)
  261      KFX 565.9E03 KFY 3.640E06 KMZ 878.2E06  $ 1/2 Pier 16 (28
Piles 36" x 3/4" Concrete Filled 50 ft effective length)
   45  345 FOR Y                                   $ Symmetrical
loadings
$
TYPE PLANE TRUSS
MEMBER INCIDENCES
$ Cantilever PT
GENERATE 38 MEMBERS ID 307 INC 1 FROM 307 INC 1 TO 308 INC 1
DEFINE GROUP 'PT1' ADD MEMBERS 307 TO 343
$
TYPE PLANE FRAME
MEMBER INCIDENCES
$ Span 16 Column
  1601 261 262
  1602 262 263
  1603 263 264
  1604 264 265
  1605 265 266
  1606 266  25
  1607 266  27
$ Span 15 Positive moment PT
  118   1  14     $ Tendons B1 B3 B5 B7 B9  B11
  119   1  12     $ Tendons B2 B4 B6 B8 B10 B12
$ Span 15 Negative moment PT
  120   1   9
  121   1   7
$ Span 16 Positive moment PT
  122  38 45      $ Tendons B1 B3 B5 B7 B9  B11 B13
  123  40 45      $ Tendons B2 B4 B6 B8 B10 B12 B14
$ Span 16 Negative moment PT
  124  44 45
$
$ Rigid links from cgc to cgs cantilever
GENERATE 39 MEMBERS ID 407 INC 1 FROM 7 INC 1 TO 307 INC 1
$
GENERATE 44 MEMBERS ID 201 INC 1 FROM 1 INC 1 TO 2 INC 1
$
DEFINE GROUP 'CONST' ADD MEMBERS 201 TO 209  242 TO 244    $ Constant
depth sections
DEFINE GROUP 'PIER'  ADD MEMBERS 225 226                   $ Pier
sections
DEFINE GROUP 'VAR'   ADD MEMBERS 210 TO 224  227 TO 241    $ Variable
depth sections
DEFINE GROUP 'SUPER' ADD MEMBERS 201 TO 244                $ All
superstructure members
```

```
DEFINE GROUP 'PT2' ADD MEMBERS 118 TO 119                    $ 6 12x0.6"
Diam
DEFINE GROUP 'PT3' ADD MEMBERS 120 TO 121                    $ 16 1 1/4"
Bar
DEFINE GROUP 'PT4' ADD MEMBERS 122 TO 123                    $ 6 12x0.6"
Diam
DEFINE GROUP 'PT5' ADD MEMBERS 124                           $  8 1 1/4"
Bar
DEFINE GROUP 'PT_LINK' ADD MEMBERS 407 TO 445 1606 1607    $ Rigid
links for cantilever PT and column
DEFINE GROUP 'COLUMN_PH' ADD MEMBERS 1601 1605             $ Column
plastic hinges
DEFINE GROUP 'COLUMN'    ADD MEMBERS 1602 TO 1604          $ Columns
outside plastic hinge
$
MEMBER ECCENTRICITIES
$ Span 15 positive moment PT
  118 START Y -7.372 END Y -8.196
  119 START Y -7.372 END Y -7.868
$ Pier 15 Top EQ PT
  120 START Y  3.885 END Y  3.885
  121 START Y  3.885 END Y  3.885
$ Span 16 positive moment PT
  122 START Y -7.636 END Y -7.372
  123 START Y -7.313 END Y -7.372
$ Span 16 CL Closure top PT
  124 START Y  3.885 END Y  3.885
$ Column 16 ends
  1601 START Y   7.500
  1605 END   Y -13.671
$
  GROUP 'CONST' AX 106.185 AY 32.634 IZ  2217.8  YC  4.260  YD  12.000
  210        AX  106.322  AY 32.670  IZ  2228.6  YC  4.265  YD  12.013
  211        AX  106.564  AY 32.942  IZ  2270.9  YC  4.301  YD  12.113
  212        AX  107.929  AY 33.634  IZ  2416.5  YC  4.442  YD  12.368
  213        AX  110.452  AY 34.763  IZ  2684.3  YC  4.630  YD  12.783
  214        AX  113.388  AY 36.332  IZ  3051.3  YC  5.009  YD  13.360
  215        AX  116.721  AY 38.339  IZ  3537.3  YC  5.391  YD  14.098
  216        AX  124.872  AY 40.785  IZ  4374.4  YC  6.112  YD  14.997
  217        AX  137.951  AY 43.669  IZ  5722.0  YC  7.148  YD  16.058
  218        AX  151.294  AY 46.993  IZ  7303.2  YC  8.201  YD  17.280
  219        AX  168.484  AY 50.754  IZ  9178.4  YC  9.278  YD  18.663
  220        AX  177.411  AY 54.955  IZ 11429.7  YC 10.397  YD  20.208
  221        AX  189.689  AY 59.594  IZ 14134.0  YC 11.558  YD  21.914
  222        AX  201.816  AY 64.672  IZ 17396.5  YC 12.786  YD  23.781
  223        AX  213.679  AY 70.188  IZ 21327.2  YC 14.083  YD  25.809
  224        AX  226.404  AY 77.320  IZ 26801.4  YC 15.685  YD  28.432
  GROUP 'PIER' AX 233.531 AY 81.584  IZ 30856.1  YC 16.618  YD  30.000
  227        AX  227.197  AY 78.790  IZ 28262.6  YC 16.014  YD  28.972
  228        AX  219.654  AY 73.021  IZ 23517.7  YC 14.745  YD  26.851
  229        AX  208.858  AY 67.292  IZ 19270.0  YC 13.446  YD  24.744
  230        AX  197.481  AY 62.001  IZ 15718.0  YC 12.206  YD  22.799
  231        AX  185.260  AY 57.149  IZ 12766.0  YC 11.028  YD  21.015
```

```
  232        AX  173.370  AY 52.736  IZ 10323.1  YC  9.909  YD  19.392
  233        AX  160.840  AY 48.762  IZ  8304.2  YC  8.845  YD  17.931
  234        AX  148.115  AY 45.226  IZ  6627.9  YC  7.826  YD  16.630
  235        AX  135.282  AY 42.129  IZ  5216.6  YC  6.832  YD  15.491
  236        AX  122.822  AY 39.470  IZ  4019.8  YC  5.864  YD  14.514
  237        AX  114.964  AY 37.250  IZ  3270.1  YC  5.186  YD  13.698
  238        AX  111.527  AY 35.469  IZ  2832.0  YC  4.819  YD  13.043
  239        AX  108.517  AY 34.127  IZ  2504.1  YC  4.517  YD  12.549
  240        AX  106.813  AY 33.223  IZ  2314.8  YC  4.337  YD  12.217
  241        AX  106.399  AY 32.757  IZ  2242.1  YC  4.276  YD  12.045
$
  GROUP 'COLUMN_PH' AX 150.25 AY 85.0 IZ 3277. YC 8.5 YD 17.0
     $  60% I gross
  GROUP 'COLUMN'  AX 150.25 AY 85.000  IZ 5462. YC 8.5 YD 17.0
     $ 100% I gross 17.0' x 17.75', 2.5' Walls
  GROUP 'PT_LINK' AX 100.0 AY 100.0 IZ 1E04
     $ Rigid link cgc to cgs cantilever PT
$
UNITS INCH
MEMBER PROPERTIES PRISMATIC
  307 308  AX  11.628  $   4 tendons 19x0.5" diam
  309  AX  23.256  $   8 tendons 19x0.5" diam
  310  AX  34.884  $  12 tendons 19x0.5" diam
  311  AX  52.326  $  18 tendons 19x0.5" diam
  312  AX  69.768  $  24 tendons 19x0.5" diam
  313  AX  87.210  $  30 tendons 19x0.5" diam
  314  AX  98.838  $  34 tendons 19x0.5" diam
  315  AX 116.280  $  40 tendons 19x0.5" diam
  316  AX 133.722  $  46 te36ons 19x0.5" diam
  317  AX 151.164  $  52 tendons 19x0.5" diam
  318  AX 168.606  $  58 tendons 19x0.5" diam
  319  AX 186.048  $  64 tendons 19x0.5" diam
  320  AX 203.490  $  70 tendons 19x0.5" diam
  321  AX 215.118  $  74 tendons 19x0.5" diam
  322  AX 232.560  $  80 tendons 19x0.5" diam
  323  AX 250.002  $  86 tendons 19x0.5" diam
  324 TO 328 AX 273.258  $  94 tendons 19x0.5" diam
  $
  329  AX 255.816  $  88 tendons 19x0.5" diam
  330  AX 238.374  $  82 tendons 19x0.5" diam
  331  AX 220.932  $  76 tendons 19x0.5" diam
  332  AX 209.304  $  72 tendons 19x0.5" diam
  333  AX 191.862  $  66 tendons 19x0.5" diam
  334  AX 174.420  $  60 tendons 19x0.5" diam
  335  AX 156.978  $  54 tendons 19x0.5" diam
  336  AX 139.528  $  48 tendons 19x0.5" diam
  337  AX 122.094  $  42 tendons 19x0.5" diam
  338  AX 104.652  $  36 tendons 19x0.5" diam
  339  AX  93.024  $  32 tendons 19x0.5" diam
  340  AX  75.582  $  26 tendons 19x0.5" diam
  341  AX  58.140  $  20 tendons 19x0.5" diam
  342  AX  40.698  $  14 tendons 19x0.5" diam
  343  AX  29.070  $  10 tendons 19x0.5" diam
```

```
  344  AX  17.442  $   6 tendons 19x0.5" diam
$
  GROUP 'PT2' AX 20.382 AY 1E-5 IZ 1E-5             $  6 12x0.6" Diam
  GROUP 'PT3' AX 19.945 AY 1E-5 IZ 1E-5             $ 16 1 1/4"  Bar
  GROUP 'PT4' AX 15.624 AY 1E-5 IZ 1E-5             $  6 12x0.6" Diam
  GROUP 'PT5' AX  9.973 AY 1E-5 IZ 1E-5             $  8 1 1/4"  Bar
$
UNITS FEET
CONSTANTS
$ 5000 psi concrete
  E  580000   GROUP LIST 'CONST'  'PIER'  'VAR'
  G  217000   GROUP LIST 'CONST'  'PIER'  'VAR'
  DEN 0.160   GROUP LIST 'CONST'  'PIER'  'VAR'
  CTE 5.5E-06 GROUP LIST 'CONST'  'PIER'  'VAR'
$ 4000 psi concrete
  E  508000   GROUP LIST 'COLUMN_PH' 'COLUMN'
  G  215000   GROUP LIST 'COLUMN_PH' 'COLUMN'
  DEN 0.160   GROUP LIST 'COLUMN_PH' 'COLUMN'
  CTE 5.5E-06 GROUP LIST 'COLUMN_PH' 'COLUMN'
$ 0.5" Diam Lo-lax strand
  E  3888000   GROUP LIST 'PT1' 'PT2' 'PT4'
  DEN 0.335    GROUP LIST 'PT1' 'PT2' 'PT4'  $ Density difference
between steel & concrete
  CTE 6.5E-06  GROUP LIST 'PT1' 'PT2' 'PT4'
$ 1 1/4" Diam D&W bars
  E  4176000   GROUP LIST 'PT3'  'PT5'
  DEN 0.335    GROUP LIST 'PT3'  'PT5'  $ Density difference between
steel & concrete
  CTE 6.5E-06  GROUP LIST 'PT3'  'PT5'
$ Rigid link cgc to cgs cantilever PT
  E 4E07    GROUP 'PT_LINK'
  DEN 1E-06 GROUP 'PT_LINK'
  G 4E07    GROUP 'PT_LINK'
  CTE 1E-09 GROUP 'PT_LINK'
$
$
SELF WEIGHT LOAD 'DC1' 'Member weight' DIR -Y FACTOR 1.00 ALL MEMBERS
$
LOAD 'DC2' 'Blister, diaphragm, footing, seal, & overburden dead load'
  JOINT LOADS
    1  FOR Y  -216.3    $ End  diaphragm 5.5' thick
  261  FOR Y -8204.0    $ Footing, seal, overburden
 MEMBER LOADS
    225 226 FOR Y GLO UNIF W -41.0 LA 0.0 LB 8.5   $ Thickened top
slab and webs
    225 FOR Y GLO UNIF W -85.0 LA 3.5 LB 8.5
       $ Diaphragm + pier strut
    226 FOR Y GLO UNIF W -85.0 LA 3.5 LB 8.5
       $ Diaphragm + pier strut
    225 FOR Y GLO UNIF W -25.6 LA 0.0 LB 2.5
       $ Diaphragm between piers
    226 FOR Y GLO UNIF W -25.6 LA 6.0 LB 8.5
       $ Diaphragm between piers
```

```
    201  FOR Y GLO CONC P -39.3 L 8.25  $ Bottom EQ blister
    211 213 FOR Y GLO CONC P -26.5 L 2.76  $ Bottom blister
    238 240 FOR Y GLO CONC P -21.3 L 2.76  $ Bottom blister
    244  FOR Y GLO CONC P  -6.3 L 4.00  $ Top closure blister
$
LOAD 'DW1' 'Barriers'
  MEMBER LOADS
    201 TO 244  FOR Y GLO UNIF -0.800
     $ 1 WSB Barrier (562 plf)& 1/2 ctr barrier (238 plf) at 0.155 kcf
$
LOAD 'DW2' 'Overlay'
 MEMBER LOADS
    201 TO 244 FOR Y GLO UNIF -1.250     $ 25 psf on roadway
$
LOAD 'BOUY' 'Buoyancy to WS Elev -3.0'
  JOINT LOAD
      261  FOR Y +3432.0
$
$
LOAD 'CANT_PT' 'Cantilever PT'
  MEMBER TEMPERATURE LOAD
       $ T seated w/ friction per VSL shop dwgs and 3% relaxation
      307   FR 0.0 1.0 AXIAL -1293
      308   FR 0.0 1.0 AXIAL -1293
      309   FR 0.0 1.0 AXIAL -1266
      310   FR 0.0 1.0 AXIAL -1261
      311   FR 0.0 1.0 AXIAL -1257
      312   FR 0.0 1.0 AXIAL -1268
      313   FR 0.0 1.0 AXIAL -1273
      314   FR 0.0 1.0 AXIAL -1278
      315   FR 0.0 1.0 AXIAL -1280
      316   FR 0.0 1.0 AXIAL -1283
      317   FR 0.0 1.0 AXIAL -1297
      318   FR 0.0 1.0 AXIAL -1293
      319   FR 0.0 1.0 AXIAL -1299
      320   FR 0.0 1.0 AXIAL -1282
      321   FR 0.0 1.0 AXIAL -1308
      322   FR 0.0 1.0 AXIAL -1310
      323   FR 0.0 1.0 AXIAL -1312
      324   FR 0.0 1.0 AXIAL -1257
      325   FR 0.0 1.0 AXIAL -1317
      326   FR 0.0 1.0 AXIAL -1317
      327   FR 0.0 1.0 AXIAL -1317
      328   FR 0.0 1.0 AXIAL -1317
      329   FR 0.0 1.0 AXIAL -1309
      330   FR 0.0 1.0 AXIAL -1304
      331   FR 0.0 1.0 AXIAL -1299
      332   FR 0.0 1.0 AXIAL -1291
      333   FR 0.0 1.0 AXIAL -1286
      334   FR 0.0 1.0 AXIAL -1276
      335   FR 0.0 1.0 AXIAL -1268
      336   FR 0.0 1.0 AXIAL -1270
      337   FR 0.0 1.0 AXIAL -1264
```

```
      338   FR 0.0 1.0 AXIAL -1260
      339   FR 0.0 1.0 AXIAL -1244
      340   FR 0.0 1.0 AXIAL -1234
      341   FR 0.0 1.0 AXIAL -1228
      342   FR 0.0 1.0 AXIAL -1233
      343   FR 0.0 1.0 AXIAL -1219
      344   FR 0.0 1.0 AXIAL -1259
$
LOAD 'CREEP' 'Creep for cantilever PT only'   $ Estimated as 2 time
elastic shortening from cantilever model Case DC
  MEMBER TEMPERATURE LOAD
      309   FR 0.0 1.0 AXIAL   2
      310   FR 0.0 1.0 AXIAL   6
      311   FR 0.0 1.0 AXIAL  15
      312   FR 0.0 1.0 AXIAL  27
      313   FR 0.0 1.0 AXIAL  51
      314   FR 0.0 1.0 AXIAL  64
      315   FR 0.0 1.0 AXIAL  79
      316   FR 0.0 1.0 AXIAL  97
      317   FR 0.0 1.0 AXIAL 117
      318   FR 0.0 1.0 AXIAL 131
      319   FR 0.0 1.0 AXIAL 144
      320   FR 0.0 1.0 AXIAL 157
      321   FR 0.0 1.0 AXIAL 169
      322   FR 0.0 1.0 AXIAL 179
      323   FR 0.0 1.0 AXIAL 188
      324   FR 0.0 1.0 AXIAL 196
      325   FR 0.0 1.0 AXIAL 207
      326   FR 0.0 1.0 AXIAL  25
      327   FR 0.0 1.0 AXIAL  25
      328   FR 0.0 1.0 AXIAL 194
      329   FR 0.0 1.0 AXIAL 199
      330   FR 0.0 1.0 AXIAL 191
      331   FR 0.0 1.0 AXIAL 182
      332   FR 0.0 1.0 AXIAL 167
      333   FR 0.0 1.0 AXIAL 160
      334   FR 0.0 1.0 AXIAL 147
      335   FR 0.0 1.0 AXIAL 136
      336   FR 0.0 1.0 AXIAL 119
      337   FR 0.0 1.0 AXIAL 104
      338   FR 0.0 1.0 AXIAL  84
      339   FR 0.0 1.0 AXIAL  62
      340   FR 0.0 1.0 AXIAL  48
      341   FR 0.0 1.0 AXIAL  31
      342   FR 0.0 1.0 AXIAL  18
      343   FR 0.0 1.0 AXIAL   7
      344   FR 0.0 1.0 AXIAL   1
$
$  Following 2 loads include creep losses for phi = 2
$
LOAD 'SPAN15PT' 'Span 15 +M & EQ'
  MEMBER TEMPEERATURE LOAD
    GROUP 'PT2' FR 0.0 1.0 AXIAL -817
```

```
      $ Final PT estimated at 143 ksi
    GROUP 'PT3' FR 0.0 1.0 AXIAL -456
      $ Final PT estimated at  86 ksi
$
LOAD 'SPAN16PT' 'Span 16 +M & Closure'
  MEMBER TEMPEERATURE LOAD
    GROUP 'PT4' FR 0.0 1.0 AXIAL -796
      $ Final PT estimated at 140 ksi
    GROUP 'PT5' FR 0.0 1.0 AXIAL -451
      $ Final PT estimated at  85 ksi
$
LOAD 'HS20T' 'HS20 Truck (1/2) at Jt 38'
  MEMBER LOAD
    236 FOR Y CONC P  -4.0 L 11.0
    237 FOR Y CONC P -16.0 L  8.5
    238 FOR Y CONC P -16.0 L  8.0
$
LOAD 'HS20U' 'HS20 Uniform lane load'
  MEMBER LOAD
    226 TO 244 FOR Y UNIF FR W -0.64 LA 0.0 LB 1.0
$
LOAD 'SHRINK' 'Shrinkage strain 160 millionths'
  MEMBER TEMPEERATURE LOAD
    GROUP LIST 'CONST' 'VAR'  'PIER' 'COLUMN_PH' 'COLUMN' AXIAL -29.0
UNITS RADIANS
$
LOAD 'DIFFTC'  'Differential temperature curvature'
  MEMBER DISTORTIONS
201 TO 210  UNIF ROTZ -5.28E-06
211   UNIF ROTZ -5.27E-06
212   UNIF ROTZ -5.22E-06
213   UNIF ROTZ -5.08E-06
214   UNIF ROTZ -4.86E-06
215   UNIF ROTZ -4.59E-06
216   UNIF ROTZ -4.29E-06
217   UNIF ROTZ -3.93E-06
218   UNIF ROTZ -3.56E-06
219   UNIF ROTZ -3.23E-06
220   UNIF ROTZ -2.93E-06
221   UNIF ROTZ -2.65E-06
222   UNIF ROTZ -2.39E-06
223   UNIF ROTZ -2.16E-06
224   UNIF ROTZ -1.94E-06
225   UNIF ROTZ -1.72E-06
$
228   UNIF ROTZ -1.68E-06
229   UNIF ROTZ -1.85E-06
230   UNIF ROTZ -2.05E-06
231   UNIF ROTZ -2.27E-06
232   UNIF ROTZ -2.52E-06
233   UNIF ROTZ -2.79E-06
234   UNIF ROTZ -3.08E-06
235   UNIF ROTZ -3.39E-06
```

```
236    UNIF ROTZ -3.72E-06
237    UNIF ROTZ -4.09E-06
238    UNIF ROTZ -4.57E-06
239    UNIF ROTZ -4.99E-06
240    UNIF ROTZ -5.17E-06
241    UNIF ROTZ -5.25E-06
242 to 244  UNIF ROTZ -5.28E-06$
$
UNITS FAHRENHEIT
LOAD 'DIFFTNA'  'Axial temperature change'
  MEMBER TEMPERATURE LOAD
    201 TO  210  AXIAL 4.48
    211    AXIAL 4.47
    212    AXIAL 4.46
    213    AXIAL 4.41
    214    AXIAL 4.31
    215    AXIAL 4.20
    216    AXIAL 4.08
    217    AXIAL 3.82
    218    AXIAL 3.45
    219    AXIAL 3.14
    220    AXIAL 2.89
    221    AXIAL 2.68
    222    AXIAL 2.51
    223    AXIAL 2.36
    224    AXIAL 2.23
    225    AXIAL 2.10
    228    AXIAL 2.08
    229    AXIAL 2.16
    230    AXIAL 2.28
    231    AXIAL 2.41
    232    AXIAL 2.56
    233    AXIAL 2.74
    234    AXIAL 2.96
    235    AXIAL 3.21
    236    AXIAL 3.52
    237    AXIAL 3.88
    238    AXIAL 4.14
    239    AXIAL 4.27
    240    AXIAL 4.38
    241    AXIAL 4.45
    242    AXIAL 4.47
    243    AXIAL 4.47
    244    AXIAL 4.47
$
FORM LOAD 'DC'     FROM 'DC1' 1.0 'DC2' 1.0 'BOUY' 1.0
FORM LOAD 'DW'     FROM 'DW1' 1.0 'DW2' 1.0
FORM LOAD 'PT_ALL' FROM 'CANT_PT' 1.0 'SPAN15PT' 1.0 'SPAN16PT' 1.0
FORM LOAD 'PERM'   FROM 'DC' 1.0 'DW' 1.0 'CANT_PT' 1.0 'SPAN15PT' 1.0
'SPAN16PT' 1.0  'BOUY' 1.0
FORM LOAD 'DELTA_T'   FROM 'DIFFTNA' 1.0 'DIFFTC' 1.0
$
$
```

```
STIFFNESS ANALYSIS
$
OUTPUT DEC 1
LIST REACTIONS
LIST SUM REACTIONS
OUTPUT BY LOAD
OUTPUT DECIMAL 5
LIST DISPLACEMENTS JOINTS 1 4 10 18 22 26 30 34 38 42 45
OUTPUT DEC 1
OUTPUT BY MEMBER
SECTION FR NS 1 0.7 MEMBERS EXISTING  GROUP LIST 'SUPER'
WRITE REPLACE JOINT RESULTS JOINTS  EXISTING
WRITE REPLACE MEMBER RESULTS MEMBERS  EXISTING
WRITE REPLACE SECTION FORCES NS 2  MEMBERS  EXISTING
```

A. 3. Asymmetrical Structure

```
STRUDL 'WSB I'  'WSB I High Level Bridge 1 Box'
$ Created 10 Oct 2013 JH Clark'
$ 2D model of one box modelled along cg of section
$ Coordinates are station and elevation
$ Final condition, complete structure, all PT
$ PT as per VSL shop drawings
$ Cantilever PT modelled as truss members between offset joints
$ Continuity  (+M) PT modelled as eccentric beam members
$ Revised 20 Oct  Added column at Pier 16, seismic response spectra
(WSB design and AASHTO 2009 D)
$ Asymmetrical
UNIT FEET KIPS FAHRENHEIT
JOINT COORDINATES
$ Box section cgc
 1    9302.5     128.890   S     $ CL brg Pier 15
 2    9315.5     129.670
 3    9332.0     130.660
 4    9348.5     131.650
 5    9354.0     131.980
 6    9365.0     132.640
 7    9377.0     133.360
 8    9385.5     133.870
 9    9396.5     134.530
10    9413.0     135.520
11    9429.5     136.500
12    9446.0     137.428
13    9462.5     138.181
14    9479.0     138.839
15    9495.5     139.401
16    9512.0     139.864
17    9528.5     139.687
18    9545.0     139.458
19    9561.5     139.184
20    9578.0     138.844
21    9594.5     138.425
22    9611.0     137.938
23    9627.5     137.322
24    9644.0     136.637
25    9666.5     135.568         $ Face column Pier 16
26    9675.0     135.858         $ CL    column Pier 16
261  9675.0     -10.500   S     $ CL Footing Pier 16
262  9675.0      14.000         $ End of bottom plastic hinge
263  9675.0      45.074
264  9675.0      76.149
265  9675.0     107.223         $ Start of upper plastic hinge
266  9675.0     122.477         $ Soffit at Pier 16
27    9683.5     136.141         $ Face column Pier 16
28    9698.0     137.813
29    9714.5     139.638
30    9731.0     141.375
31    9747.5     143.019
```

```
32   9764.0     144.571
33   9780.5     146.034
34   9797.0     147.414
35   9813.5     148.726
36   9830.0     149.990
37   9846.5     151.191
38   9863.0     151.811
39   9879.5     152.330
40   9896.0     152.755
41   9912.5     152.969
42   9929.0     153.094
43   9945.5     153.156
44   9962.0     153.186
45   9970.0     153.190   S    $ CL Span 16
$ Cantilever PT cgs
307  9377.0     137.120
308  9385.5    137.630
309  9396.5    138.290
310  9413.0    139.280
311  9429.5    140.270
312  9446.0    141.260
313  9462.5    142.233
314  9479.0    143.174
315  9495.5    144.084
316  9512.0    144.963
317  9528.5    145.812
318  9545.0    146.629
319  9561.5    147.414
320  9578.0    148.169
321  9594.5    148.893
322  9611.0    149.585
323  9627.5    150.247
324  9644.0    150.877
325  9666.5    151.686
326  9675.0    151.977     $ CL Pier 16
327  9683.5    152.260
328  9698.0    152.722
329  9714.5    153.220
330  9731.0    153.686
331  9747.5    154.121
332  9764.0    154.525
333  9780.5    154.898
334  9797.0    155.420
335  9813.5    155.550
336  9830.0    155.830
337  9846.5    156.078
338  9863.0    156.296
339  9879.5    156.482
340  9896.0    156.637
341  9912.5    156.761
342  9929.0    156.854
343  9945.5    156.916
344  9962.0    156.946
```

```
345  9970.0     156.950      $ CL Span 16
$
JOINT RELEASES
   1    FOR X  MOM Z  KFY 1.544E06              $ 1/2 Pier 15 (32
Piles 24" hollow PSC 38.5' eff length)
  261   KFX 565.9E03 KFY 3.640E06 KMZ 878.2E06  $ 1/2 Pier 16 (28
Piles 36"x3/4" Conc filled 50' eff length)
   45   FOR X  MOM Z      $ A/Symmetrical loadings
$
TYPE PLANE TRUSS
MEMBER INCIDENCES
$ Cantilever PT
GENERATE 38 MEMBERS ID 307 INC 1 FROM 307 INC 1 TO 308 INC 1
DEFINE GROUP 'PT1' ADD MEMBERS 307 TO 344
$
TYPE PLANE FRAME
MEMBER INCIDENCES
$ Span 16 Column
  1601 261 262
  1602 262 263
  1603 263 264
  1604 264 265
  1605 265 266
  1606 266 25
  1607 266 27
$ Span 15 Positive moment PT
  118   1  14     $ Tendons B1 B3 B5 B7 B9  B11
  119   1  12     $ Tendons B2 B4 B6 B8 B10 B12
$ Span 15 Negative moment PT
  120   1   9
  121   1   7
$ Span 16 Positive moment PT
  122  38 45      $ Tendons B1 B3 B5 B7 B9  B11 B13
  123  40 45      $ Tendons B2 B4 B6 B8 B10 B12 B14
$ Span 16 Negative moment PT
  124  44 45
$
$ Rigid links from cgc to cgs cantilever
GENERATE 39 MEMBERS ID 407 INC 1 FROM 7 INC 1 TO 307 INC 1
$
GENERATE 44 MEMBERS ID 201 INC 1 FROM 1 INC 1 TO 2 INC 1
$
DEFINE GROUP 'CONST' ADD MEMBERS 201 TO 209  242 TO 244
DEFINE GROUP 'PIER'  ADD MEMBERS 225 226
DEFINE GROUP 'VAR'   ADD MEMBERS 210 TO 224  227 TO 241
DEFINE GROUP 'PT2' ADD MEMBERS 118 TO 119                 $ 6 12x0.6"
Diam
DEFINE GROUP 'PT3' ADD MEMBERS 120 TO 121                 $ 16 1 1/4"
Bar
DEFINE GROUP 'PT4' ADD MEMBERS 122 TO 123                 $ 6 12x0.6"
Diam
DEFINE GROUP 'PT5' ADD MEMBERS 124                        $  8 1 1/4"
Bar
```

```
DEFINE GROUP 'PT_LINK' ADD MEMBERS 407 TO 445 1606 1607
DEFINE GROUP 'COLUMN_PH' ADD MEMBERS 1601 1605
DEFINE GROUP 'COLUMN'    ADD MEMBERS 1602 TO 1604
$
MEMBER ECCENTRICITIES
$ Span 15 positive moment PT
  118 START Y -7.372 END Y -8.196
  119 START Y -7.372 END Y -7.868
$ Pier 15 Top EQ PT
  120 START Y  3.885 END Y  3.885
  121 START Y  3.885 END Y  3.885
$ Span 16 positive moment PT
  122 START Y -7.636 END Y -7.372
  123 START Y -7.313 END Y -7.372
$ Span 16 CL Closure top PT
  124 START Y  3.885 END Y  3.885
$ Column 16 ends
  1601 START Y 8.000
$
MEMBER PROPERTIES PRISMATIC
  GROUP 'CONST' AX 106.185 AY 32.634 IZ  2217.8  YC  4.260  YD  12.000
  210        AX  106.322  AY 32.670  IZ  2228.6  YC  4.265  YD  12.013
  211        AX  106.564  AY 32.942  IZ  2270.9  YC  4.301  YD  12.113
  212        AX  107.929  AY 33.634  IZ  2416.5  YC  4.442  YD  12.368
  213        AX  110.452  AY 34.763  IZ  2684.3  YC  4.630  YD  12.783
  214        AX  113.388  AY 36.332  IZ  3051.3  YC  5.009  YD  13.360
  215        AX  116.721  AY 38.339  IZ  3537.3  YC  5.391  YD  14.098
  216        AX  124.872  AY 40.785  IZ  4374.4  YC  6.112  YD  14.997
  217        AX  137.951  AY 43.669  IZ  5722.0  YC  7.148  YD  16.058
  218        AX  151.294  AY 46.993  IZ  7303.2  YC  8.201  YD  17.280
  219        AX  168.484  AY 50.754  IZ  9178.4  YC  9.278  YD  18.663
  220        AX  177.411  AY 54.955  IZ 11429.7  YC 10.397  YD  20.208
  221        AX  189.689  AY 59.594  IZ 14134.0  YC 11.558  YD  21.914
  222        AX  201.816  AY 64.672  IZ 17396.5  YC 12.786  YD  23.781
  223        AX  213.679  AY 70.188  IZ 21327.2  YC 14.083  YD  25.809
  224        AX  226.404  AY 77.320  IZ 26801.4  YC 15.685  YD  28.432
  GROUP 'PIER' AX 233.531 AY 81.584  IZ 30856.1  YC 16.618  YD  30.000
  227        AX  227.197  AY 78.790  IZ 28262.6  YC 16.014  YD  28.972
  228        AX  219.654  AY 73.021  IZ 23517.7  YC 14.745  YD  26.851
  229        AX  208.858  AY 67.292  IZ 19270.0  YC 13.446  YD  24.744
  230        AX  197.481  AY 62.001  IZ 15718.0  YC 12.206  YD  22.799
  231        AX  185.260  AY 57.149  IZ 12766.0  YC 11.028  YD  21.015
  232        AX  173.370  AY 52.736  IZ 10323.1  YC  9.909  YD  19.392
  233        AX  160.840  AY 48.762  IZ  8304.2  YC  8.845  YD  17.931
  234        AX  148.115  AY 45.226  IZ  6627.9  YC  7.826  YD  16.630
  235        AX  135.282  AY 42.129  IZ  5216.6  YC  6.832  YD  15.491
  236        AX  122.822  AY 39.470  IZ  4019.8  YC  5.864  YD  14.514
  237        AX  114.964  AY 37.250  IZ  3270.1  YC  5.186  YD  13.698
  238        AX  111.527  AY 35.469  IZ  2832.0  YC  4.819  YD  13.043
  239        AX  108.517  AY 34.127  IZ  2504.1  YC  4.517  YD  12.549
  240        AX  106.813  AY 33.223  IZ  2314.8  YC  4.337  YD  12.217
  241        AX  106.399  AY 32.757  IZ  2242.1  YC  4.276  YD  12.045
$
```

```
  GROUP 'COLUMN_PH' AX 150.25 AY 85.0 IZ 3277. YC 8.5 YD 17.0
     $  60% I gross
  GROUP 'COLUMN'    AX 150.25 AY 85.0 IZ 5462. YC 8.5 YD 17.0
     $ 100% I gross 17.0' x 17.75', 2.5' Walls
  GROUP 'PT_LINK'   AX  100.0 AY 100.0 IZ 1E04
     $ Rigid link cgc to cgs cantilever PT
$
UNITS INCH
MEMBER PROPERTIES PRISMATIC
  GROUP 'PT2'  AX  20.382 AY 1E-5 IZ 1E-5            $  6 12x0.6" Diam
  GROUP 'PT3'  AX  19.945 AY 1E-5 IZ 1E-5            $ 16 1 1/4"  Bar
  GROUP 'PT4'  AX  15.624 AY 1E-5 IZ 1E-5            $  6 12x0.6" Diam
  GROUP 'PT5'  AX   9.973 AY 1E-5 IZ 1E-5            $  8 1 1/4"  Bar
  307 308 AX  11.628  $   4 tendons 19x0.5" diam
  309  AX  23.256  $   8 tendons 19x0.5" diam
  310  AX  34.884  $  12 tendons 19x0.5" diam
  311  AX  52.326  $  18 tendons 19x0.5" diam
  312  AX  69.768  $  24 tendons 19x0.5" diam
  313  AX  87.210  $  30 tendons 19x0.5" diam
  314  AX  98.838  $  34 tendons 19x0.5" diam
  315  AX 116.280  $  40 tendons 19x0.5" diam
  316  AX 133.722  $  46 te36ons 19x0.5" diam
  317  AX 151.164  $  52 tendons 19x0.5" diam
  318  AX 168.606  $  58 tendons 19x0.5" diam
  319  AX 186.048  $  64 tendons 19x0.5" diam
  320  AX 203.490  $  70 tendons 19x0.5" diam
  321  AX 215.118  $  74 tendons 19x0.5" diam
  322  AX 232.560  $  80 tendons 19x0.5" diam
  323  AX 250.002  $  86 tendons 19x0.5" diam
  324 TO 328  AX 273.258  $  94 tendons 19x0.5" diam
  $
  329  AX 255.816  $  88 tendons 19x0.5" diam
  330  AX 238.374  $  82 tendons 19x0.5" diam
  331  AX 220.932  $  76 tendons 19x0.5" diam
  332  AX 209.304  $  72 tendons 19x0.5" diam
  333  AX 191.862  $  66 tendons 19x0.5" diam
  334  AX 174.420  $  60 tendons 19x0.5" diam
  335  AX 156.978  $  54 tendons 19x0.5" diam
  336  AX 139.528  $  48 tendons 19x0.5" diam
  337  AX 122.094  $  42 tendons 19x0.5" diam
  338  AX 104.652  $  36 tendons 19x0.5" diam
  339  AX  93.024  $  32 tendons 19x0.5" diam
  340  AX  75.582  $  26 tendons 19x0.5" diam
  341  AX  58.140  $  20 tendons 19x0.5" diam
  342  AX  40.698  $  14 tendons 19x0.5" diam
  343  AX  29.070  $  10 tendons 19x0.5" diam
  344  AX  17.442  $   6 tendons 19x0.5" diam
$
UNITS FEET
CONSTANTS
$ 5000 psi concrete
  E  580000   GROUP LIST 'CONST'  'PIER'  'VAR'
  G  217000   GROUP LIST 'CONST'  'PIER'  'VAR'
```

```
  DEN 0.160   GROUP LIST 'CONST'  'PIER'  'VAR'
  CTE 5.5E-06 GROUP LIST 'CONST'  'PIER'  'VAR'
$ 4000 psi concrete
  E  508000   GROUP LIST 'COLUMN_PH' 'COLUMN'
  G  215000   GROUP LIST 'COLUMN_PH' 'COLUMN'
  DEN 0.160   GROUP LIST 'COLUMN_PH' 'COLUMN'
  CTE 5.5E-06 GROUP LIST 'COLUMN_PH' 'COLUMN'
$ 0.5" Diam Lo-lax strand
  E  3888000   GROUP LIST 'PT1' 'PT2' 'PT4'
  DEN 0.335    GROUP LIST 'PT1' 'PT2' 'PT4'
     $ Density difference between steel & concrete
  CTE 6.5E-06  GROUP LIST 'PT1' 'PT2' 'PT4’
  E  4176000   GROUP LIST 'PT3'  'PT5' $ 1 1/4" Diam D&W bars
  DEN 0.335    GROUP LIST 'PT3'  'PT5'
     $ Density difference between steel & concrete
  CTE 6.5E-06  GROUP LIST 'PT3'  'PT5'
$ Rigid link cgc to cgs cantilever PT
  E 4E07  GROUP 'PT_LINK'
  DEN 1E-06 GROUP 'PT_LINK'
  G 4E07  GROUP 'PT_LINK'
  CTE 1E-09 GROUP 'PT_LINK'
$
$
SELF WEIGHT LOAD 'DC1' 'Member weight' DIR -Y FACTOR 1.00 ALL MEMBERS
$
LOAD 'DC2' 'Blisters, diaphragm, footing, seal, & OB dead load'
  JOINT LOADS
    1  FOR Y  -216.3    $ End  diaphragm 5.5' thick
  261  FOR Y -8204.0    $ Footing, seal & overburden
 MEMBER LOADS
    225 226 FOR Y GLO UNIF W -41.0 LA 0.0 LB 8.5   $ Thickened top
slab and webs
    225 FOR Y GLO UNIF W -85.0 LA 3.5 LB 8.5
      $ Diaphragm + pier strut
    226 FOR Y GLO UNIF W -85.0 LA 3.5 LB 8.5
      $ Diaphragm + pier strut
    225 FOR Y GLO UNIF W -25.6 LA 0.0 LB 2.5
      $ Diaphragm between piers
    226 FOR Y GLO UNIF W -25.6 LA 6.0 LB 8.5
       $ Diaphragm between piers
    201  FOR Y GLO CONC P -39.3 L 8.25  $ Bottom EQ blister
    211 213 FOR Y GLO CONC P -26.5 L 2.76  $ Bottom blister
    238 240 FOR Y GLO CONC P -21.3 L 2.76  $ Bottom blister
    244 FOR Y GLO CONC P  -6.3 L 4.00  $ Top closure blister
$
$
LOAD 'HS20T' 'HS20 Truck (1/2)at Joint 38'
  MEMBER LOADS
    236 FOR Y CONC P  -4.0 L 11.0
    237 FOR Y CONC P -16.0 L  8.5
    238 FOR Y CONC P -16.0 L  8.0
$
LOAD 'UFX' '1000 kip horizontal load at top Pier 16'
```

```
  JOINT 26 LOAD FOR X 1000
$
STORE RESPONSE SPECTRA ACCELERATION LOGARITHMIC VS PERIOD LOGARITHMIC
'WSBEQ'
  DAMPING PERCENT 5.0 FACTOR 32.2
  0.32 0.001  0.32 0.03  0.70 0.12  0.70 0.53  0.14 2.70  0.01 10.0
END OF RESPONSE SPECTRUM
$
$
STORE RESPONSE SPECTRA ACCELERATION LOGARITHMIC VS PERIOD LOGARITHMIC
'EQ2009D'
  DAMPING PERCENT 5.0 FACTOR 32.2
  0.482 0.001  1.122 0.105  1.122 0.527  0.591 1.00  0.0591 10.0
END OF RESPONSE SPECTRUM
$
RESPONSE SPECTURM LOAD 'EQX500' 'Response spectrum translation X
direction'
    SUPPORT ACCELERATION
    TRANSLATION X 1.0 FILE 'WSBEQ'
END OF RESPONSE SPECTRUM LOAD
$
 DELETIONS
  INERTIA OF JOINTS LUMPED
   INERTIA OF JOINTS ALL
   MEMBER ADDED INERTIA ALL
 ADDITIONS
 INERTIA FROM LOADS  'DC1' 'DC2' 'DW1' 'DW2' ALL DOF
$
DAMPING PERCENTS  5.0000 15
EIGENVALUE PARAMETERS
 SOLVE USING GTLANCZOS
 NUMBER OF MODES 15
 PRINT MAXIMUM
 INITIAL STRESS LOADING OFF
END EIGENVALUE PARAMETERS
$
DYNAMIC ANALYSIS EIGENVALUES
LIST DYNAMIC MASS SUMMARY JOINTS  EXISTING
LIST DYNAMIC PARTICIPATION FACTORS
$
LOAD LIST 'EQX500'
PERFORM RESPONSE SPECTRUM ANALYSIS
$
FORM STATIC LOAD 'XEQ' 'Longitudinal eq 15 modes' FROM RMS OF LOAD
'EQX500' FACTOR 1.0
LOAD LIST 'XEQ' 'HS20T' 'UFX'
STIFFNESS ANALYSIS
$
LIST DISP JOINTS 1 26 261 38 45
$
UNITS FEET
OUTPUT DEC 1
LIST SECTION FORCES MEMBER 237 238
```

A. 4. Principal Results

The principal results for the section where the cracking was observed are summarized in the following output spread sheet file. These are global forces and moments and do not include stresses from local effects such as tensions from positive moment post-tensioning as discussed in 2.9 above. Axial forces for cantilever post-tensioning in member 238 are shown as this is more realistic as far as stresses in the bottom slab at this location is concerned (see discussion in 2.10 above). Section properties based on dimensions at this location are shown.

Load	Factor	Nx [kips]	Vy [kips]	Mz [k-ft]			
On Cantilever Structure							
DC	1.00	-837.9	-1,836.3	-90,481			
CANT_PT	1.00	-24,889.0	606.1	114,654	Nx =	-21504.2	for Mbr 238
CNSTRCT	1.00	-25,726.9	-1,230.2	24,172			
On Symmetrical Structure as if built on falsework							
DC1	1.00	-1,344.7	-1,907.1	1,303			
DC2	1.00	-33.1	-47.7	69			
DW1	1.00	-57.4	-87.5	-148			
DW2	1.00	-89.7	-136.7	-231			
BOUY	1.00	0.6	0.0	-3			
CANT_PT	1.00	-23,906.6	554.9	-12,090	Nx =	-20170.5	for Mbr 238
CREEP	1.00	1,929.9	-44.0	2,824			
SPAN15PT	1.00	-239.3	9.3	1,362			
SPAN16PT	1.00	304.8	-9.7	18,322			
HS20T	1.00	-38.2	-14.5	615			
HS20U	1.00	-171.9	-65.1	544			
SHRINK	1.00	666.6	-18.3	2,389			
DIFFTC	1.00	-83.9	3.3	8,874			
DIFFTNA	1.00	-86.3	2.4	-178			
DC	1.00	-1,377.3	-1,954.8	1,369			
DW	1.00	-147.2	-224.2	-379			
PT_ALL	1.00	-23,841.1	554.5	7,594			
PERM	1.00	-25,365.0	-1,624.6	8,581			
DELTA_T	1.00	-170.2	5.7	8,695			
On Asymmetrical Structure							
HS20T	1.00	13.2	1.1	1,679			
UFX	1.00	140.5	151.2	16,690			
XEQ	1.00	2,968.6	2,294.3	208,793	A =	16,445	in^2

					yt =	61.286	in
Resultant Loads at t = infinity					yb =	101.397	in
CNSTRCT	0.20	-4,468.4	-246.0	4,834	Iz =	65,986,289	in^4
PERM	0.80	-20,292.0	-1,299.7	6,864			
SHRINK	1.00	666.6	-18.3	2,389		**Stresses [ksi]**	
CREEP	1.00	1,929.9	-44.0	2,824		**fct**	**fcb**
Σ1		-22,163.9	-1,608.0	16,911		-1.536	0.214
DELTA_T	1.00	-170.2	5.7	8,695			
Σ2		-22334.1	-1602.3	25,606		-1.644	0.375
HS20T	2.00	-50.1	-26.8	4,588			
Σ3		-22,213.9	-1,634.8	21,499		-1.590	0.297
EQX	0.15	445.3	344.1	31,319			
Σ4		-21,718.6	-1,263.9	48,230		-1.858	0.812

Notes:
1. Axial PT force taken as that existing in member 238 (on CL side of joint 38)
2. Signs are beam sign convention. Tension +
3. Segment weight is 22,34 kips at Jt 37 and 22.10 Kips at Jt 37
4. DW1 is 0.8 klf and DW2 is 1.25 klf
5. HS20T is 16.0k at 8.5 ft from Jt 37
6. Factor on EQX is based on observed displacement in 2001 EQ vs displacement in design EQ (500 yr MRI)