5.1.8.8 Dynamic Isolators

Isolators may be useful for either new construction or retrofit work. Isolators change structure response by lengthening the periods of primary vibration. This tunes the structure response away from the typical earthquake's maximum response frequencies. This effect, along with added damping, works to reduce the system response. The result is reduced substructure forces.

Typical steps to model an isolated structure:

1 Compute service loads (D, L, LF, CF, W, WL, R, S, T) for the worst single girder.

2 Use these loads, and the applicable seismic loading, in the Dynamic Isolation System, Inc. (DIS) program PC-LEADER to get a preliminary isolator size and its properties. DIS has given us permission to use the program even though we will not specify only their bearing.

3 Develop a full M-STRUDL model (superstructure, substructure, and bearings/isolators). Normally this will be done on a per girder basis so the substructure should be proportioned to fit this basis. The model can often be a two dimensional model.

4 In the M-STRUDL model use the equivalent isolator stiffnesses (K_{eff}). This stiffness should be further modified to fit modeling assumptions of a bearing cantilevered from the substructure at interior supports.

5 Load the M-STRUDL model with dynamic loading through a modified response spectrum. The response spectrum can be taken from the PC-LEADER output or developed from the Guide Specifications for Seismic Isolation Design.

6 Develop another full M-STRUDL model to represent the "as is" structure. Dynamically load this model with a normal response spectrum. This gives a basis to evaluate the isolation effectiveness.

7 It may be necessary or desirable to adjust the relative isolator stiffnesses' to better distribute the dynamic forces. It is important the final isolator properties function adequately for service loads. The isolator characteristics must also be realistic and achievable.

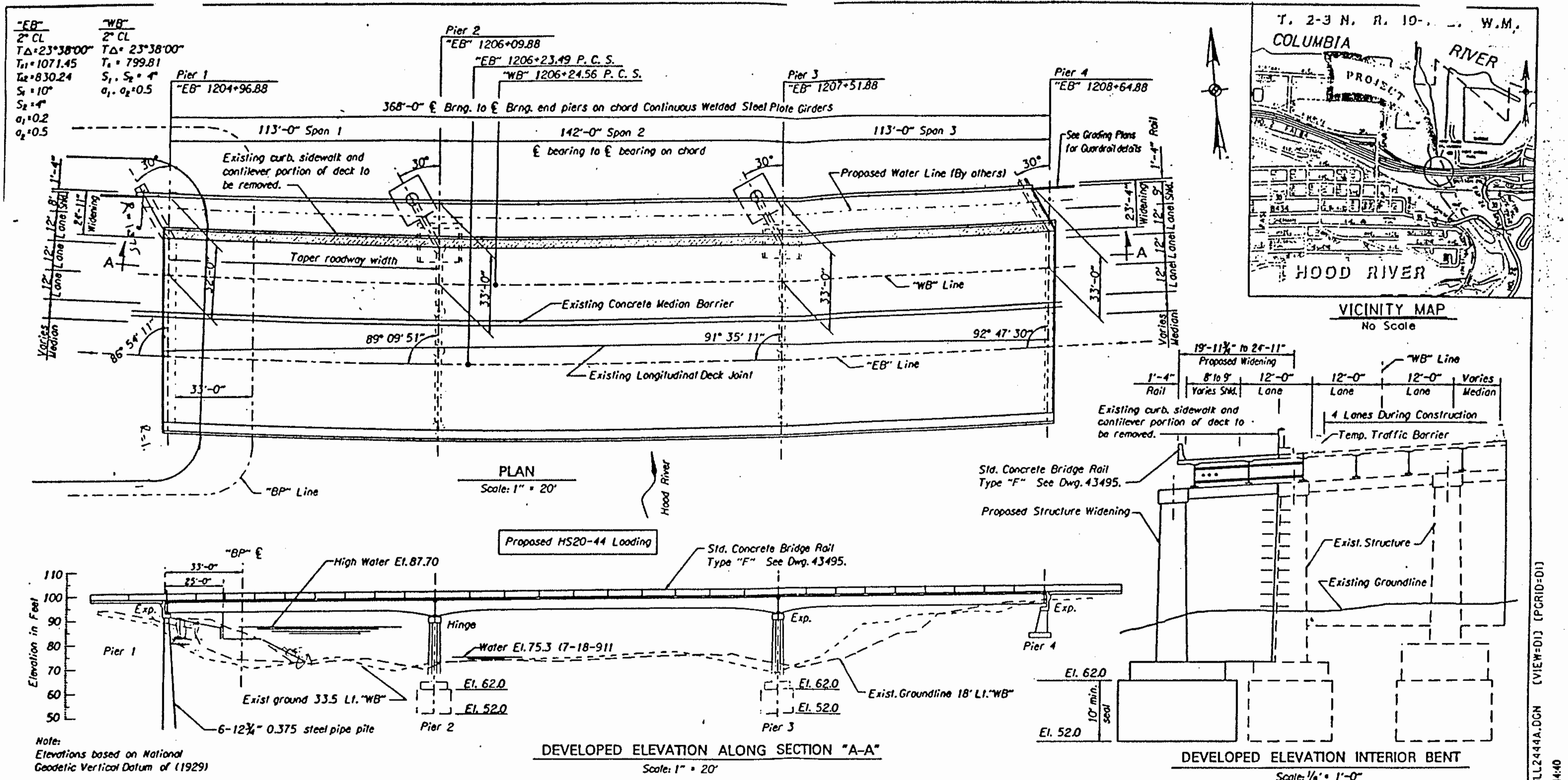
A5.1.8.8 Dynamic Isolators Sample Problem

The following 38 sheets demonstrate the use of the Dynamic Isolation System, Inc. program PC-LEADER in determining preliminary isolator sizes and stiffness properties. M-STRUDL is used to model the entire structure with the base isolation retrofit. M-STRUDL is also used to model the "as is" condition.

Sheet	Description	
1	Plan and Elevation	
2	Description	
3-6	Calculate Loads	(Step 1)
7-18	PC-LEADER Run/Output	(Step 2)
19-20	M-STRUDL Model	(Step 3)
21	Equivalent Isolator Stiffness	(Step 4)
22-24	Response Spectrum Loading	(Step 5)
25-30	M-STRUDL Run	(Step 5 cont.)
31-37	M-STRUDL Model/Run	(Step 6)
38	Results Summary	

"EB"
2° CL
T∆=23°38'00"
T_{s1}=1071.45
T_{s2}=830.24
S_1=10"
S_2=4"
a_1=0.2
a_2=0.5

"WB"
2° CL
T∆= 23°38'00"
T_s = 799.81
S_1 , S_2 = 4"
a_1 , a_2=0.5



VICINITY MAP
No Scale

PLAN
Scale: 1" = 20'

Proposed HS20-44 Loading

DEVELOPED ELEVATION ALONG SECTION "A-A"
Scale: 1" = 20'

DEVELOPED ELEVATION INTERIOR BENT
Scale: ⅛" = 1'-0"

Note:
Elevations based on National Geodetic Vertical Datum of (1929)

HYDRAULIC DATA

		DESIGN FLOOD	BASE FLOOD	MAX. PROBABLE FLOOD
DISCHARGE	CFS	30,900	35,200	45,700
FREQUENCY-YRS.		50	100	500
H.W. ELEVATION NAT. CHANNEL	FT.	87.70	88.30	90.30

DATE	REVISION	BY

ACTING BRIDGE ENGINEER

APPROVED:

DESIGNED Hormoz Seradj
DRAWN Jeffrey Lannigan
CHECKED
REVIEWED
REVIEWED

OREGON DEPARTMENT OF TRANSPORTATION
BRIDGE DESIGN SECTION

HOOD RIVER BRIDGE WIDENING
2ND STREET INTCHG. (HOOD RIVER)
COLUMBIA RIVER HWY. (M.P. 64.15) HOOD RIVER COUNTY

PRELIMINARY PLAN AND ELEVATION

ACCOMPANIED BY DWGS.

DATE JULY 1992 CALC.BOOK 4017 SHEET 1 OF 1
BRIDGE NO. 2444A DRAWING NO. 48887

br225o:/usr/br/projects/04346/JLL2444A.DGN (VIEW=D1) (PGRID=D1)
Plotted by br from br225a (jll.m) on 07/28/92 13:44:40

000001

Sheet 000002

Bridge Name Dynamic Isolators Sample Problem

Calculations by SS Date 12/10/93 Bridge No. 2444A

Design isolators for retrofit and model the bridge w/ & w/o isolators.

Do only the EB portion for this sample.

EB is separated from the other portion by a longitudinal joint.

The EB is a two girder system w/ floor beams and stringers.

Bridge Name Dynamic Isolators Sample Problem

Calculations by SS Date 12/10/93 Bridge No. 2444A

Calc. service loads:

Dead Loads:

Item	Calc.	Wt. (k.)
Deck + AC.	$\frac{(6+2)}{12}(33)(368)(0.15)$	1220
Walk / Rail	$\frac{5}{12}(4.5)(368)(0.15)+0.20(368)$	180
Stringers	$0.073(3)(368)(2.0)$	160
Girders	$0.200(2)(368)(1.3)$	190
Floorbeams*	This factor	—
Misc.*	This factor	—
Total	(2 girders)	1750

* Floorbeams are truss form. For this sample we approximate factors to include floorbeams, lateral bracing, stiffeners, etc.

Proportion loads to bents (per girder)

$$DL_1 = DL_4 = \frac{1750}{2(368)}(113)(0.35) = \underline{\underline{95\,k}}$$

$$DL_2 = DL_3 = \left[\frac{1750}{2} - 95(2)\right]\frac{1}{2} = \underline{\underline{345\,k}}$$

BRIDGE SECTION
Oregon State Highway Division

Sheet 000004

Bridge Name Dynamic Isolators Sample Problem

Calculations by SS Date 12/10/93 Bridge No. 2444A

Live (no impact):

HS25 w/ 1.43 lanes/girder

Use AISC "M, V & R for Cont. Brs" tables.

$$L_1 = L_4 = 65(1.25)(1.43) = \underline{\underline{115\ k}}$$

$$L_2 = L_3 = 121(1.25)(1.43) = \underline{\underline{215\ k}}$$

Longitudinal Force:

$$\text{Total EB} = 0.05[0.64(368)+18](1.25)(2\ \text{lanes})$$
$$= 32\ k$$

Distribute equally to all supports

$$LF_1 = LF_4 = \frac{32}{2}\left(\frac{1}{4}\right) = \underline{\underline{4\ k}}$$

$$LF_2 = LF_3 = \underline{\underline{4\ k}}$$

Wind:

By tributary area & resolving longit. and trans. components ($\sqrt{(50)^2+(12)^2} = 52$ psf)

$$W_1 = W_4 = 0.052(6.5)\left(\frac{113}{2}\right)\left(\frac{1}{2}\right) = \underline{\underline{10\ k}}$$

BRIDGE SECTION
Oregon State Highway Division

Sheet 000005

Bridge Name Dynamic Isolators Sample Problem

Calculations by SS Date 12/10/93 Bridge No. 2444A

$$W_2 = W_3 = \left[0.052(6.5)\frac{(113+142)}{2} + 0.052\frac{(22)(4)(2)}{3}\right]\frac{1}{2}$$

$$= \underline{\underline{23\ k}}$$

Wind on Live:

As w/ wind before, $(\sqrt{(100)^2+(40)^2} = 108\ psf$

$$WL_1 = WL_4 = 0.108\frac{(113)}{2}\left(\frac{1}{2}\right) = \underline{\underline{3\ k}}$$

$$WL_2 = WL_3 = 0.108\frac{(113+142)}{2}\left(\frac{1}{2}\right) = \underline{\underline{7\ k}}$$

Temperature Effect:

Steel bridge, Section II, Temp. Rise

Assume zero movement pt. @ midpoint of span 2:

$$TR_1 = TR_4 = (6.5\times10^{-6})(68^\circ)(113+71)(12)$$

$$= \underline{\underline{0.98''}}$$

$$TR_2 = TR_3 = (6.5\times10^{-6})(68^\circ)(71)(12)$$

$$= \underline{\underline{0.38''}}$$

BRIDGE SECTION
Oregon State Highway Division

Sheet 000006

Bridge Name Dynamic Isolators Sample Problem

Calculations by SS Date 12/10/93 Bridge No. 2444A

There are no centrifugal forces or creep and shrinkage effects to consider.

Seismic Loading:

$A = 0.29\,g$

$S_i = 1.5$ (soil type unknown ∴ assume type II)

Run DIS's program PC-LEADER

Use the results from PC-LEADER for isolator properties in an M-STRUDL model.

```
Hood River Bridge (2444A)                                          LPT1  Page   1
Design of DIS Force Control Bearings                          12-10-1993  10:59:00
DIS, Inc. USA Patents 4,117,637  4,499,694  4,593,502                  LEADeR 2.0
010-0242 Licensed to : Oregon DOT, Bridge Section, Salem OR
```

```
***********************************************************************************
***********************************************************************************

    -----------------    L         EEEEEEE  AAAAAAAA   DDDDDDD    EEEEEEE    RRRRRR      -----------------
   -----------------    L         E        A      A   D      D   E          R      R   -----------------
  -----------------    L         E        A      A   D      D   E          R      R   -----------------
 -----------------    L         EEEEE    AAAAAAAA   D      D   EEEEE      RRRRRRR   -----------------
-----------------    L         E        A      A   D      D   E          R      R   -----------------
-----------------   L         E        A      A   D      D   E          R      R   -----------------
-----------------  LLLLLLLL  EEEEEEEE A      A   DDDDDDDD   EEEEEEE    R       R  -----------------

***********************************************************************************
***********************************************************************************
```

DESIGN OF DIS FORCE CONTROL BEARINGS
12-10-1993   10:59:00

The purpose of the procedures in this computer program is to aid in the evaluation of the impact that DIS Force Control Bearings have on the design of a bridge. Seismic isolation design, energy dissipation design and force redistribution capabilities are incorporated in the program. The information set forth herein is based on technical data that DIS believes to be reliable. It is intended for use by persons having appropriate engineering skill, at their own discretion and risk. The entire and whole risk as to the quality, adequacy, correctness and applicability of the information is with the user.

The information contained is insufficient for the specification of DIS Force Control Bearings. Materials and quality control procedures unique to the DIS product are inherent in the use of this program. DIS must be contacted at the completion of design in order that a detailed design check is performed. For information on specifications, connection details or cost information see the Users Manual Page (v) or call DIS at (415) 843-7233 (FAX 415-843-0366)

PROJECT   : Hood River Bridge (2444A)
Design Acceleration Level : 0.29
Soil Type   :   2

SUMMARY OF INPUT LOAD DATA AND SCHEDULE OF BEARING TYPES (Units Kips, inches)

The loads listed in the schedule below have been used to design the Force Control Bearings using DIS design procedures based on the rated load method of calculating vertical load capacity. The non-seismic lateral loads have been combined according to the AASHTO Specification load groups for the design of the lead core.

The bearings types are identified according to the DIS naming convention as follows: The first character refers to the plan shape of the bearing (S = Square, C = Circular, R = Rectangular). This is followed by the plan dimension (in inches), the overall height (to the nearest inch) and the diameter of the lead core (in inches).

BEARING LOCATION	No. of Brgs.	DL	LL	W	WL	CF	LF	R+S+T	BEARING
ABUTMENT 1									
Bearings	1	95	115						S15-5-4.75
SUB-TOTAL :	1	95	115	10.0	3.0	0.0	4.0	0.98	
PIER 2									
Bearings	1	345	215						S20-3-4.75
SUB-TOTAL :	1	345	215	23.0	7.0	0.0	4.0	0.38	
PIER 3									
Bearings	1	345	215						S20-3-4.75
SUB-TOTAL :	1	345	215	23.0	7.0	0.0	4.0	0.38	
ABUTMENT 2									
Bearings	1	95	115						S15-5-4.75
SUB-TOTAL :	1	95	115	10.0	3.0	0.0	4.0	0.98	
SEGMENT TOTAL	4	880	660	66.0	20.0	0.0	16.0	0.98	

BEARING CONSTRUCTION DETAILS (Sheet 1 of 1) Units Kips, In.

		S15-5-4.75	S20-3-4.75
Number of Bearings	:	2	2
DESIGN CONDITIONS			
Maximum D+L	:	210	560
Maximum D	:	95	345
Minimum D	:	95	345
Maximum R+S+T Disp.	:	0.98	0.38
Maximum EQ Disp.	:	1.91	1.91
BEARING DIMENSIONS			
Overall Width	:	15.00	20.00
Overall Height	:	4.875	3.375
Lead Core Diameter	:	4.75	4.75
Weight (lbs)	:	163	218

```
BEARING PROPERTIES (Sheet  1 of  1) Units Kips, In.


                            S15-5-4.75     S20-3-4.75

DIMENSIONAL PROPERTIES
Shape Factor          :        9.33          12.67
Gross Bonded Area     :      196.00         361.00
Plug Area             :       17.72          17.72
Net Bonded Area       :      178.28         343.28
Rubber Thickness      :       2.250          1.125

STRENGTH AND STIFFNESS PROPERTIES
Yielded Stiffness     :        7.92          30.51
Elastic Stiffness     :      112.93         321.20
Characteristic Str.   :       20.31          20.31
Yield Strength        :       21.84          22.44
Yield Displacement    :       0.193          0.070
Inner Layer Stiff.    :       21725          76740
Outer Layer Stiff.    :       22031          72077
Vertical Stiffness    :        2725          14961    k/in            Vert Stiff.

VERTICAL LOAD CAPACITIES
Maximum Rotation on Bearing
      At 0% Strain    :       291.0          757.3
      At R+S+T        :       214.2          597.5
      At EQ Disp.     :       291.3          597.6
Zero Rotation on Bearing
      At 0% Strain    :       291.0          757.3
      At R+S+T        :       347.0          987.9
      At EQ Disp.     :       459.1          956.1

VERTICAL STRESSES AND DEFLECTIONS
Dead Load Stress      :       0.485          0.956
          Deflection  :       0.035          0.023"   (for 315 k)     Vert. Stiff.
          Rotation (deg)      0.285          0.139
D+L       Stress      :       1.071          1.551
          Deflection  :       0.077          0.037
          Rotation (deg)      0.631          0.226

LIMIT STATES
Rollover Displ.       :       9.212         14.479
Buckling Load Longl.  :      1690.0        11764.0
Buckling Load Trans.  :      1690.0        11764.0
```

OVERALL SEISMIC PERFORMANCE : SEGMENT 1

Seismic performance is calculated assuming rigid substructures and a rigid structure above the bearings. If the substructures are flexible then the estimated effective period will be less than the actual effective period. The assumption of rigid substructures is a conservative method of calculating maximum earthquake forces. The values of effective period, maximum displacement and elastic force coefficient are based on the DIS Non-Linear response spectra for the specified acceleration level and soil type. This is a single mode spectral analysis method assuming that the dominant mode is the deformation of the bearings and the force coefficient is calculated from the period of this mode. The non-linear spectra allow the additional damping from the lead cores to be accounted for in calculating forces and displacements. The reduction factor listed is the ratio between the peak acceleration on the response spectrum and the elastic force coefficient using isolation.

DESIGN LEVEL : 0.29 g Soil Type 2 (Qd 0.092)

(AASHTO Guide Specifications Spectral Shape)

Effective Period (secs) : 0.87
Maximum Displacement (inches) : 1.91
Elastic Force Coefficient : 0.259
Reduction Factor from Peak : 2.8

PERFORMANCE FOR OTHER ACCELERATION LEVELS :

	EARTHQUAKE G LEVEL				
	0.10G	0.19G	0.29G	0.39G	0.49G
Effective Period (secs) :	0.60	0.76	0.87	0.93	0.96
Maximum Displacement (inches) :	0.48	1.04	1.91	2.99	3.90
Elastic Force Coefficient :	0.133	0.183	0.259	0.354	0.435
Reduction Factor from Peak :	1.9	2.6	2.8	2.8	2.8

T & Δ

AASHTO TABLE 3.22.1A LOAD GROUPS

The forces at each bent are calculated using the load factors specified in Table 3.22.1A of the AASHTO Standard Specifications for Highway Bridges. As the lead cores are sized based on ultimate strength procedures the load factor design procedure is used. The following groups are considered in developing maximum substructure forces:

GROUP II : 1.30 (W)
GROUP III : 1.30 (CF + 0.3W + WL + LF)
GROUP IV : 1.30 (CF + [R+S+T])
GROUP V : 1.25 (W + [R+S+T])
GROUP VI : 1.25 (CF + 0.3W + WL + LF + [R+S+T])

NOTE : These load groups are based on providing the bearing design forces. Other load conditions may control the design of piers and foundations, e.g. different skew angles of wind.

The loads and forces in each group are those specified in the input data except for the [R+S+T] load which is a function of the lead core size. The force due to [R+S+T] is calculated as (0.25Qd + Kd.Dt) where Qd is the characteristic strength, Kd the yielded stiffness and Dt the [R+S+T] displacement (see Bearing Properties for values). Depending on the options selected when designing the lead cores there may be some redistribution of loads between substructures. This may occur at the designers option as a result of the lead core distribution or it may occur when the cores at some locations reach their yield strength and the remainder of the load is taken by other cores in the segment which have not reached their yield strength. Redistribution was required for load groups II and V. The procedure used to calculate redistribution is as follows:

1. Calculate loads on cores at all substructures for Groups II to VI (Include lead core R+S+T force of 0.25Qd only)

2. Check whether total load exceeds the yield strength of all cores at a substructure using vector sum of longitudinal and transverse forces.

3. If greater than the yield level, set to yield level and distribute remaining load to other substructures with forces less than yield.

4. For load groups with [R+S+T], add in Kd.Dt force component.

CALCULATION OF REDISTRIBUTED LOADS FOR AASHTO GROUP II - NO BENT FLEXIBILITY

	Group Loads (No Kd.Dt) Trans	Longl	Vector Force With 0.25Qd	Core Yield Force	Factor Applied to Vector	Elastic R+S+T (Kd.Dt)	Re-Distributed. Forces Trans	Longl
ABUTMENT 1	13.00	0.00	13.00	21.84	1.574	0.00	20.46	0.00
PIER 2	29.90	0.00	29.90	22.44	0.750	0.00	22.44	0.00
PIER 3	29.90	0.00	29.90	22.44	0.750	0.00	22.44	0.00
ABUTMENT 2	13.00	0.00	13.00	21.84	1.574	0.00	20.46	0.00
TOTAL :	85.80	0.00	85.80	88.55		0.00	85.80	0.00

CALCULATION OF REDISTRIBUTED LOADS FOR AASHTO GROUP V - NO BENT FLEXIBILITY

	Group Loads (No Kd.Dt) Trans	Longl	Vector Force With 0.25Qd	Core Yield Force	Factor Applied to Vector	Elastic R+S+T (Kd.Dt)	Re-Distributed. Forces Trans	Longl
ABUTMENT 1	12.50	6.35	14.02	21.84	1.489	9.71	19.34	17.56
PIER 2	28.75	6.35	29.44	22.44	0.762	14.49	21.91	19.33
PIER 3	28.75	6.35	29.44	22.44	0.762	14.49	21.91	19.33
ABUTMENT 2	12.50	6.35	14.02	21.84	1.489	9.71	19.34	17.56
TOTAL :	82.50	25.38	86.92	88.55		48.40	82.50	73.78

TRANSVERSE SEISMIC AND NON-SEISMIC SUBSTRUCTURE FORCES - NO BENT FLEXIBILITY

	NON-SEISMIC FORCES						ELASTIC
	AASHTO LOAD GROUP NUMBER					MAXIMUM	EARTHQUAKE
SUBSTRUCTURE	II	III	IV	V	VI	FORCE	FORCE
ABUTMENT 1	20.5	7.8	0.0	19.3	7.5	20.5 (21.54% D)	35.4 (37.27% D)
PIER 2	22.4	18.1	0.0	21.9	17.4	22.4 (6.50% D)	78.4 (22.74% D)
PIER 3	22.4	18.1	0.0	21.9	17.4	22.4 (6.50% D)	78.4 (22.74% D)
ABUTMENT 2	20.5	7.8	0.0	19.3	7.5	20.5 (21.54% D)	35.4 (37.27% D)
SEGMENT TOTAL	85.8	51.7	0.0	82.5	49.8	85.8 (9.75% D)	227.7 (25.87% D)

LONGITUDINAL SEISMIC AND NON-SEISMIC SUBSTRUCTURE FORCES - NO BENT FLEXIBILITY

	NON-SEISMIC FORCES						ELASTIC
	AASHTO LOAD GROUP NUMBER					MAXIMUM	EARTHQUAKE
SUBSTRUCTURE	II	III	IV	V	VI	FORCE	FORCE
ABUTMENT 1	0.0	5.2	16.7	17.6	21.1	21.1 (22.16% D)	35.4 (37.27% D)
PIER 2	0.0	5.2	21.7	19.3	25.8	25.8 (7.49% D)	78.4 (22.74% D)
PIER 3	0.0	5.2	21.7	19.3	25.8	25.8 (7.49% D)	78.4 (22.74% D)
ABUTMENT 2	0.0	5.2	16.7	17.6	21.1	21.1 (22.16% D)	35.4 (37.27% D)
SEGMENT TOTAL	0.0	20.8	76.7	73.8	93.8	93.8 (10.66% D)	227.7 (25.87% D)

EARTHQUAKE EFFECTIVE STIFFNESS

	EARTHQUAKE G LEVEL				
	0.10G	0.19G	0.29G	0.39G	0.49G
S15-5-4.75					
Earthquake Displacement :	0.48	1.04	1.91	2.99	3.90
Effective Stiffness (kip/in) :	50.66	27.45	18.58	14.72	13.14
S20-3-4.75					
Earthquake Displacement :	0.48	1.04	1.91	2.99	3.90
Effective Stiffness (kip/in) :	73.25	50.04	41.17	37.31	35.73

(translation stiffness,
keff)

COMPOSITE RESPONSE SPECTRUM

The composite response spectrum listed below is provided for use in an equivalent elastic analysis. The bearing properties for this analysis should be based on the effective stiffness values for the bearings as listed on the previous sheet. The spectra below is formed of the AASHTO Guide Specifications spectrum (acceleration level of 0.29g and soil type 2) for periods less than the isolated periods. For the isolated periods the curve is formed on the appropriate non-linear spectrum. This is so that the isolated modes will incorporate the hysteretic damping of the lead cores.

Segment 1 0.29 G Qd= 0.092

PERIOD	ACCELERATION
0.00	0.290
0.15	0.725
0.30	0.725
0.40	0.725
0.50	0.725
0.60	0.703
0.69	0.618
0.74	0.293
0.80	0.276
0.90	0.251
1.00	0.232
1.25	0.193
1.50	0.162
1.75	0.143
2.00	0.134
2.25	0.125
2.50	0.124
2.75	0.119
3.00	0.118
3.25	0.115
3.50	0.112
3.75	0.109
4.00	0.106
4.25	0.103
4.50	0.100
4.75	0.097
5.00	0.094
5.25	0.091
5.50	0.088
5.75	0.085
6.00	0.082
0.00	0.000

Base Isolation Response Spectrum

PERFORMANCE SPECIFICATION DATA

The data in the tables below is a summary of the design performance information which may be included in a performance specification. AASHTO load group forces are factored values to be used for bearing design. Other conditions may control substructure design. Earthquake forces and displacements are unfactored, elastic response values. Bearing force displacement characteristics (Table 3) are based on the maximum earthquake displacement or the displacement corresponding to 50% strain, whichever is greater.

For assistance or further information on Specifications and Connection details call DIS, Attention : SPECIFICATIONS. Please send or fax this output file, a schematic layout and connection configuration. For information regarding the cost of isolation bearings and delivery information call DIS, Attention : BRIDGE MARKETING. This output file will help provide the requested information quickly.

TABLE 1 : Maximum Non-Seismic Loads (Units Kips, inches)

LOCATION	DL	LL	R + S + T		Factored AASHTO Groups II - VI Maximum Forces		Unfactored Wind Load	
			Disp.	Force	Long.	Trans.	Force	Disp.
ABUTMENT 1	95	115	0.98	12.8	21.1	20.5	15.7	0.16
PIER 2	345	215	0.38	16.7	25.8	22.4	17.3	0.16
PIER 3	345	215	0.38	16.7	25.8	22.4	17.3	0.16
ABUTMENT 2	95	115	0.98	12.8	21.1	20.5	15.7	0.16

TABLE 2 : Maximum Earthquake Loads (0.29 G Soil 2)(Units Kips, inches)

LOCATION	LONGITUDINAL		TRANSVERSE	
	Force	Displacement	Force	Displacement
ABUTMENT 1	35.4	1.91	35.4	1.91
PIER 2	78.4	1.91	78.4	1.91
PIER 3	78.4	1.91	78.4	1.91
ABUTMENT 2	35.4	1.91	35.4	1.91

← Seismic Forces

TABLE 3 : Force Deflection Characteristics (0.29 G Soil 2) (Units Kips, inches)

BEARING TYPE	Effective Stiffness, Keff	Post-Elastic Stiffness, Kr	Area of Hysteresis Loop, EDC
S15-5-4.75	18.58	7.92	139.05
S20-3-4.75	41.17	30.51	149.08

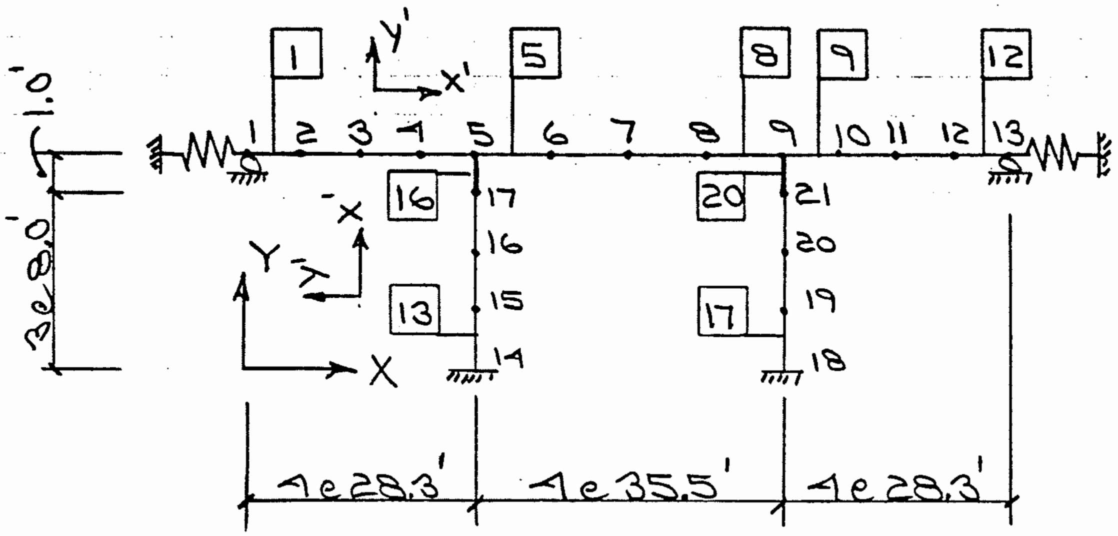
BRIDGE SECTION
Oregon State Highway Division

Sheet 000019

Bridge Name Dynamic Isolators Sample Problem

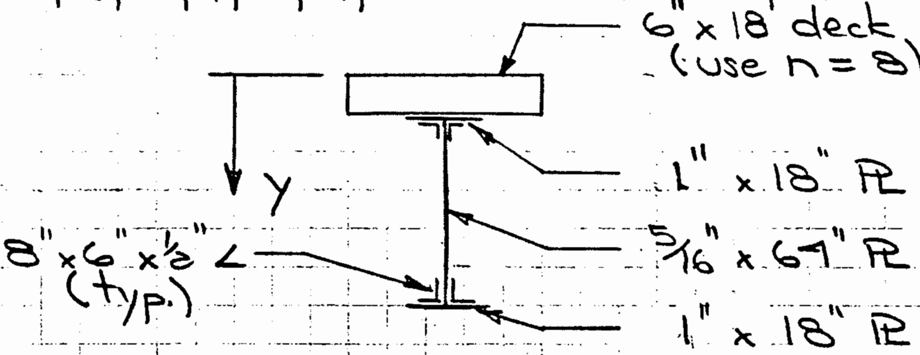
Calculations by SS Date 12/10/93 Bridge No. 2444A

M-STRUDL model: (plane frame)
(Base Isolated Structure)



Members:

1, 2, 3, 6, 7, 10, 11, 12:



$E = 29{,}000\ k/in^2$ $(4176000\ k/ft^2)$

$A = 245\ in^2$ $(1.7\ ft^2)$

$I = 142{,}000\ in^4$ $(6.8\ ft^4)$ $(y = 15.2")$

$\gamma = \frac{1750}{2(368)}\left(\frac{1}{1.7}\right) = 1.40\ k/ft^3$

BRIDGE SECTION
Oregon State Highway Division

Sheet 000020

Bridge Name Dynamic Isolators Sample Problem

Calculations by SS

Date 12/10/93 Bridge No. 2444 A

4,5,8,9:

Similar to previous members but web is ½" x 88" PL

$E = 417600 \ k/ft^2$

$A = 1.9 \ ft^2$

$I = 14.3 \ ft^4 \quad (y = 22.1")$

$\gamma = 1.40\left(\frac{1.7}{1.9}\right) = 1.25 \ k/ft^3$

13, 17: (5' ø, 3300 psi conc.)

$E = 3300 \ k/in^2 \quad (475,200 \ k/ft^2)$

$A = 19.6 \ ft^2$

$I = 30.8 \ ft^4$

$\gamma = 0.28 \ k/ft^3$ (increased above 0.15 to include web wall)

14, 18: (4.7' ø)

E & γ as above

$A = 17.4 \ ft^2$

$I = 23.9 \ ft^4$

Sheet 000021

Bridge Name Dynamic Isolators Sample Problem
Calculations by SS Date 12/10/93 Bridge No. 2444A

15, 19: (4.3' ø)

E & γ as above

$A = 14.8\ ft^2$

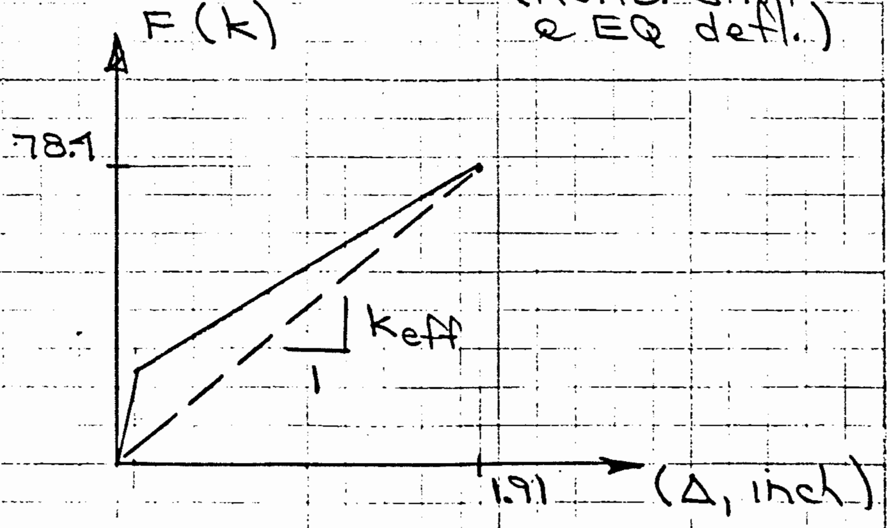
$I = 16.8\ ft^4$

16, 20: (bearings)

From PC-LEADER output, brg. properties are:

$k_v = \frac{345}{0.023}\left(\frac{12}{1}\right) = 180{,}000\ k/ft$ (vert. stiff.)

$k_{eff} = 41.2\ k/in = 495\ k/ft$ (horiz. stiff @ EQ defl.)



Bridge Name Dynamic Isolators Sample Problem

Calculations by SS Date 12/14/93 Bridge No. 2444 A

Using $\underline{\underline{E = 1000\ k/ft^2}}$ & $K_v = \frac{AE}{L}$

$A = \frac{180{,}000\,(1)}{1000} = \underline{\underline{180\ ft^2}}$

With the brg. "cantilevered" from the superstructure

$k_h = \frac{3EI}{L^3} = k_{eff}$

$I = \frac{495\,(1)^3}{3\,(1000)} = \underline{\underline{0.165\ ft^4}}$

Use $\underline{\underline{\gamma = 0.01\ k/ft^3}}$

Translation springs @ nodes 1 & 13:

$k_{eff} = 18.6\ k/in = \underline{\underline{223\ k/ft}}$

Seismic Loading:

Use the response spectrum of sheet 16. (PC-LEADER output)

A copy of the stored data follows (\STR\M-STRUDL\BI2915A)

A plot of the response spectrum also follows the data.

(A = 0.29g , S_i = 1.5)

-Dynamic Isolators Sample Problem

Base Isolation Response Spectrum
(BI2915A)

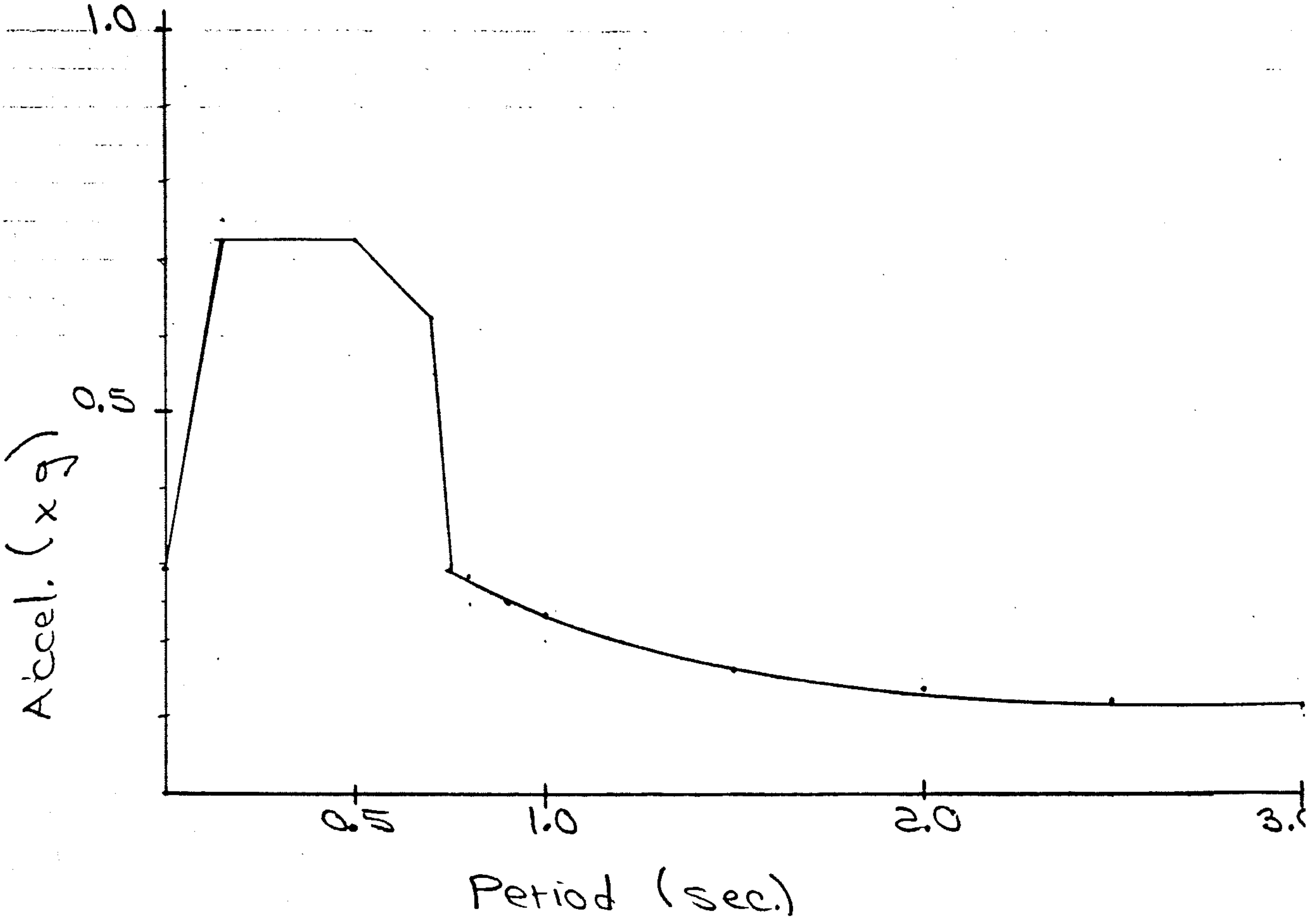
3.00	0.118
2.75	0.119
2.50	0.124
2.25	0.125
2.00	0.134
1.75	0.143
1.50	0.162
1.25	0.193
1.00	0.232
0.90	0.251
0.80	0.276
0.74	0.293
0.69	0.618
0.60	0.703
0.50	0.725
0.15	0.725
0.01	0.290

BRIDGE SECTION
Oregon State Highway Division

Sheet 000024

Bridge Name Dynamic Isolators Sample Problem

Calculations by SS Date 12/14/93 Bridge No. 2444A



Base Isolation Response Spectrum

```
TITLE  BR. 2444A   HOOD RIVER BR.      STARKEY  12-14-93  (BR2444C)
$ DYNAMIC LOADING MODEL (WITH BASE ISOLATION)
TYPE PLANE FRAME
UNITS KIPS FT RADIANS
SAVE ON
REPORT DEVICE OUT1
JOI COO
1           0.0      25.0       S
2          28.3      25.0
5         113.2      25.0
9         255.2      25.0
12        340.1      25.0
13        368.4      25.0       S
14        113.2       0.0       S
15        113.2       8.0
16        113.2      16.0
17        113.2      24.0
18        255.2       0.0       S
19        255.2       8.0
20        255.2      16.0
21        255.2      24.0
2 TO 5 BY 1
5 TO 9 BY 1
9 TO 12 BY 1
$
JOI REL
1 13  KFX 223.0  KFY 10000.  KMZ 0.1
$
MEM INC
1   1   2
12  12  13
13  14  15
14  15  16
15  16  17
16  17   5
17  18  19
18  19  20
19  20  21
20  21   9
1  TO 12  BY 1  I BY 1  J BY 1
$
MEM REL
16 20 STA MOM Z
$
MEMBER   PROPERTIES
APRO1  AX  1.7     IZ   6.8     1 2 3 6 7 10 11 12
APRO2  AX  1.9     IZ   14.3    4 5 8 9
APRO3  AX  19.6    IZ   30.8    13 17
APRO4  AX  17.4    IZ   23.9    14 18
APRO5  AX  14.8    IZ   16.8    15 19
APRO6  AX  180.0   IZ   0.165   16 20
$
MATERIAL PROPERTIES
A1     E 4176000.0  DEN 1.40   CTE 0.000006    1 2 3 6 7 10 11 12
A2     E 4176000.0  DEN 1.25   CTE 0.000006    4 5 8 9
A3     E 475200.0   DEN 0.28   CTE 0.000006    13 14 15 17 18 19
A4     E 1000.0     DEN 0.01   CTE 0.000006    16 20
$
DYNAMIC ANALYSIS REACTIONS MODES 15
$ A=0.29  S=1.5  G=32.2
```

(stored data)

```
LOAD EQL
RSA X 32.2 PERIOD ACCE BI2915A SRSS
OUT DEC 5
LIST FREQ 1 TO 15
LIST DISP ALL
OUT DEC 2
LIST REA ALL
LIST MEM FOR 13 TO 20
FINISH
```

```
 ================================================================
| M-STRUDL BY CAST / REV.  V2.90 SER :  722d TIME : 12/14/1993 17:51:29 |
| L I C E N S E E : Oregon DOT #11, OR                                  |
| TITLE:  BR. 2444A   HOOD RIVER BR.      STARKEY  12-14-93 PAGE     1 |
 ================================================================


  ***********************
  * RESULTS OF ANALYSIS *
  ***********************

TYPE OF THE PROBLEM :  PLANE FRAME  RESTART STATUS :     NONE GIVEN
ACTIVE UNITS :  KIPS     FEET   RADIANS


 * TOLERANCE = 0.01   MAX. NO. ITERATIONS = 20

 * TOTAL WEIGHT IN X DIRECTION = 1110.02
 * TOTAL WEIGHT IN Y DIRECTION = 1110.02


 * NO. OF EIGEN VALUES REQUESTED : 15

   MODE FREQUENCY   PERIOD /--- % MASS PARTICIPATED ---/ /-- PARTICIPATION FACTOR ---/
    NO.       HZ.   SECOND        X DIR.       Y DIR.            X DIR.       Y DIR.

     1       1.09     0.915   81.13945      0.00000        889.18075      0.00041
     2       2.02     0.494    0.00000      0.05717         -0.03323     13.06629
     3       3.20     0.313    0.00056      0.00000          1.31799     -0.00335
     4       4.18     0.239    0.00000     56.03261         -0.06615    454.06800
     5       8.19     0.122    0.00038      0.00000         -0.99774     -0.00171
     6      10.11     0.099    0.00000      0.00019          0.04837      0.34381
     7      10.13     0.099    9.38057      0.00000        -75.71999      0.00781
     8      10.41     0.096    0.00001      0.32276         -0.15047     33.70077
     9      11.16     0.090    0.00003      0.00000         -0.37519     -0.01621
    10      13.64     0.073    0.00007      0.00000         -0.56740      0.00078
    11      15.43     0.065    0.00000      0.62832          0.07563    -41.49658
    12      16.83     0.059    0.00016      0.00000         -0.38966      0.01303
    13      16.98     0.059    0.00001     13.08533         -0.09142   -120.58130
    14      22.77     0.044    0.00017      0.99908          0.58603    -44.37443
    15      22.85     0.044    0.00001      1.10102         -0.15295    -46.76717
```

Period

```
 ================================================================
| M-STRUDL BY CAST / REV.  V2.90 SER :  722d TIME : 12/14/1993 17:51:29 |
| L I C E N S E E : Oregon DOT #11, OR                                  |
| TITLE:  BR. 2444A   HOOD RIVER BR.      STARKEY  12-14-93 PAGE     2 |
 ================================================================



  ***  LOAD INDEX :    1  LOAD TAG :          EQL   ***

* X - RSA, FACTOR = 32.2  FREQ. VS.  ACCEL. CURVE

  0.33333:3.799600.36364:3.831800.40000:3.992800.44444:4.025000.50000:4.31480
```

```
0.57143:4.604600.66667:5.216400.80000:6.214601.00000:7.470401.11111:8.08220
1.25000:8.887201.35135:9.434601.44928:19.899601.66667:22.636602.00000:23.34500
6.66667:23.34500100.00000:9.33800

 RESULTANT JOINT DISPLACEMENTS -----

JOINT  /--- GLOBAL DISPLACEMENTS ---/-- ROTATION --/
 NO.      X DIRECTION    Y DIRECTION    Z DIRECTION

   1       0.17108        0.00004        0.00002      (2.05")     <- Defl.
   2       0.17120        0.00051        0.00001
   3       0.17125        0.00074        0.00000
   4       0.17124        0.00055        0.00002
   5       0.17116        0.00001        0.00002
   6       0.17130        0.00038        0.00000
   7       0.17136        0.00002        0.00002
   8       0.17130        0.00038        0.00000
   9       0.17116        0.00001        0.00002
  10       0.17124        0.00055        0.00002
  11       0.17125        0.00074        0.00000
  12       0.17120        0.00051        0.00001
  13       0.17108        0.00004        0.00002
  14       0.00000        0.00000        0.00000
  15       0.00361        0.00000        0.00084
  16       0.01320        0.00000        0.00148
  17       0.02660        0.00000        0.00177
  18       0.00000        0.00000        0.00000
  19       0.00361        0.00000        0.00084
  20       0.01320        0.00000        0.00148
  21       0.02660        0.00000        0.00177


 ==================================================================
| M-STRUDL BY CAST / REV.  V2.90 SER :  722d TIME : 12/14/1993 17:51:29 |
| L I C E N S E E : Oregon DOT #11, OR                                  |
| TITLE:  BR. 2444A   HOOD RIVER BR.      STARKEY  12-14-93 PAGE     2  |
 ==================================================================


***  LOAD INDEX :    1  LOAD TAG :         EQL  ***


 ==================================================================
| M-STRUDL BY CAST / REV.  V2.90 SER :  722d TIME : 12/14/1993 17:51:29 |
| L I C E N S E E : Oregon DOT #11, OR                                  |
| TITLE:  BR. 2444A   HOOD RIVER BR.      STARKEY  12-14-93 PAGE     3  |
 ==================================================================


* X - RSA. FACTOR = 32.2  FREQ. VS.  ACCEL. CURVE

    0.33:3.80      0.36:3.83      0.40:3.99      0.44:4.03      0.50:4.31
    0.57:4.60      0.67:5.22      0.80:6.21      1.00:7.47      1.11:8.08
    1.25:8.89      1.35:9.43      1.45:19.90     1.67:22.64     2.00:23.35
    6.67:23.35   100.00:9.34

 * FOR REACTIONS OF DYNAMIC ANALYSIS AT SKEWED SPRING SUPPORTS, PLEASE
```

```
USE THE MEMBER END FORCE RESULTS INSTEAD OF TABULATED RESULTS.

 JOINT REACTIONS AT SUPPORTS -----

JOINT  LD      /------------ GLOBAL REACTIONS ------------/
 NO.                X FORCE        Y FORCE       Z MOMENT

    1              -38.15          -0.38          -0.00
   13              -38.15          -0.38          -0.00
   14              -82.39          -0.77       -1871.30
   18              -82.36          -0.78       -1870.84
```

Seismic
Force (k)

```
 ====================================================================
| M-STRUDL BY CAST / REV.  V2.90 SER :  722d TIME : 12/14/1993 17:51:29 |
| L I C E N S E E : Oregon DOT #11, OR                                 |
| TITLE:  BR. 2444A   HOOD RIVER BR.      STARKEY  12-14-93 PAGE    3 |
 ====================================================================


 ***  LOAD INDEX :    1  LOAD TAG :          EQL  ***

* X - RSA, FACTOR = 32.2  FREQ. VS.  ACCEL. CURVE

    0.33:3.80      0.36:3.83      0.40:3.99      0.44:4.03      0.50:4.31
    0.57:4.60      0.67:5.22      0.80:6.21      1.00:7.47      1.11:8.08
    1.25:8.89      1.35:9.43      1.45:19.90     1.67:22.64     2.00:23.35
    6.67:23.35   100.00:9.34

  RESULTANT MEMBER FORCES -----

MEMBER        SECTION   JOINT /--- AXIAL ---/--- LOCAL Y --/-- LOCAL Z --/
 NO.             TAG.    NO.       FORCE       SHEAR FORCE      MOMENT

   13           APR03    14         0.77           82.39        1871.30
                         15         0.77           82.39        1218.98
   14           APR04    15         0.77           79.62        1218.98
                         16         0.77           79.62         590.16
   15           APR05    16         0.77           73.77         590.16
                         17         0.77           73.77           0.00
   16           APR06    17         0.77           72.22           0.00
                          5         0.77           72.22          72.22
```

Seismic
Moment (k-ft)

Seismic
Force (k)

```
 ====================================================================
| M-STRUDL BY CAST / REV.  V2.90 SER :  722d TIME : 12/14/1993 17:51:29 |
| L I C E N S E E : Oregon DOT #11, OR                                 |
| TITLE:  BR. 2444A   HOOD RIVER BR.      STARKEY  12-14-93 PAGE    4 |
 ====================================================================


  RESULTANT MEMBER FORCES -----

MEMBER        SECTION   JOINT /--- AXIAL ---/--- LOCAL Y --/-- LOCAL Z --/
 NO.             TAG.    NO.       FORCE       SHEAR FORCE      MOMENT

   17           APR03    18         0.78           82.36        1870.84
```

		19	0.78	82.36	1218.78
18	APR04	19	0.78	79.59	1218.78
		20	0.78	79.59	590.13
19	APR05	20	0.78	73.77	590.13
		21	0.78	73.77	0.00
20	APR06	21	0.77	72.22	0.00
		9	0.77	72.22	72.22

Sheet 000031

Bridge Name Dynamic Isolators Sample Problem

Calculations by SS Date 12/14/93 Bridge No. 2444A

M-STRUDL model: (plane frame)
("As Is" Structure)

Use previous model (sheets 19-21) with these modifications:

Springs off @ nodes 1 & 13
(allow rotation & horiz. translation)

Mem 16: Use properties of mem 15
Pin to superstructure (@ node 5)

Mem 20: Use properties of mem 19
Provide only vert. support to superstructure. (@ node 9)

Seismic Loading:

Std. AASHTO response spectrum
w/ A = 0.29 g
S = 1.2 (Soil Type II)

```
TITLE  BR. 2444A   HOOD RIVER BR.      STARKEY  12-14-93  (BR2444D)
$ DYNAMIC LOADING MODEL (AS IS)
TYPE PLANE FRAME
UNITS KIPS FT RADIANS
SAVE ON
REPORT DEVICE OUT2
JOI COO
1           0.0     25.0        S
2          28.3     25.0
5         113.2     25.0
9         255.2     25.0
12        340.1     25.0
13        368.4     25.0        S
14        113.2      0.0        S
15        113.2      8.0
16        113.2     16.0
17        113.2     24.0
18        255.2      0.0        S
19        255.2      8.0
20        255.2     16.0
21        255.2     24.0
2 TO 5 BY 1
5 TO 9 BY 1
9 TO 12 BY 1
$
JOI REL                                                 "Roller" ends.
1 13  KFX 0.1   KFY 10000.   KMZ 0.1
$
MEM INC
1   1   2
12  12  13
13  14  15
14  15  16
15  16  17
16  17   5
17  18  19
18  19  20
19  20  21
20  21   9
1   TO 12   BY 1   I BY 1   J BY 1
$
MEM REL
16 END MOM Z                                              Col. Connections
20 END FOR Y MOM Z
$
MEMBER   PROPERTIES
APRO1  AX  1.7      IZ   6.8     1 2 3 6 7 10 11 12
APRO2  AX  1.9      IZ   14.3    4 5 8 9
APRO3  AX  19.6     IZ   30.8    13 17
APRO4  AX  17.4     IZ   23.9    14 18
APRO5  AX  14.8     IZ   16.8    15 16 19 20              Mem Props.
$ APRO6  AX  180.0    IZ   0.165   16 20
$
MATERIAL PROPERTIES
A1    E 4176000.0  DEN 1.40   CTE 0.000006    1 2 3 6 7 10 11 12
A2    E 4176000.0  DEN 1.25   CTE 0.000006    4 5 8 9
A3    E 475200.0   DEN 0.28   CTE 0.000006    13 14 15 16 17 18 19 20      Mem. Materials
$ A4     E 1000.0      DEN 0.01    CTE 0.000006    16 20
$
DYNAMIC ANALYSIS REACTIONS MODES 15
```

(stored. data)

```
$ A=0.29  S=1.2  G=32.2
LOAD EQL
RSA X 11.2 FREQ ACCE RESSOIL2 SRSS
OUT DEC 5
LIST FREQ 1 TO 15
LIST DISP ALL
OUT DEC 2
LIST REA ALL
LIST MEM FOR 13 TO 20
FINISH
```

```
 =========================================================================
| M-STRUDL BY CAST / REV.  V2.90 SER :  722d TIME : 12/14/1993 18:24:53 |
| L I C E N S E E : Oregon DOT #11, OR                                   |
| TITLE:  BR. 2444A   HOOD RIVER BR.      STARKEY  12-14-93 PAGE     1  |
 =========================================================================


   ***********************
   * RESULTS OF ANALYSIS *
   ***********************

TYPE OF THE PROBLEM :  PLANE FRAME  RESTART STATUS :     NONE GIVEN
ACTIVE UNITS :  KIPS     FEET    RADIANS


  * TOLERANCE = 0.01    MAX. NO. ITERATIONS = 20

  * TOTAL WEIGHT IN X DIRECTION = 1112.36
  * TOTAL WEIGHT IN Y DIRECTION = 1112.36


  * NO. OF EIGEN VALUES REQUESTED : 15

     MODE FREQUENCY    PERIOD /--- % MASS PARTICIPATED ---/ /-- PARTICIPATION FACTOR ---/
      NO.       HZ.    SECOND        X DIR.       Y DIR.            X DIR.        Y DIR.

       1       1.50     0.667    83.55716      0.00000        -901.53778      -0.00013
       2       2.03     0.494     0.00000      0.06946          -0.00226      14.44363
       3       3.21     0.312     0.00000      0.00000           0.05254       0.00083
       4       4.23     0.237     0.00000     54.77172          -0.00132     445.94503
       5       8.22     0.122     0.00000      0.00000          -0.10885       0.01096
       6       9.03     0.111     5.82612      0.00000          43.57267       0.00120
       7      10.51     0.095     0.00000      0.18460          -0.08022      25.66639
       8      11.46     0.087     0.00000      0.00000          -0.15191      -0.02511
       9      13.52     0.074     0.05538      0.00000          16.41541      -0.00936
      10      15.57     0.064     0.00001      0.04807          -0.14668      12.24900
      11      16.99     0.059     0.00023      0.00000           0.46795       0.00571
      12      17.28     0.058     0.00001     11.70867           0.08816    -119.24759
      13      23.28     0.043     0.00000      0.39072           0.04959     -28.95727
      14      23.36     0.043     0.00034      1.37611          -0.85491     -54.40066
      15      26.96     0.037     0.07708      0.00000          17.99653      -0.00961


 =========================================================================
| M-STRUDL BY CAST / REV.  V2.90 SER :  722d TIME : 12/14/1993 18:24:53 |
| L I C E N S E E : Oregon DOT #11, OR                                   |
| TITLE:  BR. 2444A   HOOD RIVER BR.      STARKEY  12-14-93 PAGE     2  |
 =========================================================================



  ***  LOAD INDEX :    1  LOAD TAG :         EQL  ***

 * X - RSA. FACTOR = 11.2  FREQ. VS.  ACCEL. CURVE

  0.25000:5.376000.29000:5.824000.33000:6.496000.40000:7.280000.50000:8.51200
```

← Period

```
0.53000:8.736000.56000:9.072000.59000:9.408000.63000:9.856000.67000:10.30400
0.71000:10.752000.77000:11.312000.83000:11.872000.91000:12.656001.00000:13.44000
1.11000:14.448001.25000:15.568001.43000:17.024001.67000:18.928002.00000:21.28000
2.29000:23.29600100.00000:23.29600

 RESULTANT JOINT DISPLACEMENTS -----

JOINT  /--- GLOBAL DISPLACEMENTS ---/-- ROTATION --/
 NO.       X DIRECTION    Y DIRECTION    Z DIRECTION

    1        0.19956        0.00001        0.00000
    2        0.19948        0.00001        0.00000
    3        0.19926        0.00001        0.00000
    4        0.19889        0.00001        0.00000
    5        0.19843        0.00000        0.00000
    6        0.19984        0.00001        0.00000
    7        0.20119        0.00000        0.00000
    8        0.20230        0.00001        0.00000
    9        0.20308        0.00000        0.00000
   10        0.20355        0.00001        0.00000
   11        0.20393        0.00001        0.00000
   12        0.20416        0.00001        0.00000
   13        0.20423        0.00001        0.00000
   14        0.00000        0.00000        0.00000
   15        0.02448        0.00000        0.00575
   16        0.09061        0.00000        0.01031
   17        0.18563        0.00000        0.01278
   18        0.00000        0.00000        0.00000
   19        0.00160        0.00000        0.00037
   20        0.00559        0.00000        0.00059
   21        0.01076        0.00000        0.00067
```

(2.39") ← Defl.

```
 ==========================================================================
| M-STRUDL BY CAST / REV.  V2.90 SER :  722d TIME : 12/14/1993 18:24:53 |
| L I C E N S E E : Oregon DOT #11, OR                                  |
| TITLE:  BR. 2444A   HOOD RIVER BR.      STARKEY  12-14-93 PAGE     2  |
 ==========================================================================


***  LOAD INDEX :    1  LOAD TAG :         EQL  ***


 ==========================================================================
| M-STRUDL BY CAST / REV.  V2.90 SER :  722d TIME : 12/14/1993 18:24:53 |
| L I C E N S E E : Oregon DOT #11, OR                                  |
| TITLE:  BR. 2444A   HOOD RIVER BR.      STARKEY  12-14-93 PAGE     3  |
 ==========================================================================


* X - RSA, FACTOR = 11.2  FREQ. VS.  ACCEL. CURVE

    0.25:5.38       0.29:5.82       0.33:6.50       0.40:7.28       0.50:8.51
    0.53:8.74       0.56:9.07       0.59:9.41       0.63:9.86       0.67:10.30
    0.71:10.75      0.77:11.31      0.83:11.87      0.91:12.66      1.00:13.44
    1.11:14.45      1.25:15.57      1.43:17.02      1.67:18.93      2.00:21.28
    2.29:23.30    100.00:23.30
```

```
* FOR REACTIONS OF DYNAMIC ANALYSIS AT SKEWED SPRING SUPPORTS. PLEASE
USE THE MEMBER END FORCE RESULTS INSTEAD OF TABULATED RESULTS.

  JOINT REACTIONS AT SUPPORTS -----

 JOINT  LD      /------------ GLOBAL REACTIONS ------------/
  NO.                X FORCE        Y FORCE        Z MOMENT

    1                  -0.02          -0.12           -0.00
   13                  -0.02          -0.11           -0.00
   14                -507.55          -0.19       -12550.62
   18                 -46.90          -0.11         -857.89
```

Seismic Moment (k-ft)

```
  ==================================================================
 | M-STRUDL BY CAST / REV.  V2.90 SER :  722d TIME : 12/14/1993 18:24:53 |
 | L I C E N S E E : Oregon DOT #11, OR                                  |
 | TITLE:  BR. 2444A   HOOD RIVER BR.      STARKEY  12-14-93 PAGE     3  |
  ==================================================================


 ***  LOAD INDEX :    1  LOAD TAG :         EQL  ***

* X - RSA. FACTOR = 11.2  FREQ. VS.  ACCEL. CURVE

     0.25:5.38      0.29:5.82      0.33:6.50      0.40:7.28      0.50:8.51
     0.53:8.74      0.56:9.07      0.59:9.41      0.63:9.86      0.67:10.30
     0.71:10.75     0.77:11.31     0.83:11.87     0.91:12.66     1.00:13.44
     1.11:14.45     1.25:15.57     1.43:17.02     1.67:18.93     2.00:21.28
     2.29:23.30   100.00:23.30

  RESULTANT MEMBER FORCES -----

 MEMBER        SECTION  JOINT /--- AXIAL ---/--- LOCAL Y --/-- LOCAL Z --/
  NO.              TAG.   NO.      FORCE      SHEAR FORCE      MOMENT

    13           APR03   14          0.19         507.55      12550.62
                         15          0.19         507.55       8490.20
    14           APR04   15          0.18         504.75       8490.20
                         16          0.18         504.75       4452.17
    15           APR05   16          0.18         495.75       4452.17
                         17          0.18         495.75        486.20

  ==================================================================
 | M-STRUDL BY CAST / REV.  V2.90 SER :  722d TIME : 12/14/1993 18:24:53 |
 | L I C E N S E E : Oregon DOT #11, OR                                  |
 | TITLE:  BR. 2444A   HOOD RIVER BR.      STARKEY  12-14-93 PAGE     4  |
  ==================================================================


  RESULTANT MEMBER FORCES -----

 MEMBER        SECTION  JOINT /--- AXIAL ---/--- LOCAL Y --/-- LOCAL Z --/
  NO.              TAG.   NO.      FORCE      SHEAR FORCE      MOMENT
```

16	APR05	17	0.17	486.20	486.20
		5	0.17	486.20	0.00
17	APR03	18	0.11	46.90	857.89
		19	0.11	46.90	482.70
18	APR04	19	0.11	40.26	482.70
		20	0.11	40.26	160.66
19	APR05	20	0.10	20.08	160.66
		21	0.10	20.08	0.00
20	APR05	21	0.10	0.00	0.00
		9	0.10	0.00	0.00

Seismic Force (k)

Dynamic Isolators Sample Problem

S.K. Starkey December 14, 1993 BR 2444A

RESULTS SUMMARY:

	Primary Period (sec.)	Defl. (inches)	Pier 1 Force (kips)	Pier 2 Force (top) (kips)	Pier 2 Moment (bot) (kip-ft)
PC-LEADER	0.87	1.91	35	78	1,870 (*)
M-STRUDL (Base Isol.)	0.92	2.04	38	72	1,870 (**)
M-STRUDL ("As Is")	0.67	2.38	0	490	12,550 (**)

(*) Computed from force at column top times the column height (24 ft). Column weight neglected.

(**) Includes column weight.