# Appendix

## Testing Equipment

### Accelerometer

Table A : PCB 393A03 Model Specifications

|  |  |
| --- | --- |
| Sensitivity: | (±5%) 1000 mV/g (102 mV/(m/s²)) |
| Measurement Range: | ±5 g pk (±49 m/s² pk) |
| Broadband Resolution: | 0.00001 g rms (0.0001 m/s² rms) |
| Frequency Range: | (±5%) 0.5 to 2000 Hz |
| Electrical Connector: | 2-Pin MIL-C-5015 |
| Weight: | 7.4 oz (210 gm) |

### Strain Gauge

Table A : Geokon Model 4000 Specifications

|  |  |
| --- | --- |
| Measurement Range: | 3000 µε |
| Resolution: | 1.0 µε |
| Accuracy: | ±0.5% F.S. |
| Nonlinearity: | <0.5% F.S. |
| Temperature Range: | −20°C to +80°C |
| Active Gauge Length | 150 mm |

## Phase 1 Testing

### Acceleration Data

|  |  |  |
| --- | --- | --- |
| Acceleration (g) |  | Pier 2 |
|  | Pier 3 |
|  | Pier 5 |
|  | Pier 7 |
|  | Time (sec) ◼-West; ◼-East |  |

Figure A : Longitudinal acceleration of piers

|  |  |  |
| --- | --- | --- |
| Acceleration (g) |  | Pier 2 |
|  | Pier 3 |
|  | Pier 5 |
|  | Pier 7 |
|  | Time (sec) |  |

Figure A : Vertical acceleration of piers

## Phase 2 Testing

### Mode shapes

|  |  |
| --- | --- |
| Figure A : Experimental Mode 1 | Figure A : Experimental Mode 2 |
| Figure A : Experimental Mode 3 | Figure A : Experimental Mode 4 |

|  |  |
| --- | --- |
| Figure A : Experimental Mode 5 | Figure A : Experimental Mode 6 |
| Figure A : Experimental Mode 7 | Figure A : Experimental Mode 8 |
| Figure A : Experimental Mode 9 | Figure A : Experimental Mode 10 |

|  |  |
| --- | --- |
| Figure A : Experimental Mode 11 | Figure A : Experimental Mode 12 |
| Figure A : Experimental Mode 13 | Figure A : Experimental Mode 14 |
| Figure A : Experimental Mode 15 | Figure A : Experimental Mode 16 |

|  |  |
| --- | --- |
| Figure A : Experimental Mode 17 | Figure A : Experimental Mode 18 |

## Phase 2 FE Model Validation

### Calibrated FE Model Mode Shapes

|  |  |
| --- | --- |
| Figure A : FEM Mode Shape 1 | Figure A : FEM Mode Shape 2 |
| Figure A : FEM Mode Shape 3 | Figure A : FEM Mode Shape 4 |
| Figure A : FEM Mode Shape 5 | Figure A : FEM Mode Shape 6 |
| Figure A : FEM Mode Shape 7 | Figure A : FEM Mode Shape 8 |

## Methods of Performing Load Rating through Refined Analysis

### Model Building

* Models are geometrically consistent with the real structure (e.g. elements located at centerline)
* Girders are modeled with 2-node beam elements
* Diaphragms are modeled with 2-node beam elements (or arrangement of beam elements)
* Deck and sidewalk are modeled with 3 and 4 node shell elements
* Barriers may be modeled with 2-node beam elements
* Continuity is enforced with rigid links so as to maintain realistic geometry
* Conservative Boundary Conditions for rating (minimal realistic restraint while maintaining stability). For example:
  + No rotational restraint
  + Long. Restraint at exterior bearings (1 end)
  + Translational restraint at center bearing (1 end)
  + Vertical restraint at all bearings
* Composite Action is modeled as elements connecting deck and girders.
  + Rigid Links, or…
  + Connection Elements (If updating of composite action is desired)
* Beam Discretization and Deck Meshing
  + Beam Discretization should be on the order of 1/4 the girder spacing, and as consistent as reasonably possible
  + Deck meshing should have an aspect ratio less than 2:1, and no elements shall have an aspect ratio greater than 3:1
  + Quad shell elements should have no internal angle greater than 45 degrees
  + The deck meshing should match the beam discretization longitudinally
* Non-structural mass (e.g. wearing surface) may be modeled as point non-structural mass at appropriate nodes and equivalent to the mass of the component being represented.

### Model Error Screening

* A natural frequency analysis shall be performed on the completed model. The first several modes shall be examined for local deformations which suggest discontinuities or improper stiffness assignments. Sufficient number of modes shall be analyzed such that at least 4 global modes are identified.
* The deflected shape under multiple load cases (dead load and live load) shall be examined for atypical behavior (e.g. nonsymmetrical deformation, unintended breaks or discontinuities).
* When further error screening is deemed necessary (recommended for any manually constructed model) the following procedures may be performed:
  + Manual calculation of structure weight shall be compared to the sum of dead load vertical reactions.
  + FE responses (e.g. deflection, moment, etc.) under simple load cases shall be compared to the corresponding theoretical responses for single line girder models (i.e. approximate analysis)

### Model Loading and Result Extraction

* Dead Load consists of the weight of the deck, girders, and diaphragms and is carried by the structure with an uncured deck. Thus, the stiffness of the deck, sidewalk and barriers is turned off for this load case (i.e. Modulus of elasticity set to 0 or arbitrarily low value that does not produce numerical errors).
* Superimposed Dead Load consists of the weight of the barriers and sidewalk after the deck has cured. Therefore, the stiffness of the deck is set to its nominal value, while sidewalk and barriers should have stiffness turned off.
* Live Load (and Wearing Surface when applicable) is carried by the completed structure. Stiffness of all acting mechanisms is included, unless certain mechanisms are to be considered inactive (e.g. stiffness of barriers and sidewalks turned off).
* Wheel loads shall consist of point loads placed on the deck element at the appropriate locations (center of tire).
* Lane loads may consist of point loads on all deck nodes within the lane load region such that the total load applied is equal to the distributed load specified.
* Composite moment may be calculated by the following equation:

|  |  |
| --- | --- |
|  | (A ) |

Where:

M1 = Principle Bending Moment

FA = Axial Force

D = Girder Depth

tD = Deck Thickness

### Phase 3

## Comparison of Experimental and FEM Mode Shapes

|  |  |
| --- | --- |
| FE Modes | Experimental Modes |
| 2.03 Hz    Figure A : FEM Mode 1 | 2.0 Hz    Figure A : Exp. Mode 1 |
| 2.07 Hz    Figure A : FEM Mode 2 | 2.1 Hz    Figure A : Exp. Mode 3 |
| 2.49 Hz    Figure A : FEM Mode 3 | 2.44 Hz    Figure A : Exp. Mode 4 |
| 2.50 Hz    Figure A : FEM Mode 4 | 2.54 Hz    Figure A : Exp. Mode 6 |
| 2.82 Hz    Figure A : FEM Mode 5 | 2.83 Hz  Figure A : Exp. Mode 7 |
| 3.14 Hz    Figure A : FEM Mode 6 | 3.2 Hz    Figure A : Exp. Mode 9 |
| 3.63 Hz    Figure A : FEM Mode 7 | 3.56 Hz    Figure A : Exp. Mode 12 |
| 3.63 Hz    Figure A : FEM Mode 8 | 3.56 Hz    Figure A : Exp. Mode 13 |

## VBI Modeling Validation

Table A : Error of Maximum Responses for Experiment vs Simulation

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Run 3 | | | Run 14 | | |
|  | Max Exp. | Max Sim. | %Diff. | Max Exp. | Max Sim. | %Diff. |
| Truck (Avg. Rear) | 0.9352 | 0.6345 | -32.15% | 0.825 | 0.738 | -10.58% |
| Span 2 | 0.0750 | 0.0890 | 18.58% | 0.137 | 0.210 | 53.61% |
| Span 3 | 0.1177 | 0.1190 | 1.09% | 0.162 | 0.225 | 38.31% |
| Span 4 | 0.1055 | 0.1230 | 16.68% | - | - | - |
| Span 7 | 0.0705 | 0.0926 | 31.48% | 0.100 | 0.168 | 68.84% |

Table A : Error of Minimum Responses for Experiment vs Simulation

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Run 3 | | | Run 14 | | |
|  | Min Exp. | Min Sim. | %Diff. | Min Exp. | Max Sim. | %Diff. |
| Truck (Avg. Rear) | -0.8044 | -0.7861 | -2.28% | -0.638 | -0.708 | 11.02% |
| Span 2 | -0.0713 | -0.0875 | 22.71% | -0.129 | -0.164 | 26.62% |
| Span 3 | -0.1115 | -0.1361 | 22.01% | -0.143 | -0.220 | 53.68% |
| Span 4 | -0.1115 | -0.1187 | 6.47% | - | - | - |
| Span 7 | -0.0798 | -0.0827 | 3.60% | -0.094 | -0.160 | 69.56% |

### Run 14 Acceleration Time Histories



Figure A : Experiment vs Simulation for Vehicle Acceleration over Bridge (Filtered and Decimated)



Figure A : “Warped” Experimental and Simulated Vehicle Acceleration



Figure A : Experiment vs Simulation for Span 2 Midspan Acceleration of Girder 8 (Filtered and Decimated)



Figure A : Experiment vs Simulation for Span 2 Midspan Acceleration of Girder 8 (Dynamic Time Warped)



Figure A : Experiment vs Simulation for Span 3 Midspan Acceleration of Girder 8 (Filtered and Decimated)



Figure A : Experiment vs Simulation for Span 3 Midspan Acceleration of Girder 8 (Dynamic Time Warped)



Figure A : Experiment vs Simulation for Span 7 Midspan Acceleration of Girder 8 (Filtered and Decimated)



Figure A : Experiment vs Simulation for Span 7 Midspan Acceleration of Girder 8 (Dynamic Time Warped)

### Run 3 Acceleration Time Histories



Figure A : Experiment vs Simulation for Vehicle Acceleration over Bridge (Filtered and Decimated)



Figure A : “Warped” Experimental and Simulated Vehicle Acceleration



Figure A : Experiment vs Simulation for Span 2 Midspan Acceleration of Girder 8 (Filtered and Decimated)



Figure A : Experiment vs Simulation for Span 2 Midspan Acceleration of Girder 8 (Dynamic Time Warped)



Figure A : Experiment vs Simulation for Span 3 Midspan Acceleration of Girder 8 (Filtered and Decimated)



Figure A : Experiment vs Simulation for Span 3 Midspan Acceleration of Girder 8 (Dynamic Time Warped)



Figure A : Experiment vs Simulation for Span 7 Midspan Acceleration of Girder 8 (Filtered and Decimated)



Figure A : Experiment vs Simulation for Span 7 Midspan Acceleration of Girder 8 (Dynamic Time Warped)



Figure A : Experiment vs Simulation for Span 8 Midspan Acceleration of Girder 8 (Filtered and Decimated)



Figure A : Experiment vs Simulation for Span 8 Midspan Acceleration of Girder 8 (Dynamic Time Warped)

## State-Space Model Validation

Validation of the 2-DOF state-space models was performed by comparing responses to those predicted by 2D FE models of the beams. The following lists the beam parameters as assigned in the state-space model.

Table A : Model parameters for model validation

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Bridge/Beam Parameters | | | Vehicle/Sprung Mass Parameters | | |
| Length | 1200 | in | Mass | 100 | slinch |
| EI | 7.50E+12 | lb-in2 | Spring K | 6.32E+04 | lb/in |
| Total Mass | 460000 | lb | Damping Coefficient | 502.65 | lb-s/in |
| Length | 1200 | in |  |  |  |

The FE models were constructed with 2D Kirchhoff beam elements which are parabolically curved thin beam elements in which shear deformations are excluded. The beams were discretized with a mesh length of 6 inches. The elements were assigned the following attributes.

Table A : FEM Beam Attributes

|  |  |  |
| --- | --- | --- |
| Moment of Inertia (I) | 1500 | in^4 |
| Cross sectional area (A) | 10 | in^2 |
| Modulus of Elasticity (E) | 5.00E+09 | psi |
| Material Density | 0.099286 | slinch/in^3 |

The sprung-mass in the FE model was assigned the same attributes as listed for the state-space model.

The profile was constructed using ISO 8608 standards whereby two parameters describe the frequency content of the profile. For these simulations a profile was constructed with a roughness coefficient (C10) of 300 and a waviness (*w*) of -2. A profile with these parameters would be categorized as average according to ISO 8608. The profile was located such that the beam began at the profile’s distance of 100 feet.

The sprung mass was assigned a velocity of 720 in/sec. Its path began 100 feet before the beam at the beginning of the profile. The state-space model evaluated each state in increments of 1 inch thus resulting in a time-step of 0.0014 sec. The FE simulations were performed with a time-step of 0.0015 sec.

### Comparison of state-space to FEM for single-span

Figure A : Comparison of midspan displacement

Figure A : Comparison of force at vehicle contact point

### Comparison of state-space to FEM for two-span continuous

Figure A : Comparison of midspan (span 1) displacement

Figure A : Comparison of force at vehicle contact point

## Simulation of VBI with Traffic

Table A : Spring-mass configurations for traffic patterns

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 1 | | 2 | | 3 | | 4 | | 5 | | 6 | |
| Location (in) | Axle # | Location (in) | Axle # | Location (in) | Axle # | Location (in) | Axle # | Location (in) | Axle # | Location (in) | Axle # |
| 0 | 6 | 0 | 2 | 0 | 9 | 0 | 9 | 0 | 4 | 0 | 4 |
| -168 | 5 | -168 | 1 | -192 | 8 | -192 | 8 | -168 | 3 | -168 | 3 |
| -432 | 5 | -336 | 1 | -264 | 8 | -264 | 8 | -528 | 3 | -528 | 3 |
| -1260 | 2 | -2028 | 6 | -540 | 7 | -540 | 7 | -2676 | 2 | -17220 | 12 |
| -1428 | 1 | -2196 | 5 | -612 | 7 | -612 | 7 | -2844 | 1 | -17316 | 12 |
| -1596 | 1 | -2460 | 5 | -3096 | 2 | -2496 | 14 | -3012 | 1 | -21672 | 12 |
| -1860 | 6 | -4260 | 14 | -3264 | 1 | -2664 | 14 | -6816 | 9 | -21768 | 12 |
| -2028 | 5 | -4428 | 14 | -3432 | 1 | -4584 | 11 | -7008 | 8 | -35880 | 9 |
| -2292 | 5 | -5568 | 12 | -5208 | 6 | -4764 | 10 | -7080 | 8 | -36072 | 8 |
| -2880 | 9 | -5664 | 12 | -5376 | 5 | -4824 | 10 | -7356 | 7 | -36144 | 8 |
| -3072 | 8 | -6828 | 2 | -5640 | 5 | -9192 | 12 | -7428 | 7 | -36420 | 7 |
| -3144 | 8 | -6996 | 1 | -7752 | 13 | -9288 | 12 | -10320 | 13 | -36492 | 7 |
| -3420 | 7 | -7164 | 1 | -7872 | 13 | -11100 | 6 | -10440 | 13 | -43068 | 14 |
| -3492 | 7 | -8772 | 13 | -9396 | 6 | -11268 | 5 | -12408 | 14 | -43236 | 14 |
| -4632 | 12 | -8892 | 13 | -9564 | 5 | -11532 | 5 | -12576 | 14 | -47508 | 2 |
| -4728 | 12 | -10860 | 12 | -9828 | 5 | -13092 | 13 | -16788 | 4 | -47676 | 1 |
| -5640 | 14 | -10956 | 12 | -11520 | 11 | -13212 | 13 | -16956 | 3 | -47844 | 1 |
| -5808 | 14 | -11760 | 6 | -11700 | 10 | -15780 | 12 | -17316 | 3 | -56724 | 14 |
| -6960 | 12 | -11928 | 5 | -11760 | 10 | -15876 | 12 | -22140 | 9 | -56892 | 14 |
| -7056 | 12 | -12192 | 5 | -12672 | 11 | -18036 | 14 | -22332 | 8 | -61128 | 6 |
| -8064 | 11 | -14148 | 4 | -12852 | 10 | -18204 | 14 | -22404 | 8 | -61296 | 5 |
| -8244 | 10 | -14316 | 3 | -12912 | 10 | -21132 | 4 | -22680 | 7 | -61560 | 5 |
| -8304 | 10 | -14676 | 3 | -15180 | 4 | -21300 | 3 | -22752 | 7 | -75024 | 11 |
| -8904 | 12 | -16632 | 2 | -15348 | 3 | -21660 | 3 | -26928 | 9 | -75204 | 10 |
| -9000 | 12 | -16800 | 1 | -15708 | 3 | -25524 | 13 | -27120 | 8 | -75264 | 10 |
| -10092 | 11 | -16968 | 1 | -17316 | 12 | -25644 | 13 | -27192 | 8 | -84300 | 11 |
| -10272 | 10 | -18336 | 4 | -17412 | 12 | -28644 | 14 | -27468 | 7 | -84480 | 10 |
| -10332 | 10 | -18504 | 3 | -19740 | 11 | -28812 | 14 | -27540 | 7 | -84540 | 10 |
| -10680 | 9 | -18864 | 3 | -19920 | 10 | -30504 | 9 | -29844 | 2 | -98004 | 12 |
| -10872 | 8 | -19824 | 14 | -19980 | 10 | -30696 | 8 | -30012 | 1 | -98100 | 12 |
| -10944 | 8 | -19992 | 14 | -23040 | 13 | -30768 | 8 | -30180 | 1 | -102528 | 2 |
| -11220 | 7 | -21540 | 2 | -23160 | 13 | -31044 | 7 | -33036 | 6 | -102696 | 1 |
| -11292 | 7 | -21708 | 1 | -24312 | 12 | -31116 | 7 | -33204 | 5 | -102864 | 1 |
| -12204 | 6 | -21876 | 1 | -24408 | 12 | -35664 | 11 | -33468 | 5 | -109392 | 14 |
| -12372 | 5 | -23760 | 6 | -25596 | 11 | -35844 | 10 | -39420 | 6 | -109560 | 14 |
| -12636 | 5 | -23928 | 5 | -25776 | 10 | -35904 | 10 | -39588 | 5 | -122256 | 2 |
| -13584 | 12 | -24192 | 5 | -25836 | 10 | -37584 | 12 | -39852 | 5 | -122424 | 1 |
| -13680 | 12 | -25716 | 9 | -28620 | 6 | -37680 | 12 | -44664 | 13 | -122592 | 1 |
| -14460 | 14 | -25908 | 8 | -28788 | 5 | -39312 | 14 | -44784 | 13 | -139116 | 13 |
| -14628 | 14 | -25980 | 8 | -29052 | 5 | -39480 | 14 | -46188 | 6 | -139236 | 13 |
| -15456 | 13 | -26256 | 7 | -30588 | 6 | -43752 | 12 | -46356 | 5 | -146268 | 12 |
| -15576 | 13 | -26328 | 7 | -30756 | 5 | -43848 | 12 | -46620 | 5 | -146364 | 12 |
| -16368 | 13 | -27276 | 11 | -31020 | 5 | -45696 | 13 | -51708 | 6 | -156360 | 2 |
| -16488 | 13 | -27456 | 10 | -33636 | 11 | -45816 | 13 | -51876 | 5 | -156528 | 1 |
| -17280 | 9 | -27516 | 10 | -33816 | 10 | -49164 | 9 | -52140 | 5 | -156696 | 1 |
| -17472 | 8 | -28356 | 12 | -33876 | 10 | -49356 | 8 | -54936 | 9 | -162732 | 2 |
| -17544 | 8 | -28452 | 12 | -35028 | 13 | -49428 | 8 | -55128 | 8 | -162900 | 1 |
| -17820 | 7 | -30072 | 11 | -35148 | 13 | -49704 | 7 | -55200 | 8 | -163068 | 1 |
| -17892 | 7 | -30252 | 10 | -36588 | 13 | -49776 | 7 | -55476 | 7 | -171156 | 6 |
| -18348 | 13 | -30312 | 10 | -36708 | 13 | -50904 | 4 | -55548 | 7 | -171324 | 5 |
| -18468 | 13 | -32340 | 12 | -39492 | 12 | -51072 | 3 | -57480 | 11 | -171588 | 5 |
| -19236 | 11 | -32436 | 12 | -39588 | 12 | -51432 | 3 | -57660 | 10 | -175704 | 4 |
| -19416 | 10 | -34416 | 4 | -41280 | 11 | -55764 | 11 | -57720 | 10 | -175872 | 3 |
| -19476 | 10 | -34584 | 3 | -41460 | 10 | -55944 | 10 | -61608 | 12 | -176232 | 3 |
| -20052 | 2 | -34944 | 3 | -41520 | 10 | -56004 | 10 | -61704 | 12 | -183612 | 14 |
| -20220 | 1 | -37224 | 13 | -42312 | 4 | -57408 | 12 | -63660 | 2 | -183780 | 14 |
| -20388 | 1 | -37344 | 13 | -42480 | 3 | -57504 | 12 | -63828 | 1 | -198480 | 4 |
| -21372 | 11 | -38256 | 12 | -42840 | 3 | -61176 | 2 | -63996 | 1 | -198648 | 3 |
| -21552 | 10 | -38352 | 12 | -45336 | 6 | -61344 | 1 | -66264 | 9 | -199008 | 3 |
| -21612 | 10 | -39456 | 14 | -45504 | 5 | -61512 | 1 | -66456 | 8 | -213192 | 4 |
| -22716 | 12 | -39624 | 14 | -45768 | 5 | -63360 | 2 | -66528 | 8 | -213360 | 3 |
| -22812 | 12 | -41688 | 11 | -47256 | 4 | -63528 | 1 | -66804 | 7 | -213720 | 3 |
| -23244 | 12 | -41868 | 10 | -47424 | 3 | -63696 | 1 | -66876 | 7 | -225048 | 14 |
| -23340 | 12 | -41928 | 10 | -47784 | 3 | -66756 | 9 | -72240 | 2 | -225216 | 14 |
| -24504 | 11 | -44004 | 6 | -50268 | 13 | -66948 | 8 | -72408 | 1 | -239328 | 12 |
| -24684 | 10 | -44172 | 5 | -50388 | 13 | -67020 | 8 | -72576 | 1 | -239424 | 12 |
| -24744 | 10 | -44436 | 5 | -53832 | 6 | -67296 | 7 | -77412 | 12 | -243732 | 9 |
| -25068 | 11 | -46416 | 12 | -54000 | 5 | -67368 | 7 | -77508 | 12 | -243924 | 8 |
| -25248 | 10 | -46512 | 12 | -54264 | 5 | -71616 | 2 | -81696 | 6 | -243996 | 8 |
| -25308 | 10 | -47664 | 12 | -56676 | 4 | -71784 | 1 | -81864 | 5 | -244272 | 7 |
| -26232 | 14 | -47760 | 12 | -56844 | 3 | -71952 | 1 | -82128 | 5 | -244344 | 7 |
| -26400 | 14 | -48684 | 12 | -57204 | 3 | -73116 | 4 | -85752 | 11 | -252432 | 9 |
| -27096 | 12 | -48780 | 12 | -60420 | 2 | -73284 | 3 | -85932 | 10 | -252624 | 8 |
| -27192 | 12 | -50520 | 12 | -60588 | 1 | -73644 | 3 | -85992 | 10 | -252696 | 8 |
| -27696 | 9 | -50616 | 12 | -60756 | 1 | -75912 | 9 | -91596 | 13 | -252972 | 7 |
| -27888 | 8 | -51444 | 12 | -61584 | 11 | -76104 | 8 | -91716 | 13 | -253044 | 7 |
| -27960 | 8 | -51540 | 12 | -61764 | 10 | -76176 | 8 | -95220 | 6 | -261276 | 2 |
| -28236 | 7 | -52248 | 14 | -61824 | 10 | -76452 | 7 | -95388 | 5 | -261444 | 1 |
| -28308 | 7 | -52416 | 14 | -63888 | 6 | -76524 | 7 | -95652 | 5 | -261612 | 1 |
| -28896 | 6 | -53988 | 12 | -64056 | 5 | -79344 | 6 | -98028 | 4 | -266820 | 14 |
| -29064 | 5 | -54084 | 12 | -64320 | 5 | -79512 | 5 | -98196 | 3 | -266988 | 14 |
| -29328 | 5 | -55884 | 13 | -66372 | 2 | -79776 | 5 | -98556 | 3 | -278844 | 2 |
| -30132 | 6 | -56004 | 13 | -66540 | 1 | -81156 | 9 | -102936 | 4 | -279012 | 1 |
| -30300 | 5 | -56856 | 12 | -66708 | 1 | -81348 | 8 | -103104 | 3 | -279180 | 1 |
| -30564 | 5 | -56952 | 12 | -68292 | 9 | -81420 | 8 | -103464 | 3 | -291204 | 12 |
| -30804 | 2 | -59124 | 9 | -68484 | 8 | -81696 | 7 | -109104 | 11 | -291300 | 12 |
| -30972 | 1 | -59316 | 8 | -68556 | 8 | -81768 | 7 | -109284 | 10 | -305184 | 6 |
| -31140 | 1 | -59388 | 8 | -68832 | 7 | -85044 | 9 | -109344 | 10 | -305352 | 5 |
| -31776 | 2 | -59664 | 7 | -68904 | 7 | -85236 | 8 | -112152 | 14 | -305616 | 5 |
| -31944 | 1 | -59736 | 7 | -70512 | 9 | -85308 | 8 | -112320 | 14 | -319728 | 2 |
| -32112 | 1 | -60216 | 11 | -70704 | 8 | -85584 | 7 | -116232 | 6 | -319896 | 1 |
| -32712 | 6 | -60396 | 10 | -70776 | 8 | -85656 | 7 | -116400 | 5 | -320064 | 1 |
| -32880 | 5 | -60456 | 10 | -71052 | 7 | -88620 | 11 | -116664 | 5 | -336072 | 6 |
| -33144 | 5 |  |  | -71124 | 7 | -88800 | 10 | -121332 | 11 | -336240 | 5 |
| -34056 | 6 |  |  | -72708 | 14 | -88860 | 10 | -121512 | 10 | -336504 | 5 |
| -34224 | 5 |  |  | -72876 | 14 | -90132 | 9 | -121572 | 10 | -348972 | 6 |
| -34488 | 5 |  |  | -74076 | 6 | -90324 | 8 | -125028 | 12 | -349140 | 5 |
| -35616 | 6 |  |  | -74244 | 5 | -90396 | 8 | -125124 | 12 | -349404 | 5 |
| -35784 | 5 |  |  | -74508 | 5 | -90672 | 7 | -130368 | 13 | -352764 | 11 |
| -36048 | 5 |  |  | -77904 | 6 | -90744 | 7 | -130488 | 13 | -352944 | 10 |
| -36288 | 11 |  |  | -78072 | 5 | -94620 | 12 | -135372 | 2 | -353004 | 10 |
| -36468 | 10 |  |  | -78336 | 5 | -94716 | 12 | -135540 | 1 |  |  |
| -36528 | 10 |  |  | -79056 | 11 | -98316 | 11 | -135708 | 1 |  |  |
|  |  |  |  | -79236 | 10 | -98496 | 10 | -137640 | 11 |  |  |
|  |  |  |  | -79296 | 10 | -98556 | 10 | -137820 | 10 |  |  |
|  |  |  |  |  |  | -103164 | 11 | -137880 | 10 |  |  |
|  |  |  |  |  |  | -103344 | 10 | -139080 | 11 |  |  |
|  |  |  |  |  |  | -103404 | 10 | -139260 | 10 |  |  |
|  |  |  |  |  |  | -104364 | 11 | -139320 | 10 |  |  |
|  |  |  |  |  |  | -104544 | 10 |  |  |  |  |
|  |  |  |  |  |  | -104604 | 10 |  |  |  |  |

Table A : Simulation Decisions

|  |  |  |
| --- | --- | --- |
| Decision | Selection | Units |
| Number of modes to solve for/include | 15 |  |
| Incremental distance along load-path | 6 | inches |
| Time integration scheme | Hilber Hughes Taylor (HHT) |  |
| Profile interpolation method | Linear |  |
| Structural damping | 1% |  |
| Traffic speed | 960, 5 | in/sec |
| Solution time-step | 0.0015, 0.5 | sec |