# Appendix

## Testing Equipment

### Accelerometer

Table 6: 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 7: 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 |

## Case Study: Phase 1 Testing

### Longitudinal Acceleration Time History

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

### Vertical Acceleration Time History

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

## Phase 2 Testing

### Mode shapes

## FE Model Creation

### 3D Element-based model

This model type employs

### Plate Eccentric-Beam (PEB) model

## FE Model Validation

### Phase 2

|  |  |
| --- | --- |
|  |  |
|  |  |
|  |  |
|  |  |

### Phase 3

|  |  |
| --- | --- |
| FE Modes | Experimental Modes |
| 2.03 Hz | 2.0 Hz |
| 2.07 Hz | 2.1 Hz |
| 2.49 Hz | 2.44 Hz |
| 2.50 Hz | 2.54 Hz |
| 2.82 Hz | 2.83 Hz |
| 3.14 Hz | 3.2 Hz |
| 3.63 Hz | 3.56 Hz |
| 3.63 Hz | 3.56 Hz |

## VBI Modeling Validation

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | 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% |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | 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





Figure 12: Experiment vs Simulation for Span 2 Midspan Acceleration of Girder 8 (Filtered and Decimated)



Figure 13: Experiment vs Simulation for Span 2 Midspan Acceleration of Girder 8 (Dynamic Time Warped)



Figure 14: Experiment vs Simulation for Span 3 Midspan Acceleration of Girder 8 (Filtered and Decimated)



Figure 15: Experiment vs Simulation for Span 3 Midspan Acceleration of Girder 8 (Dynamic Time Warped)



Figure 16: Experiment vs Simulation for Span 7 Midspan Acceleration of Girder 8 (Filtered and Decimated)



Figure 17: Experiment vs Simulation for Span 7 Midspan Acceleration of Girder 8 (Dynamic Time Warped)

### Run 3













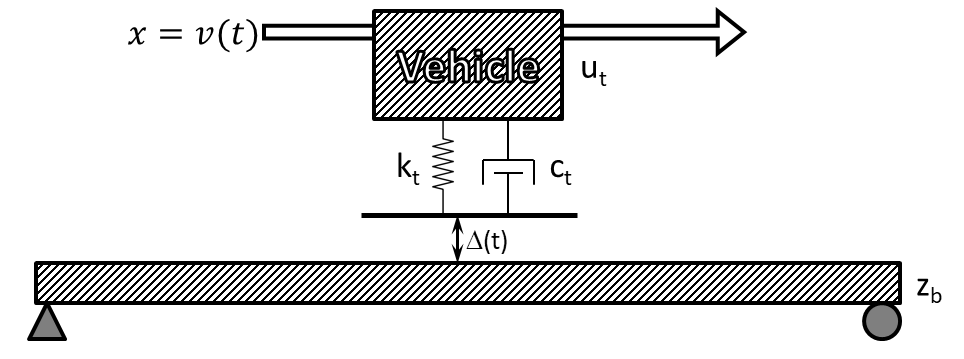






## Decoupled State Space Model

This state-space model is developed from the equations of motion for a single sprung mass traveling over a simple-supported beam with distributed mass and stiffness. The beam is reduced to a single degree-of-freedom by generalizing its displacement according to a shape function. A sinusoidal shape function was chosen to capture the excitement of the beam’s first mode of vibration (1st bending). The beam has a uniform stiffness parameter (EI), uniform mass distribution (), and a span length of *L*. Mass proportional damping of the beam is included. The vehicle is reduced to a single point mass (*mt*) with specified spring stiffness (kt), viscous damping coefficient (ct), and traveling at a specified velocity (*v*). The contact force is solved without consideration of beam displacement.



### Assumed deformation shape function

The beam is assumed to deform with a half sine function (i.e. wavelength is twice the length of the span). That function is described by the following equation.

for

Therefore, the deflection (ub) and velocity (u̇b) of the beam at the vehicle’s location at time (*t*) is related to the generalized coordinate (*zb*) by the following equations.

### Generalized mass, stiffness and damping

The generalized mass () and stiffness () properties for the beam can be calculated as follows.

The generalized damping property () is defined by the following equation for mass proportional damping.

Where *a* is the mass-proportional damping coefficient. The damping ratio is defined by the following equation.

Where *ωn* is the radial natural frequency of the beam (first mode). Thus, the damping coefficient (*a*) may be determined based on a specified damping ratio () using the following equation.

By substitution, the generalized damping property may be expressed as follows.

### Force transformation

The force applied by the vehicle mass (*p0*) must also be generalized. The force is described as a function of time and position as follows:

Where is the Dirac delta function centered at , and . The generalized force () is therefore calculated as follows for .

The force (*p0*) applied by the vehicle is calculated based on the vertical motion of the vehicle, including profile elevation, as shown below.

Where *ut* is the vertical position of the vehicle and *Δ* is the profile elevation at the vehicle location. Single dot notation indicates the first derivative and therefore *u̇t* is the vertical velocity of the vehicle and *Δ̇* is the rate of change in profile elevation.

### Equations of motion when the vehicle is on the bridge

The equations of motion of the generalized beam and moving vehicle may therefore be composed as follows for .

Vehicle DOF:

Beam DOF:

Double-dot notation is used in the preceding equations to indicate the second derivative and therefore *üt* is the vertical acceleration of the vehicle and *z̈b* is the acceleration of the generalized bridge coordinate (*zb*).

### State Space

The states of this system (*z1, z2, z3* & *z4*) may therefore be defined as follows:

; ; ;

The profile elevation and velocity are assigned to matrix *U* with elements (*u1* & *u2*):

;

The equations of motion are reorganized in terms of the defined states as follows.

;

When the vehicle is off the bridge, the bridge experiences free vibration and the vehicle’s motion is independent of the bridge motion. The state-space matrices for this condition are provided as follows.

## 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.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 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 8: 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 18: Comparison of midspan displacement

Figure 19: Comparison of force at vehicle contact point

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

Figure 20: Comparison of midspan (span 1) displacement

Figure 21: Comparison of force at vehicle contact point

## Construction of Artificial Profiles

## Simulation of VBI with Traffic

Table 9: Vehicles and their corresponding sprung-mass properties

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Vehicle # | Axle # | Name | Distance from rear axle (ft) | Weight (kip) | Mass (slinch) | Spring Stiffness (kip/in) | Damping Coefficient (lb-s/in) | Damping Ratio | Natural Frequency |
| 1 | 1 | HS20-32\_1 | 0 | 32 | 82.882 | 20 | 257.529 | 0.1 | 2.472 |
| 1 | HS20-32\_1 | 14 | 32 | 82.882 | 20 | 257.529 | 0.1 | 2.472 |
| 2 | HS20-8\_1 | 28 | 8 | 20.721 | 15 | 111.513 | 0.1 | 4.282 |
| 2 | 3 | HS20-32\_2 | 0 | 32 | 82.882 | 16 | 460.682 | 0.2 | 2.211 |
| 3 | HS20-32\_2 | 30 | 32 | 82.882 | 16 | 460.682 | 0.2 | 2.211 |
| 4 | HS20-8\_2 | 44 | 8 | 20.721 | 8 | 407.189 | 0.5 | 3.127 |
| 3 | 5 | HS20-32\_3 | 0 | 32 | 82.882 | 13 | 415.253 | 0.2 | 1.993 |
| 5 | HS20-32\_3 | 22 | 32 | 82.882 | 13 | 415.253 | 0.2 | 1.993 |
| 6 | HS20-8\_3 | 36 | 8 | 20.721 | 10 | 455.251 | 0.5 | 3.496 |
| 4 | 7 | tst-tand | 0 | 17 | 44.031 | 15 | 162.557 | 0.1 | 2.937 |
| 7 | tst-tand | 6 | 17 | 44.031 | 15 | 162.557 | 0.1 | 2.937 |
| 8 | tst-drive | 29 | 17 | 44.031 | 15 | 162.557 | 0.1 | 2.937 |
| 8 | tst-drive | 35 | 17 | 44.031 | 15 | 162.557 | 0.1 | 2.937 |
| 9 | tst-front | 51 | 12 | 31.081 | 2.2 | 261.522 | 0.5 | 1.339 |
| 5 | 10 | dump-rear | 0 | 25 | 64.752 | 12 | 176.318 | 0.1 | 2.166 |
| 10 | dump-rear | 5 | 25 | 64.752 | 12 | 176.318 | 0.1 | 2.166 |
| 11 | dump-front | 20 | 20 | 51.801 | 12 | 315.407 | 0.2 | 2.422 |
| 6 | 12 | car1 | 0 | 1.5 | 3.885 | 0.2 | 27.878 | 0.5 | 1.142 |
| 12 | car1 | 8 | 1.5 | 3.885 | 0.2 | 27.878 | 0.5 | 1.142 |
| 7 | 13 | car2 | 0 | 2 | 5.180 | 0.4 | 45.525 | 0.5 | 1.398 |
| 13 | car2 | 10 | 2 | 5.180 | 0.4 | 45.525 | 0.5 | 1.398 |
| 8 | 14 | car3 | 0 | 3 | 7.770 | 2 | 124.676 | 0.5 | 2.553 |
| 14 | car3 | 14 | 3 | 7.770 | 2 | 124.676 | 0.5 | 2.553 |

Table 10: Traffic Pattern Parameters

|  |  |  |  |
| --- | --- | --- | --- |
|  | Num. of Vehicles | Min. Spacing (ft.) | Max. Spacing (ft.) |
| 1 | 36 | 20 | 100 |
| 2 | 36 | 40 | 200 |
| 3 | 36 | 60 | 300 |
| 4 | 36 | 80 | 400 |
| 5 | 36 | 100 | 500 |
| 6 | 36 | 280 | 1400 |

Table 11: Spring-mass configuration 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 12: 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 |