TECHNICAL NOTE

The Accuracy of Subtraction Method Examined in MTR/SASSI (Part 3)
June 20, 2011
MTR & Associates

The purpose of this problem is to verify the accuracy of the Direct, Subtraction and Modified Subtraction Models using MTR/**SASSI** [1] to calculate the seismic SSI response of NPP structures. A simplified model of a typical nuclear structure configuration is used to obtain and compare the following response quantities from the three models.

- Transfer functions
- Maximum values of acceleration responses
- In-structure response spectra
- Maximum dynamic soil pressures on walls

Problem Description

The problem consists of a concrete shear-box structure. A one-half cutaway view of the structure is shown in Figure 1. The structure is 100 × 180 ft in plan dimensions, with a vertical height of 100 ft and an embedment of 25 ft below the ground surface. The structure is subjected to vertically propagating P-, SV- and SH-waves with the control motion specified at the free-field ground surface. The control motion consists of three orthogonal components, specified in terms of acceleration time histories in the global x-, y- and z-directions. The x- and z-components are associated with the SV- and P-waves, and the y-component is associated with the SH-wave propagation. Two analysis cases are considered: one corresponding to a generic soil site with standard input motion (WUS type motion), and another corresponding to a generic rock site with high frequency motion (CEUS type motion).

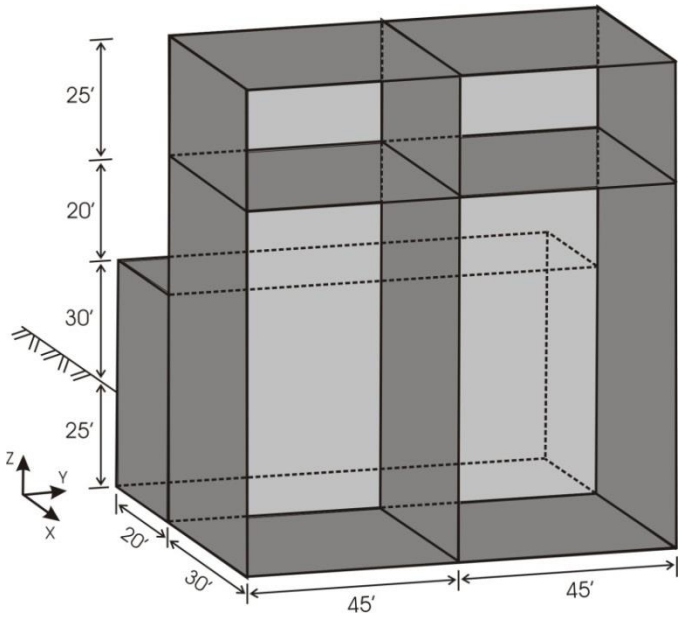


Figure 1: One-Half Cutaway View of Concrete Shear-Box Structure

The soil and structural properties are listed below.

Soil Case 1 (WUS Site):

Uniform semi-infinite halfspace

$\gamma = 0.120$ kip/ft^3
$V_s = 825$ ft/sec
$V_p = 2{,}021$ ft/sec
$\beta_s = 0.03$
$\beta_p = 0.01$

Soil Case 2 (CEUS Site):

Uniform top soil layer (25-ft thick)

$\gamma = 0.120$ kip/ft^3
$V_s = 1{,}250$ ft/sec
$V_p = 3{,}061$ ft/sec
$\beta_s = 0.03$
$\beta_p = 0.01$

Underlying uniform semi-infinite halfspace

$\gamma = 0.150$ kip/ft^3
$V_s = 10{,}000$ ft/sec
$V_p = 20{,}000$ ft/sec
$\beta_s = 0.005$
$\beta_p = 0.005$

Structure:

Concrete members

$\gamma = 0.210$ kip/ft^3
$E = 800{,}000$ kips/ft^2
$\nu = 0.17$
$\beta = 0.04$

The basemat is 6 ft thick; the exterior walls are 2 ft thick; and the wall partition, floor, and roof slabs are 1.4 ft thick.

Input Motions

Acceleration time histories of input motion in the x-, y- and z-directions for the standard soil site are shown in Figure 2, and their 5%-damped acceleration response spectra are shown in Figure 3. Acceleration time histories and response spectra for the hard rock site are shown in Figure 4 and Figure 5, respectively. Both ground motions are specified as outcrop motion at the bottom of the foundation basemat (Elev. 0 .0 ft). The standard soil site spectra are similar to the US NRC Reg. Guide 1.6 spectra. The hard rock spectra are typical high-frequency hard rock motions for the Central and Eastern United States.

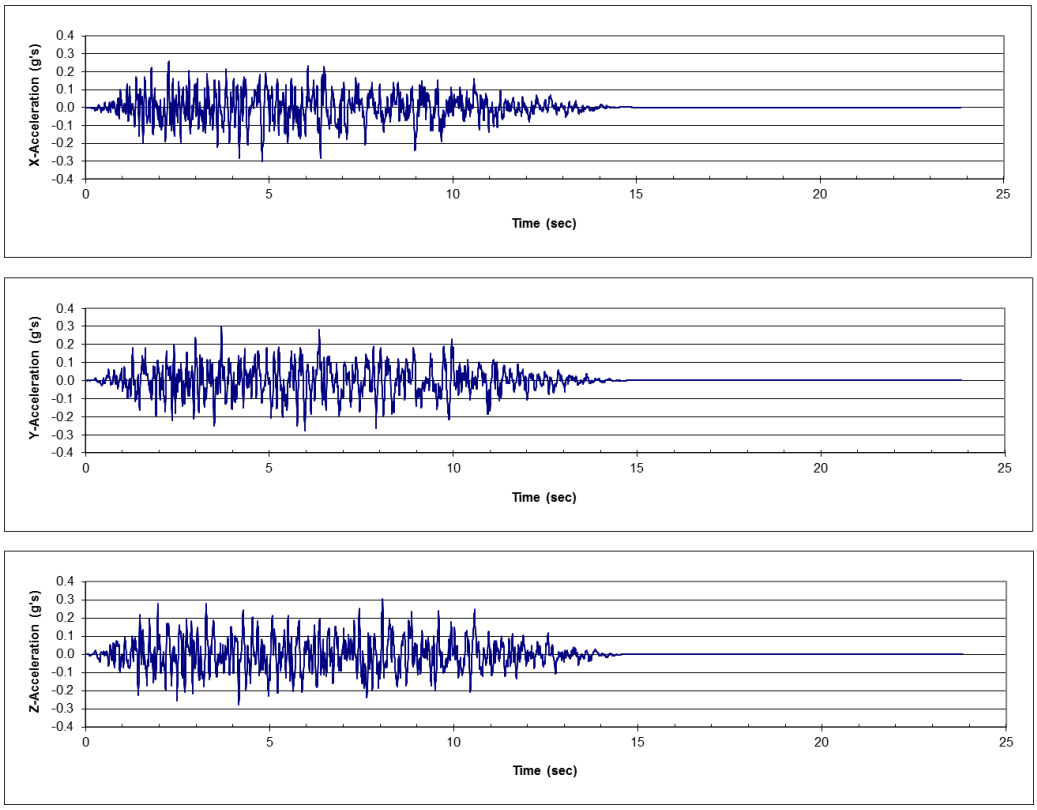


Figure 2: Acceleration Time Histories of Input Motion - Standard Soil Site

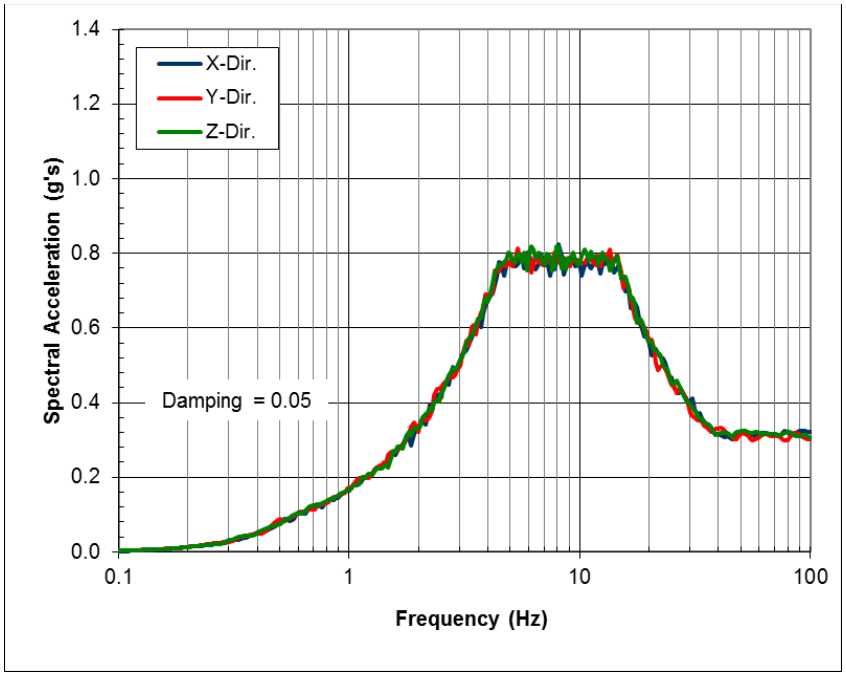


Figure 3: Acceleration Response Spectra of Input Motions - Standard Soil Site

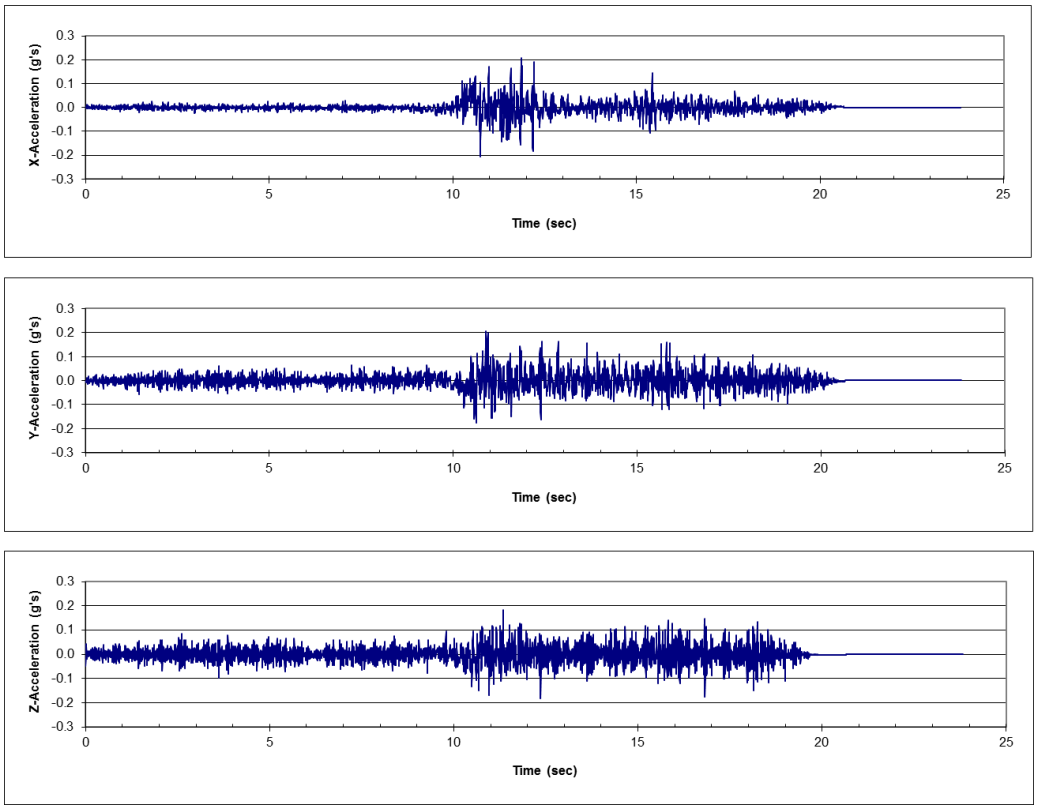


Figure 4: Acceleration Time Histories of Input Motion - Hard Rock Site

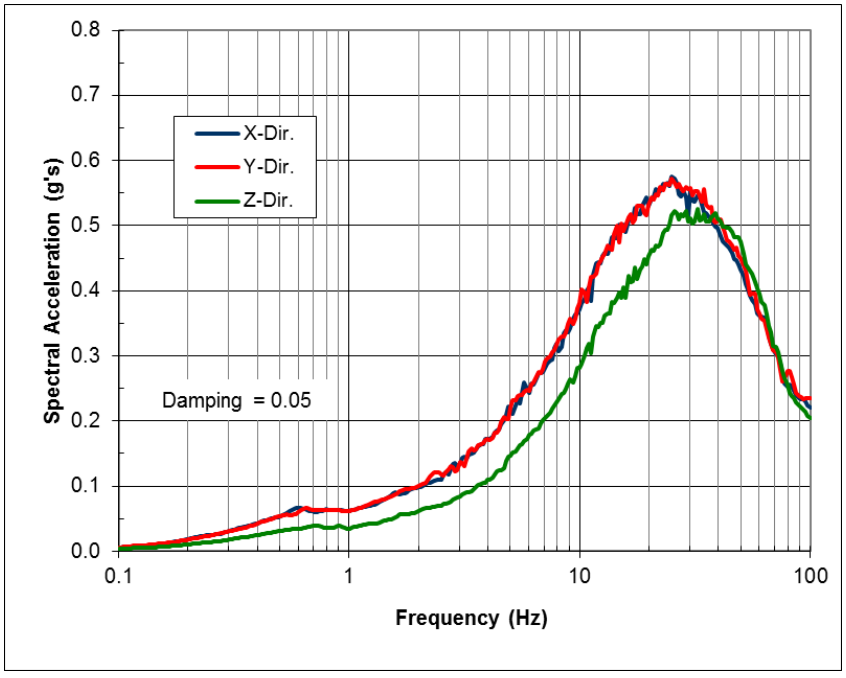


Figure 5: Acceleration Response Spectra of Input Motions - Hard Rock Site

MTR/SASSI Model

The finite element SASSI model of the structure is shown in Figure 6 and Figure 7. The structure is modeled by 4-node plate/shell elements representing the basemat, walls, partition, floor and roofs. The excavated soil model consists of 8-node solid elements, as shown in Figure 8. All elements have a uniform dimension equal to 5 ft.

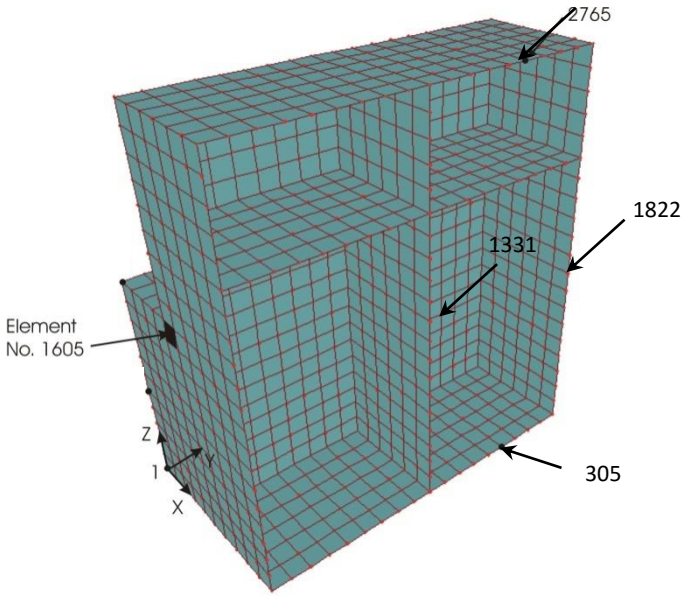


Figure 6: MTR/SASSI Finite Element Model - One-Half Cutaway View

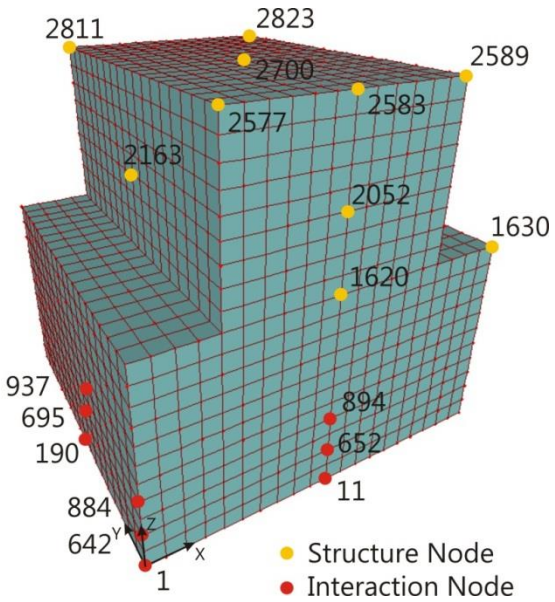


Figure 7: MTR/SASSI Finite Element Model - Structure

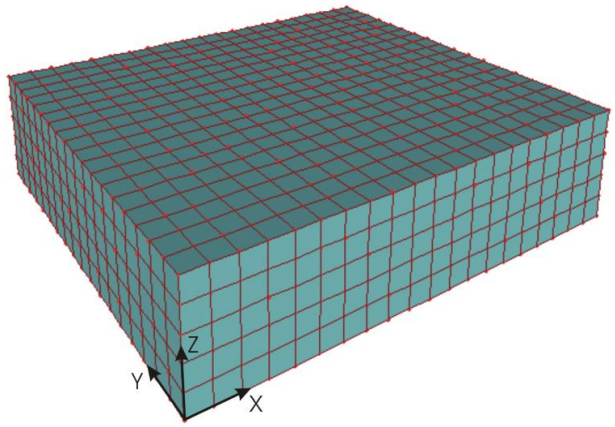


Figure 8: MTR/SASSI Finite Element Model - Excavated Soil

The problem is analyzed using the Direct, Subtraction and Modified Subtraction Models, as described below.

Direct Model: In this model, the interaction nodes include all of the excavated soil nodes. This model has 2394 interaction nodes.

Subtraction Model: In this model, the interaction node set corresponds to the nodes located on the sides and bottom surfaces of the excavated soil model. This model has 779 interaction nodes.

Modified Subtraction Model: In this model, the interaction node set corresponds to the nodes on the sides, bottom and top surfaces of the excavated soil model. This model has 1102 interaction nodes.

The passing frequency of the model ($f_{pass} = V_s/5h$, where h is the largest soil element size and V_s is the minimum shear wave velocity of the soil medium) is 825/5/5 = 33 Hz and 125/5/5 = 50 Hz for the standard and hard rock site models, respectively. The analysis is performed to a maximum frequency cut-off of f_{max} = 33.7 Hz and 50.3 Hz for the standard soil and hard rock site cases, respectively. The passing frequencies satisfy the maximum frequency of analysis, as required by the US NRC.

Analysis Results

The analysis results for the standard soil and hard rock sites obtained via the Direct, Subtraction and Modified Subtraction Models are discussed below.

Standard Soil Site

Transfer Function Responses

The computed transfer functions at Node 305 in the x-, y- and z-directions using the Direct, Subtraction and Modified Subtraction Models are compared in Figure 9 for the x-input, in Figure 10 for the y-input, and in Figure 11 for the z-input. Similar results for nodes 1331, 1822 and 2765 are shown in Figure 12 though Figure 14, Figure 15 through Figure 17, and Figure 18 through Figure 20, respectively. For the location of the output nodes, refer to Figure 6.

As the above figures show, the transfer functions for the Direct and Modified Subtraction Models are smooth and in excellent agreement for the entire frequency range. The transfer functions for the Subtraction Model begin to deviate from the Direct Model's solutions at a frequency of about 10-15 Hz, as well as exhibiting numerous peaks and valleys.

Maximum Acceleration Values

The values of maximum accelerations calculated at several nodes in the structure from the Direct, Subtraction and Modified Subtraction Models are compared in Table 1. The ratio of maximum accelerations is compared in Table 2. For the location of the output nodes, refer to Figure 7. As shown in Table 2, the results of the Modified Subtraction Model are within 1% of the Direct Model's results, while those of the Subtraction Model can vary from 88-127%.

In-Structure Response Spectra

The 5%-damped acceleration response spectra calculated from the Direct, Subtraction and Modified Subtraction Models are compared in Figure 21 through Figure 24 for nodes 305, 1331, 1822 and 2765, respectively. For the location of the output nodes, refer to Figure 7**Error! Reference source not found.**. The spectra are calculated from the input motions applied in three directions. The results show good agreement between the Direct and Modified Subtraction Models. But again, the results of the Subtraction Model deviate from those of the Direct Model at frequencies above 10 Hz. This is consistent with the results of the transfer functions discussed above. The results indicate that the calculated spectra from the Subtraction Model can be lower than those of the other two models at certain frequency ranges (e.g. see Figure 23).

Maximum Value of Dynamic Soil Reaction Forces

The maximum dynamic soil pressures at several locations on the basemat and wall slabs, calculated from the Direct, Subtraction and Modified Subtraction Models, are compared in Table 3. The ratio of computed pressures is compared in Table 4. If the relatively small pressures calculated at a few nodes (652, 695, 894 and 937) are excluded, the results of both the Subtraction and Modified Subtraction Models are within 3-4% of the Direct Model's results.

Hard Rock Site

Transfer Function Responses

The computed transfer functions in the x-, y- and z-directions, calculated from the Direct, Subtraction and Modified Subtraction Models, are compared in Figure 25 through Figure 36 for the x-, y- and z-inputs for nodes 305, 1331, 1822 and 2765. As these figures show, the transfer functions for the Direct and Modified Subtraction Models are smooth for the entire frequency range, showing excellent agreement for frequencies below 40 Hz and reasonably good agreement for frequencies between 40 and 50 Hz. But the transfer functions for the Subtraction Model begin to deviate from the Direct Model's solutions at a frequency of about 15-20 Hz, exhibiting numerous peaks and valleys, particularly at higher frequencies. In general, these results are consistent with those of the standard soil site.

Maximum Acceleration Values

The values of maximum accelerations calculated at several nodes in the structure from the Direct, Subtraction and Modified Subtraction Models are compared in Table 5. The ratio of maximum accelerations is compared in Table 6. For the location of the output nodes, refer to Figure 7. As shown in Table 2, the results of the Modified Subtraction Model are within 3% of the Direct Model's results, while those of the Subtraction Model can vary from 87-135%. These results are consistent with those of the standard soil site.

In-Structure Response Spectra

The 5%-damped acceleration response spectra calculated from the Direct, Subtraction and Modified Subtraction Models are compared in Figure 37 through Figure 40 for nodes 305, 1331, 1822 and 2765, respectively. For the location of the output nodes, refer to Figure 7. The spectra are calculated from input motions applied in three directions, the results of which show excellent agreement between the Direct and Modified Subtraction models. But again, the results of the Subtraction Model begin to deviate from those of the Direct Model at frequencies around 20 Hz. This is consistent with the results of the transfer functions discussed above, which indicate that the calculated spectra from the Subtraction Model, in general, are higher than those of the other two models at frequencies above 20 Hz, and in some cases by a significant margin (e.g. see the x-response in Figure 38).

Maximum Value of Dynamic Soil Reaction Forces

The maximum dynamic soil pressures at several locations on the basemat and wall slabs, calculated from the Direct, Subtraction and Modified Subtraction Models, are compared in Table 7. The ratio of computed pressures is compared in Table 4. If the relatively small pressures computed at a few nodes (652, 695, 894 and 937) are excluded, the results of both the Subtraction and Modified Subtraction Models are within 10% of the Direct Model's results.

Conclusions

The results of this test problem show that the transfer function responses calculated using the Modified Subtraction Model are in close agreement with those of the Direct Model for both the standard soil and hard rock sites. The calculated transfer functions are smooth and free of erroneous peaks and valleys. This, in turn, results in the final calculated response quantities that, between the two models, are closely aligned for both the standard and high frequency input motions. On the other hand, the transfer functions calculated with the Subtraction Model are jagged -- above 10-15 Hz for the standard soil site and 15-20 Hz for the hard rock site -- and exhibit numerous erroneous peaks and valleys, which cause the final response quantities (such as maximum accelerations and acceleration response spectra) to deviate from those obtained using the Direct or Modified Subtraction Models. The calculated maximum accelerations at several selected nodes in the structure obtained with the Subtraction Model varied from those of the Direct Model by about 88-127% for the standard soil site and 87-135% for the hard rock site. In terms of the calculated 5%-damped in-structure response spectra, significant differences between the Subtraction and Direct Models are observed for high frequencies.

References

1. **MTR/SASSI**, “System for Analysis of Soil-Structure Interaction,” Version 9.2, MTR & Associates, Inc., Lafayette, California, May, 2011.

Table 1: Comparison of Maximum Acceleration Responses - Standard Soil Site

Node No.	Maximum Accelerations (g's)								
	Direct			Subtraction			Modified Subtraction		
	X-Dir.	Y-Dir.	Z-Dir.	X-Dir.	Y-Dir.	Z-Dir.	X-Dir.	Y-Dir.	Z-Dir.
1	0.19	0.18	0.34	0.18	0.19	0.33	0.19	0.18	0.34
11	0.19	0.19	0.31	0.19	0.21	0.32	0.19	0.19	0.31
190	0.22	0.19	0.30	0.20	0.19	0.28	0.22	0.19	0.30
305	0.20	0.20	0.25	0.18	0.19	0.23	0.20	0.20	0.25
642	0.20	0.20	0.34	0.21	0.20	0.34	0.20	0.20	0.34
652	0.19	0.25	0.33	0.19	0.31	0.32	0.19	0.25	0.33
695	0.31	0.19	0.30	0.32	0.20	0.33	0.32	0.19	0.31
884	0.21	0.20	0.35	0.21	0.20	0.34	0.21	0.20	0.35
894	0.20	0.38	0.33	0.20	0.43	0.31	0.20	0.38	0.33
937	0.39	0.20	0.31	0.44	0.20	0.31	0.39	0.20	0.31
1331	0.40	0.20	0.29	0.40	0.20	0.29	0.39	0.20	0.29
1620	0.24	0.55	0.34	0.24	0.72	0.30	0.24	0.56	0.34
1630	0.24	0.22	0.31	0.26	0.22	0.29	0.24	0.22	0.31
1822	0.24	0.64	0.31	0.24	0.81	0.30	0.24	0.65	0.30
2052	0.26	0.23	0.35	0.26	0.23	0.32	0.26	0.23	0.35
2163	0.27	0.22	0.31	0.26	0.22	0.33	0.26	0.22	0.31
2577	0.28	0.27	0.36	0.28	0.26	0.34	0.28	0.27	0.35
2583	0.28	0.28	0.35	0.28	0.28	0.33	0.28	0.28	0.35
2589	0.29	0.26	0.36	0.28	0.26	0.31	0.29	0.26	0.35
2700	0.29	0.27	0.31	0.30	0.27	0.31	0.29	0.28	0.31
2765	0.29	0.27	1.35	0.30	0.27	1.31	0.29	0.28	1.34
2811	0.28	0.26	0.33	0.28	0.27	0.31	0.28	0.26	0.33
2823	0.29	0.27	0.36	0.29	0.27	0.36	0.29	0.27	0.36

Table 2: Ratio of Maximum Acceleration Responses - Standard Soil Site

Node No.	Ratio of Maximum Accelerations (g's)					
	Subtraction / Direct			Modified Subtraction / Direct		
	X-Dir.	Y-Dir.	Z-Dir.	X-Dir.	Y-Dir.	Z-Dir.
1	0.94	1.03	0.98	1.00	1.00	1.00
11	0.99	1.06	1.02	1.00	1.00	1.00
190	0.88	1.02	0.95	1.00	1.00	1.00
305	0.90	0.96	0.91	1.00	1.00	0.98
642	1.02	1.03	0.98	0.99	1.00	1.00
652	1.01	1.27	0.97	1.00	1.01	1.00
695	1.03	1.01	1.08	1.00	1.00	1.00
884	0.98	1.01	0.98	0.99	1.00	1.00
894	1.00	1.11	0.95	1.00	1.00	1.00
937	1.12	1.01	1.02	1.00	1.00	1.00
1331	1.00	1.00	0.98	0.98	1.00	1.00
1620	1.00	1.30	0.89	1.00	1.00	1.00
1630	1.06	1.01	0.94	1.00	1.00	1.00
1822	1.00	1.26	0.98	1.00	1.01	0.99
2052	1.00	0.99	0.93	1.00	1.00	1.00
2163	0.99	0.99	1.06	1.00	1.00	0.99
2577	0.99	0.97	0.94	1.00	1.00	0.99
2583	0.99	1.01	0.93	1.00	1.00	1.00
2589	0.99	0.99	0.88	1.00	1.00	1.00
2700	1.03	0.99	0.98	1.00	1.00	0.99
2765	1.02	0.99	0.97	1.00	1.00	0.99
2811	0.98	1.01	0.94	1.00	1.00	0.99
2823	1.00	0.99	1.00	1.00	1.00	1.00

Table 3: Comparison of Maximum Dynamic Soil Pressures - Standard Soil Site

Node No.	Maximum Dynamic Soil Pressures (Kips/ft^2)								
	Direct			Subtraction			Modified Subtraction		
	X-Dir.	Y-Dir.	Z-Dir.	X-Dir.	Y-Dir.	Z-Dir.	X-Dir.	Y-Dir.	Z-Dir.
1	3.08	3.38	8.82	3.12	3.34	9.04	3.07	3.38	8.83
11	1.31	0.84	2.09	1.29	0.88	2.03	1.29	0.82	2.02
190	1.00	1.22	1.55	0.96	1.19	1.59	1.01	1.20	1.55
642	1.98	1.57	1.85	2.06	1.62	1.85	1.97	1.59	1.83
652	0.28	0.14	0.46	0.27	0.17	0.46	0.27	0.15	0.42
695	0.14	0.26	0.43	0.17	0.28	0.41	0.16	0.26	0.40
884	1.56	1.26	1.77	1.53	1.27	1.74	1.56	1.29	1.74
894	0.13	0.39	0.26	0.14	0.46	0.35	0.13	0.39	0.28
937	0.35	0.12	0.24	0.32	0.14	0.34	0.35	0.12	0.26

Table 4: Ratio of Maximum Dynamic Soil Pressures - Standard Soil Site

Node No.	Ratio of Maximum Dynamic Soil Pressures					
	Subtraction / Direct			Modified Subtraction / Direct		
	X-Dir.	Y-Dir.	Z-Dir.	X-Dir.	Y-Dir.	Z-Dir.
1	1.01	0.99	1.02	0.99	1.00	1.00
11	0.98	1.05	0.97	0.99	0.98	0.97
190	0.96	0.97	1.02	1.02	0.98	1.00
642	1.04	1.03	1.00	1.00	1.01	0.99
652	0.98	1.19	0.98	0.98	1.10	0.91
695	1.19	1.06	0.97	1.16	0.98	0.93
884	0.98	1.00	0.98	1.00	1.02	0.98
894	1.07	1.17	1.33	1.00	1.00	1.07
937	0.91	1.09	1.39	1.00	0.98	1.07

Table 5: Comparison of Maximum Acceleration Responses - Hard Rock Site

Node No.	Maximum Accelerations (g's)								
	Direct			Subtraction			Modified Subtraction		
	X-Dir.	Y-Dir.	Z-Dir.	X-Dir.	Y-Dir.	Z-Dir.	X-Dir.	Y-Dir.	Z-Dir.
1	0.19	0.21	0.16	0.19	0.21	0.16	0.19	0.21	0.16
11	0.19	0.21	0.16	0.19	0.21	0.17	0.19	0.21	0.16
190	0.20	0.21	0.16	0.19	0.21	0.16	0.19	0.21	0.16
305	0.20	0.21	0.16	0.20	0.21	0.17	0.20	0.21	0.16
642	0.18	0.20	0.25	0.19	0.19	0.25	0.18	0.21	0.25
652	0.19	0.45	0.23	0.18	0.51	0.25	0.19	0.41	0.23
695	0.46	0.18	0.29	0.57	0.17	0.25	0.44	0.18	0.29
884	0.24	0.23	0.28	0.25	0.21	0.30	0.24	0.23	0.28
894	0.22	0.92	0.28	0.21	1.11	0.30	0.22	0.93	0.28
937	0.77	0.18	0.35	0.80	0.18	0.31	0.77	0.18	0.36
1331	0.88	0.23	0.36	1.19	0.23	0.32	0.87	0.23	0.37
1620	0.31	2.04	0.38	0.31	2.25	0.41	0.31	2.05	0.38
1630	0.36	0.31	0.34	0.40	0.35	0.35	0.38	0.31	0.34
1822	0.31	1.60	0.34	0.31	1.82	0.35	0.31	1.59	0.34
2052	0.42	0.51	0.46	0.41	0.50	0.49	0.42	0.52	0.47
2163	0.49	0.49	0.47	0.48	0.49	0.48	0.50	0.49	0.47
2577	0.54	0.65	0.55	0.52	0.67	0.55	0.54	0.65	0.53
2583	0.52	0.70	0.52	0.51	0.69	0.54	0.52	0.70	0.52
2589	0.52	0.68	0.54	0.50	0.70	0.57	0.51	0.68	0.54
2700	0.56	0.71	0.59	0.55	0.71	0.60	0.56	0.71	0.60
2765	0.56	0.72	1.61	0.55	0.73	1.62	0.56	0.72	1.60
2811	0.53	0.70	0.49	0.51	0.69	0.51	0.53	0.69	0.51
2823	0.52	0.67	0.50	0.52	0.67	0.50	0.52	0.67	0.50

Table 6: Ratio of Maximum Acceleration Responses - Hard Rock Site

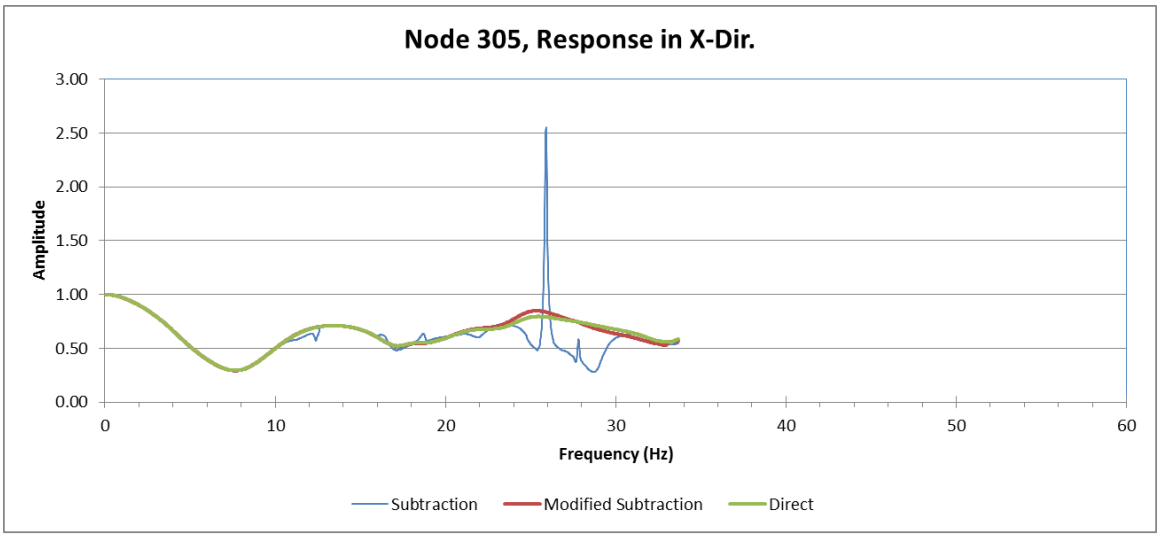
Node No.	Ratio of Maximum Accelerations (g's)					
	Subtraction / Direct			Modified Subtraction / Direct		
	X-Dir.	Y-Dir.	Z-Dir.	X-Dir.	Y-Dir.	Z-Dir.
1	1.00	1.00	1.01	1.00	1.00	1.00
11	1.00	0.99	1.05	1.00	1.00	1.00
190	1.00	1.00	1.00	1.00	1.00	1.00
305	1.00	1.00	1.04	1.00	1.00	1.00
642	1.07	0.93	0.99	1.02	1.02	1.01
652	0.99	1.14	1.08	0.99	0.92	0.98
695	1.23	0.98	0.87	0.95	1.00	1.00
884	1.03	0.92	1.09	1.00	0.99	1.02
894	0.98	1.21	1.05	1.00	1.01	0.98
937	1.04	0.98	0.89	1.00	1.01	1.01
1331	1.35	1.00	0.87	1.00	1.00	1.02
1620	1.00	1.10	1.06	1.00	1.00	1.00
1630	1.11	1.11	1.03	1.07	1.00	0.99
1822	1.00	1.14	1.05	1.00	0.99	1.00
2052	0.98	0.97	1.04	0.99	1.02	1.00
2163	0.99	0.99	1.03	1.02	1.00	1.00
2577	0.97	1.03	1.01	1.00	1.00	0.98
2583	0.97	0.99	1.05	1.00	0.99	1.00
2589	0.96	1.03	1.05	0.99	1.00	1.01
2700	0.98	0.99	1.02	1.00	1.00	1.02
2765	0.98	1.01	1.01	1.00	1.00	1.00
2811	0.97	1.00	1.04	1.00	1.00	1.03
2823	1.00	1.00	0.99	1.00	1.00	1.01

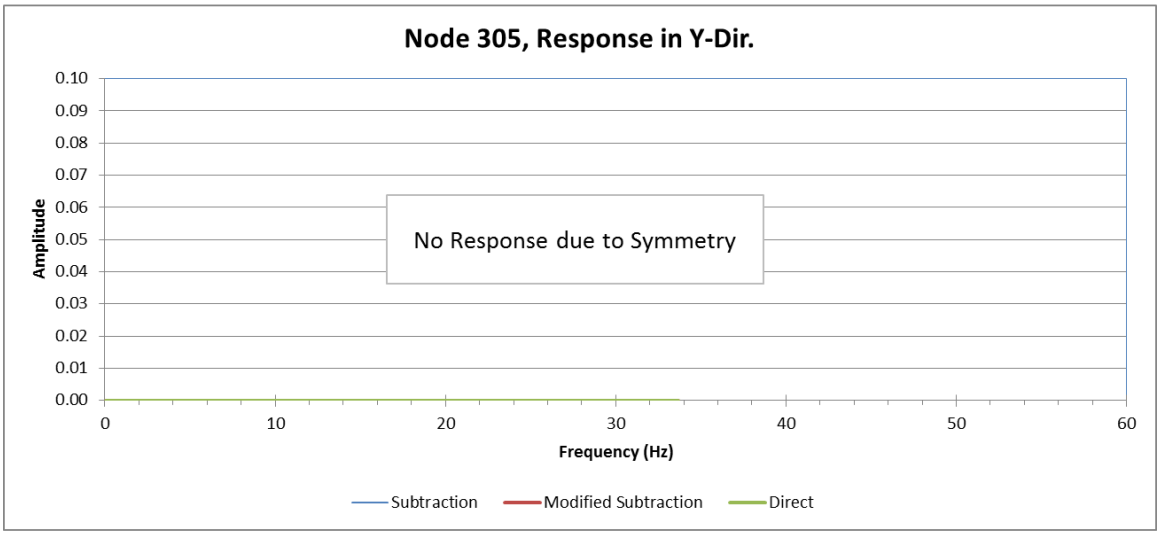
Table 7: Comparison of Maximum Dynamic Soil Pressures - Hard Rock Site

Node No.	Maximum Dynamic Soil Pressures (Kips/ft^2)								
	Direct			Subtraction			Modified Subtraction		
	X-Dir.	Y-Dir.	Z-Dir.	X-Dir.	Y-Dir.	Z-Dir.	X-Dir.	Y-Dir.	Z-Dir.
1	8.30	6.73	22.80	8.27	6.81	22.98	8.24	6.79	22.70
11	4.79	1.26	5.10	4.77	1.39	5.20	4.79	1.25	5.06
190	1.75	4.04	3.04	1.71	4.09	2.88	1.61	4.02	2.98
642	2.91	2.63	1.22	2.99	2.64	1.34	2.90	2.69	1.23
652	0.27	0.21	0.45	0.27	0.20	0.65	0.27	0.19	0.49
695	0.17	0.31	0.50	0.12	0.30	0.49	0.13	0.31	0.50
884	2.30	2.39	1.64	2.24	2.39	1.59	2.31	2.42	1.53
894	0.22	0.98	0.70	0.23	4.21	0.89	0.22	1.00	0.63
937	0.77	0.26	0.39	0.77	0.25	0.66	0.75	0.24	0.43

Table 8: Ratio of Maximum Dynamic Soil Pressures - Hard Rock Site

Node No.	Ratio of Maximum Dynamic Soil Pressures					
	Subtraction / Direct			Modified Subtraction / Direct		
	X-Dir.	Y-Dir.	Z-Dir.	X-Dir.	Y-Dir.	Z-Dir.
1	1.00	1.01	1.01	0.99	1.01	1.00
11	1.00	1.10	1.02	1.00	0.99	0.99
190	0.98	1.01	0.95	0.92	1.00	0.98
642	1.03	1.01	1.09	1.00	1.02	1.01
652	1.00	0.95	1.46	0.98	0.93	1.10
695	0.71	1.00	0.98	0.78	1.01	1.01
884	0.97	1.00	0.97	1.00	1.01	0.93
894	1.01	4.29	1.27	0.98	1.01	0.90
937	1.00	0.95	1.71	0.98	0.94	1.11





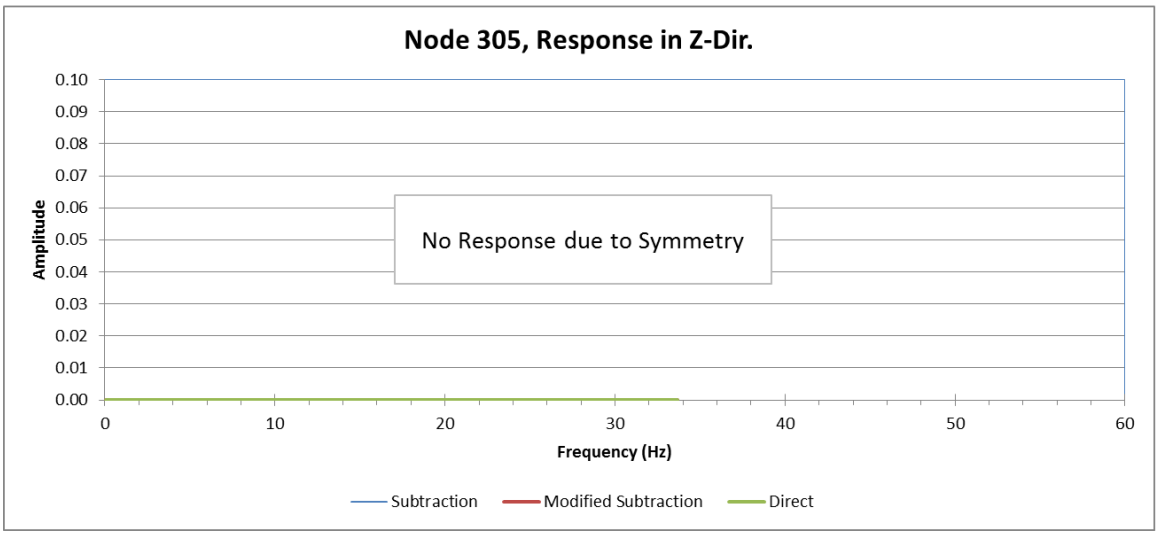
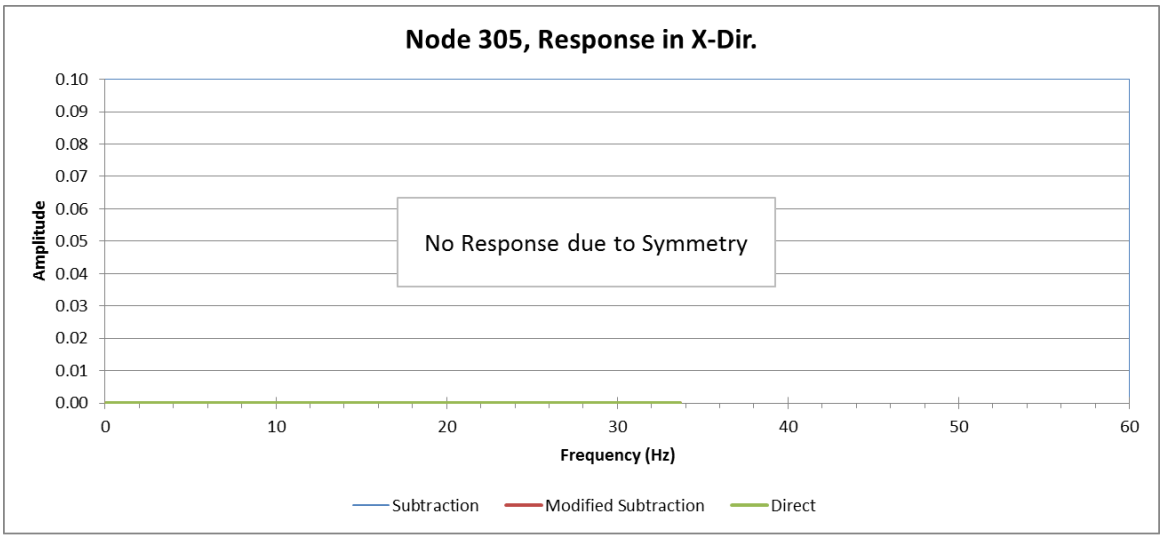
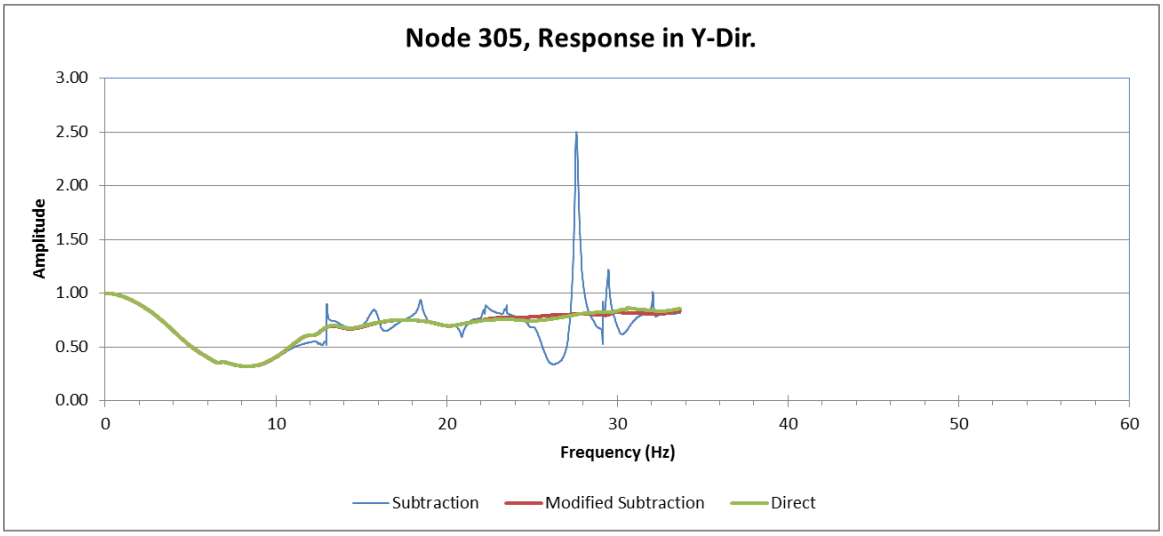


Figure 9: Comparison of Transfer Functions, Node 305, Input in X-Dir. - Standard Soil Site





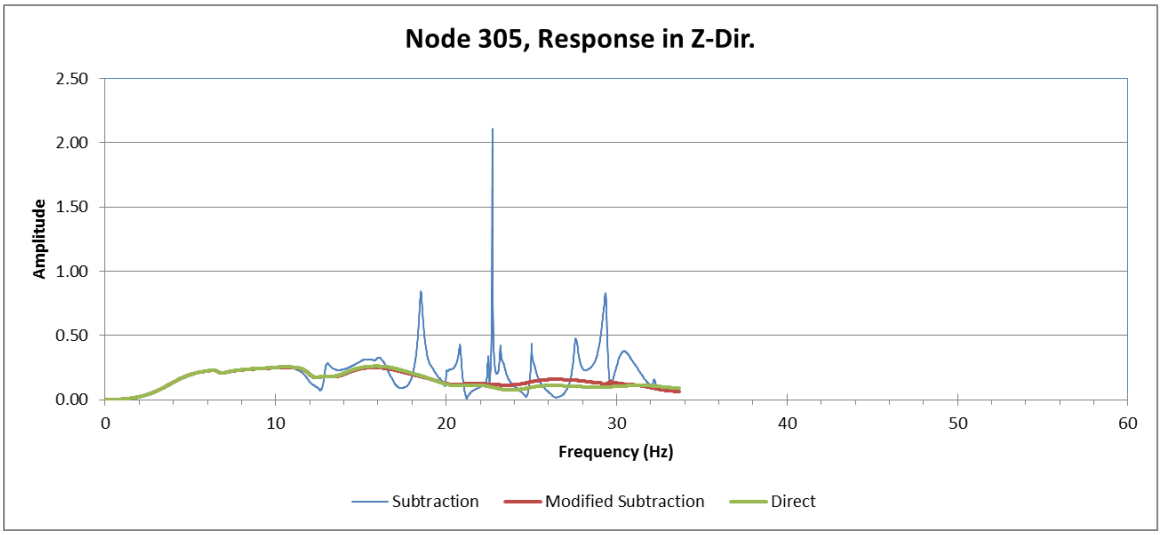
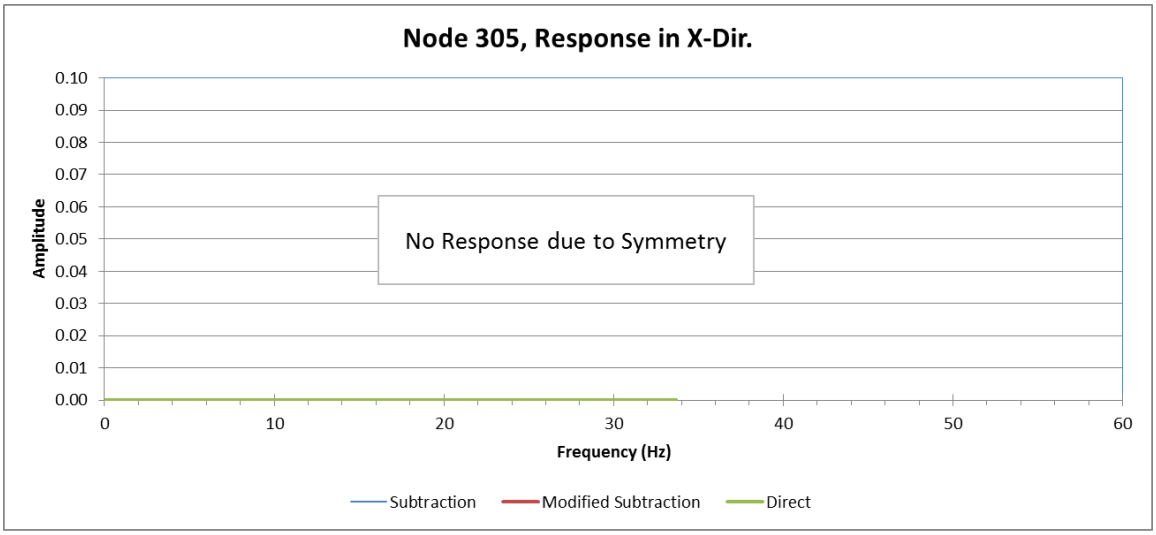
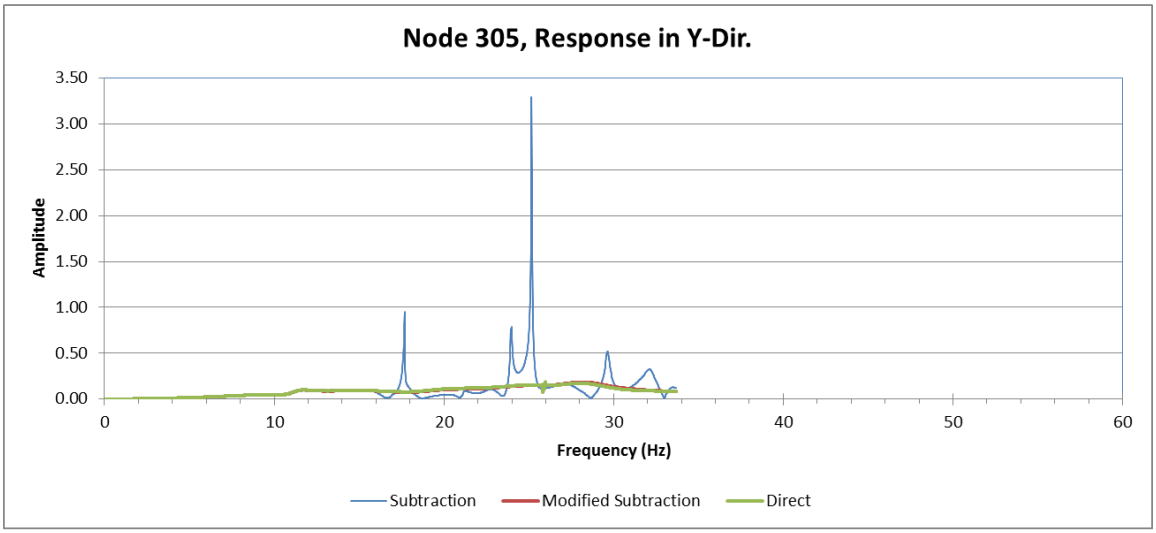


Figure 10: Comparison of Transfer Functions, Node 305, Input in Y-Dir. - Standard Soil Site





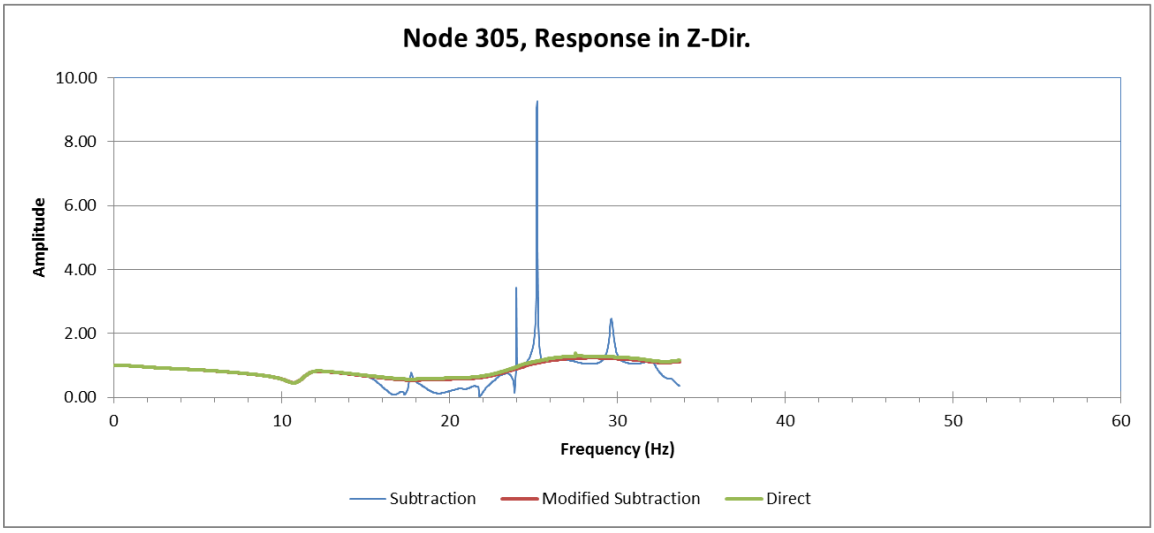
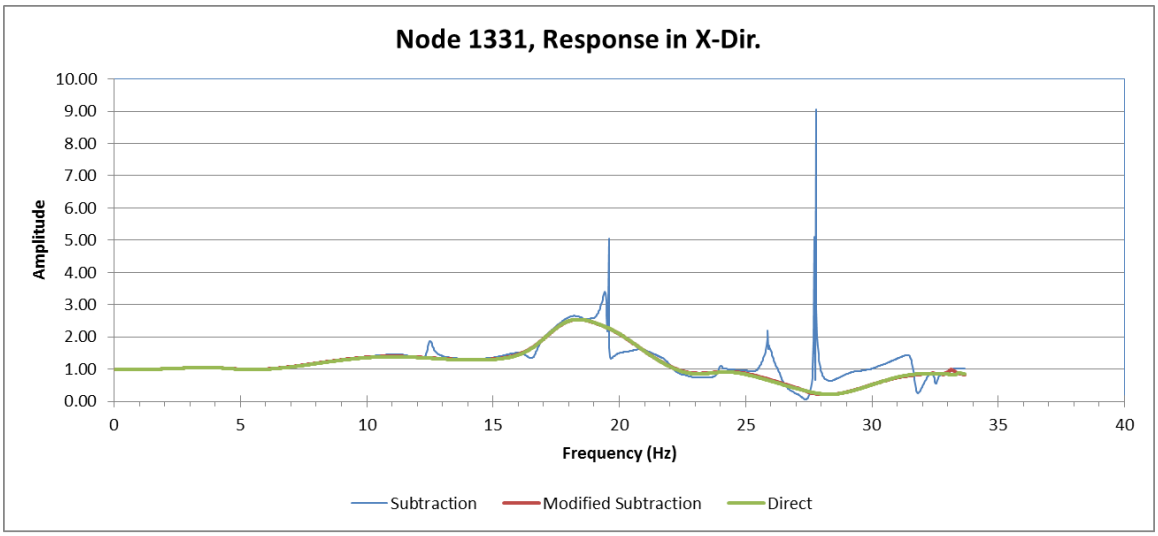
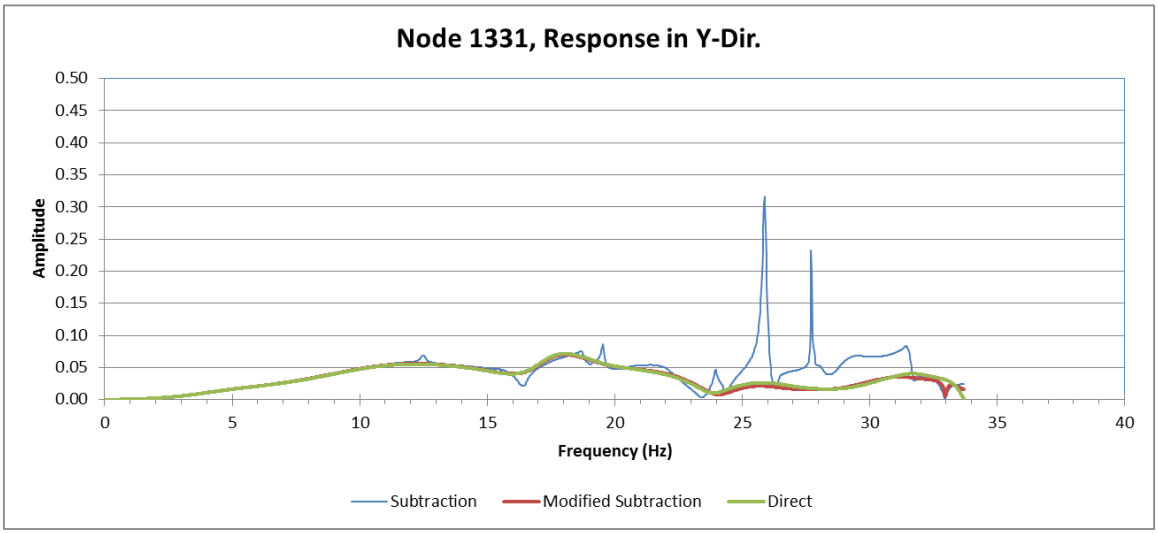


Figure 11: Comparison of Transfer Functions, Node 305, Input in Z-Dir. - Standard Soil Site





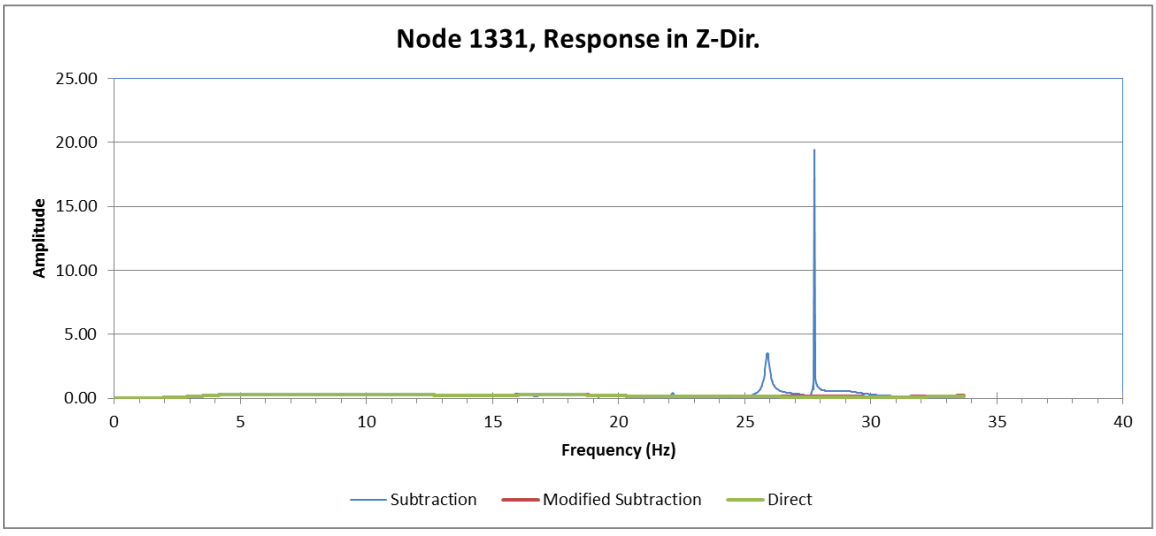
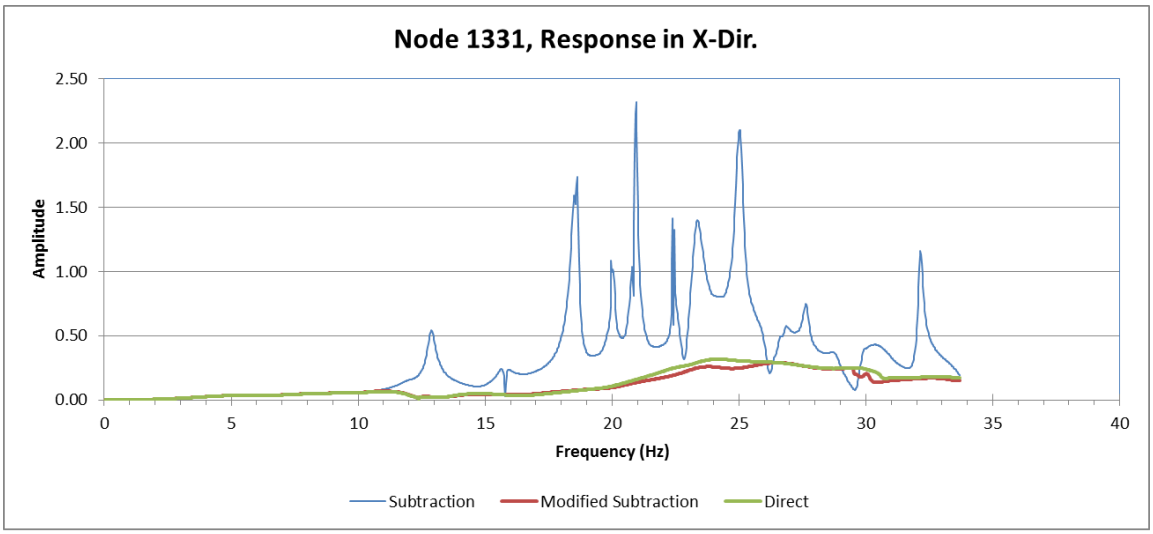
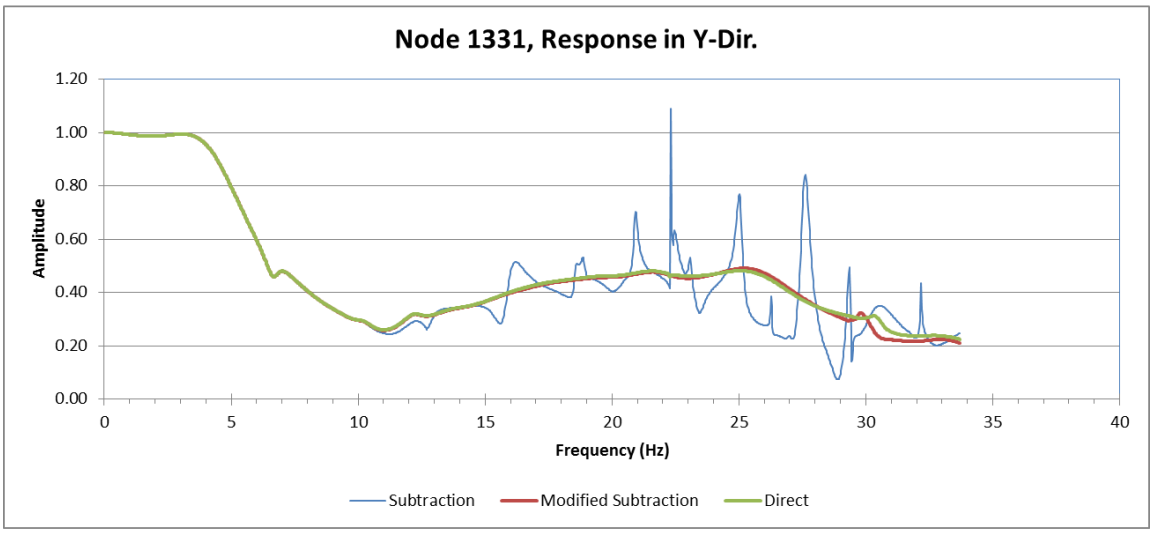


Figure 12: Comparison of Transfer Functions, Node 1331, Input in X-Dir. - Standard Soil Site





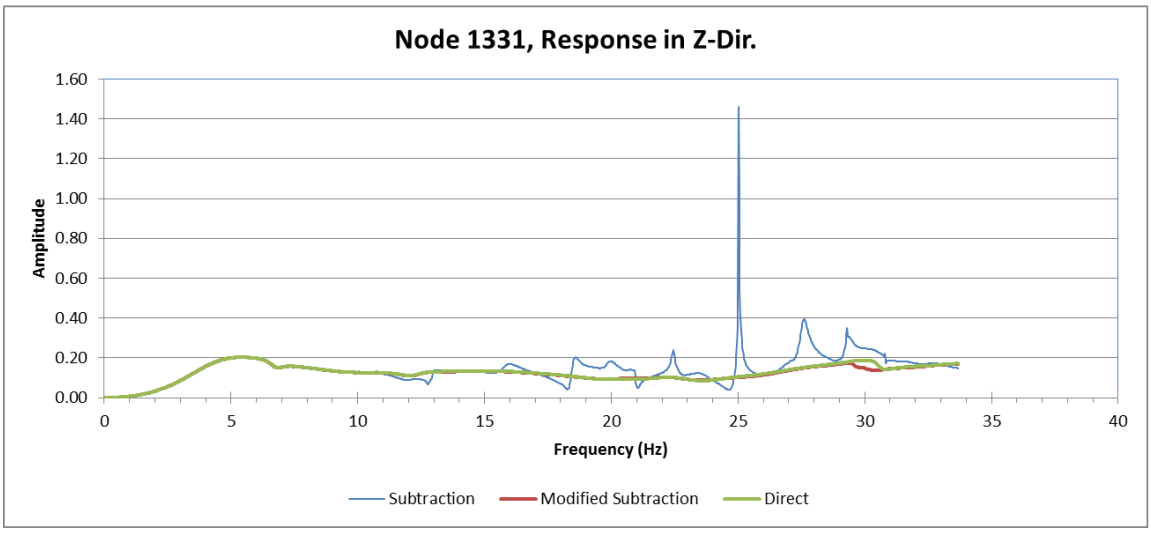
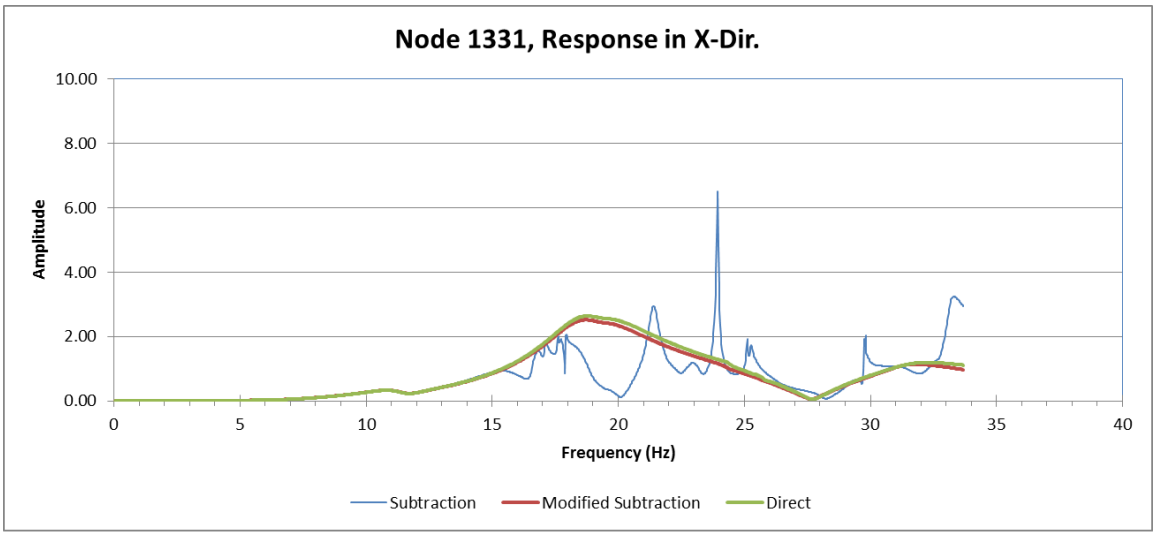
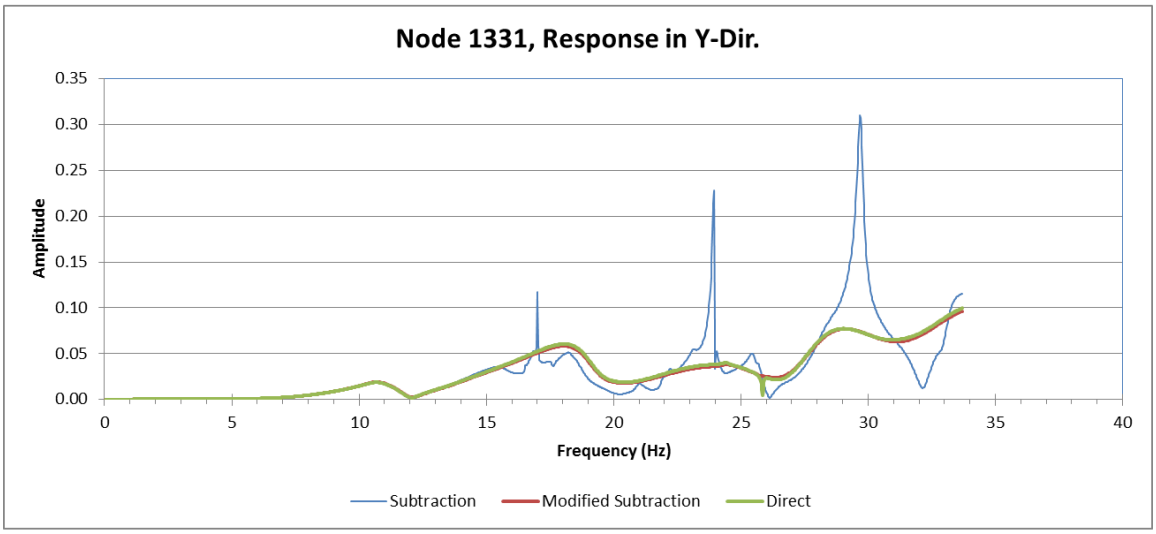


Figure 13: Comparison of Transfer Functions, Node 1331, Input in Y-Dir. - Standard Soil Site





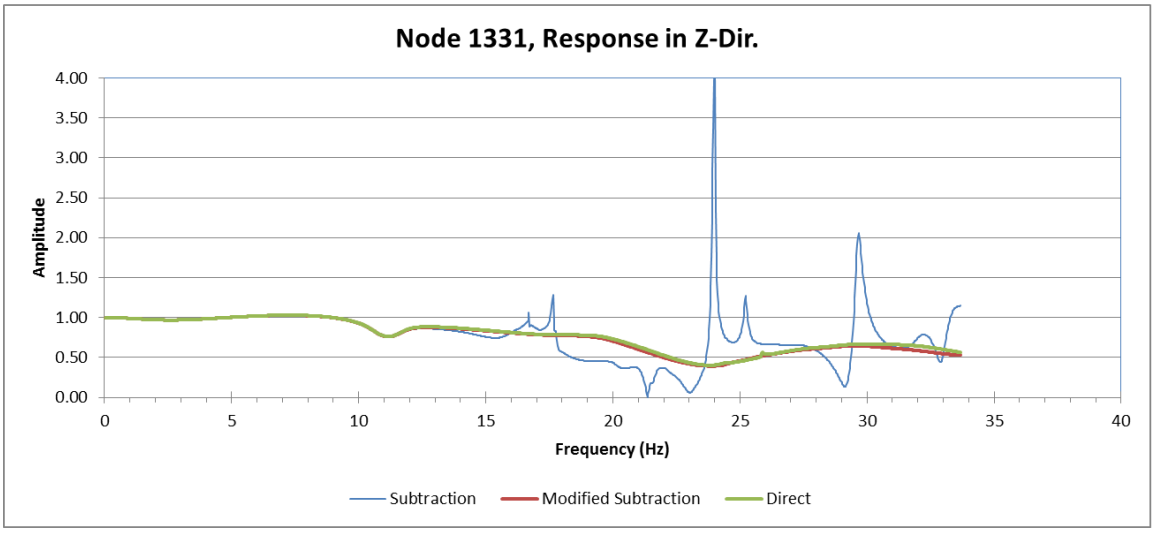
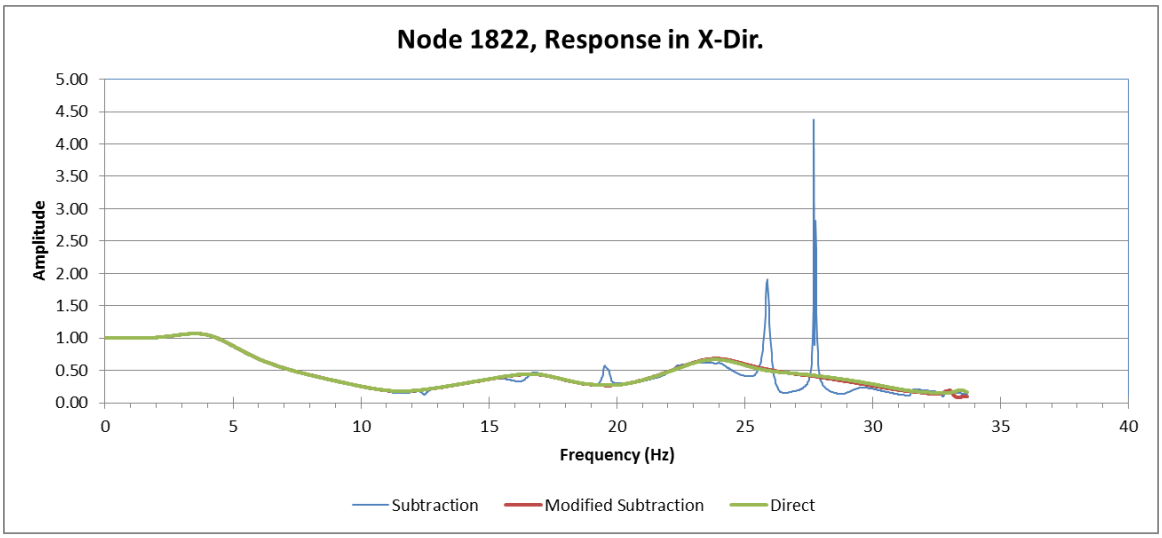
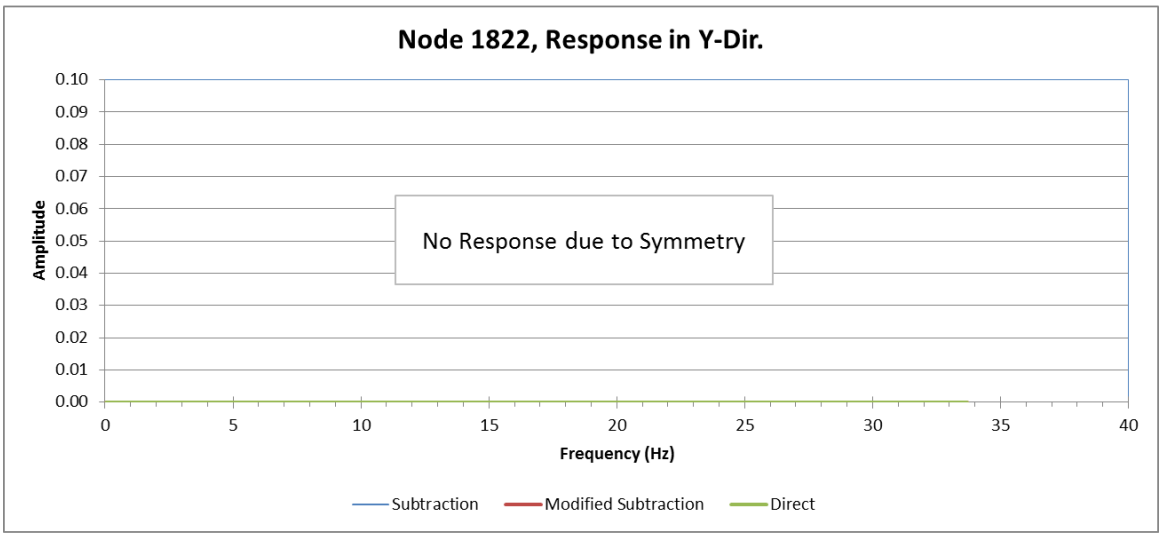


Figure 14: Comparison of Transfer Functions, Node 1331, Input in Z-Dir. - Standard Soil Site





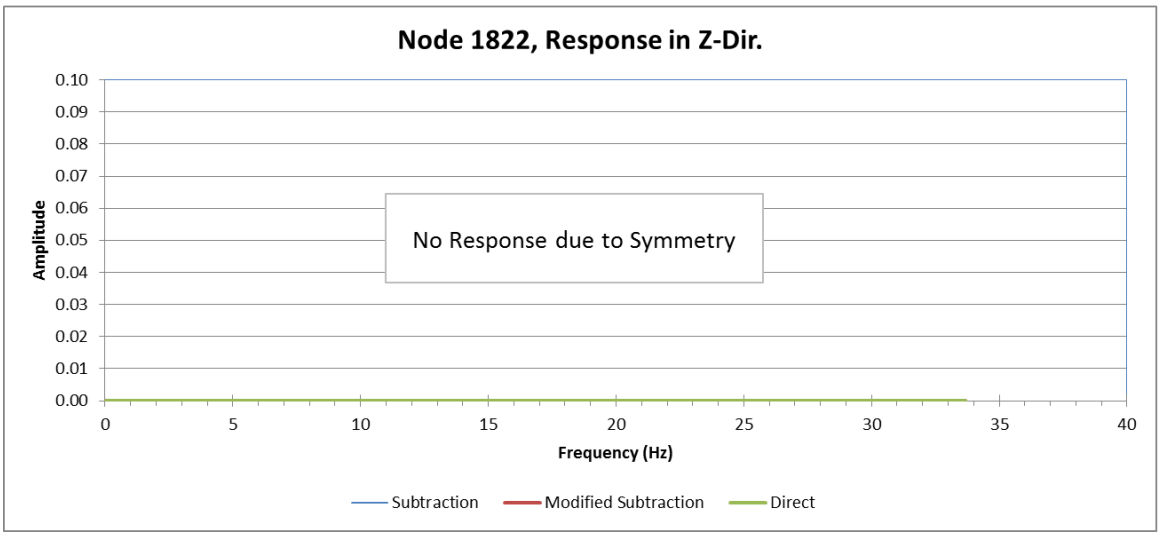
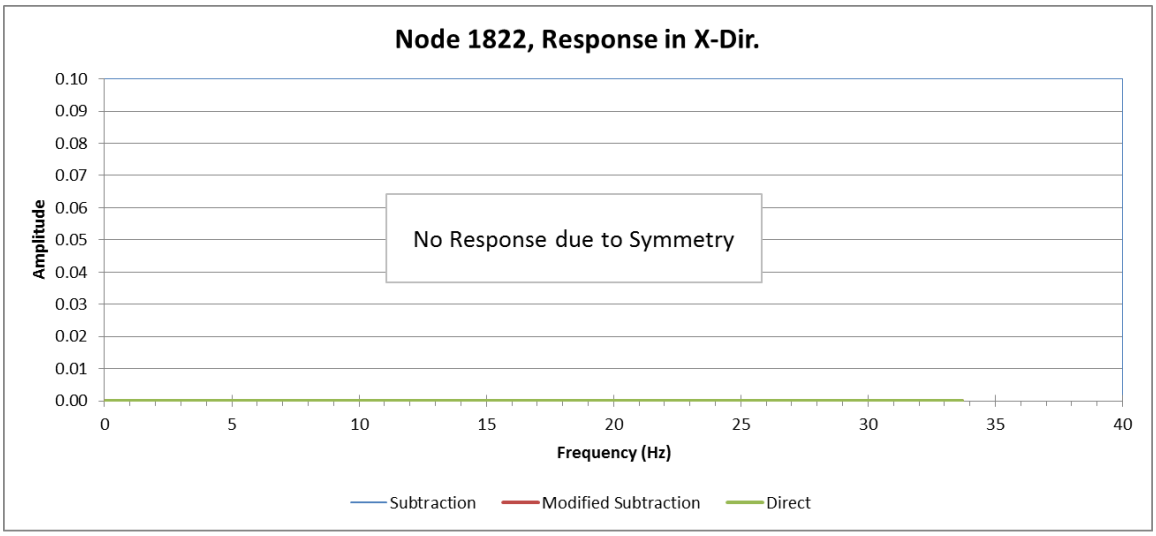
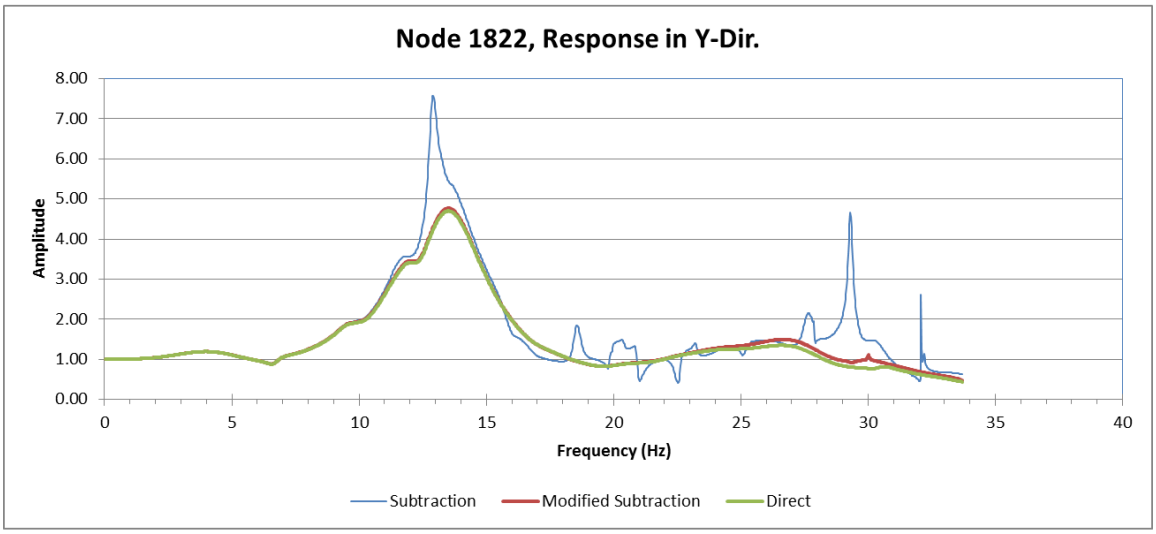


Figure 15: Comparison of Transfer Functions, Node 1822, Input in X-Dir. - Standard Soil Site





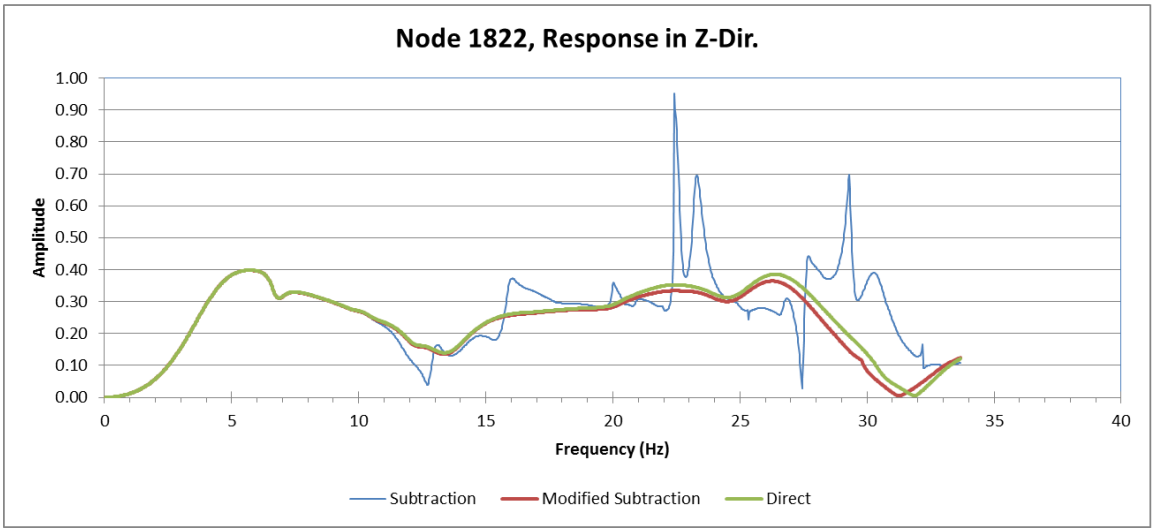
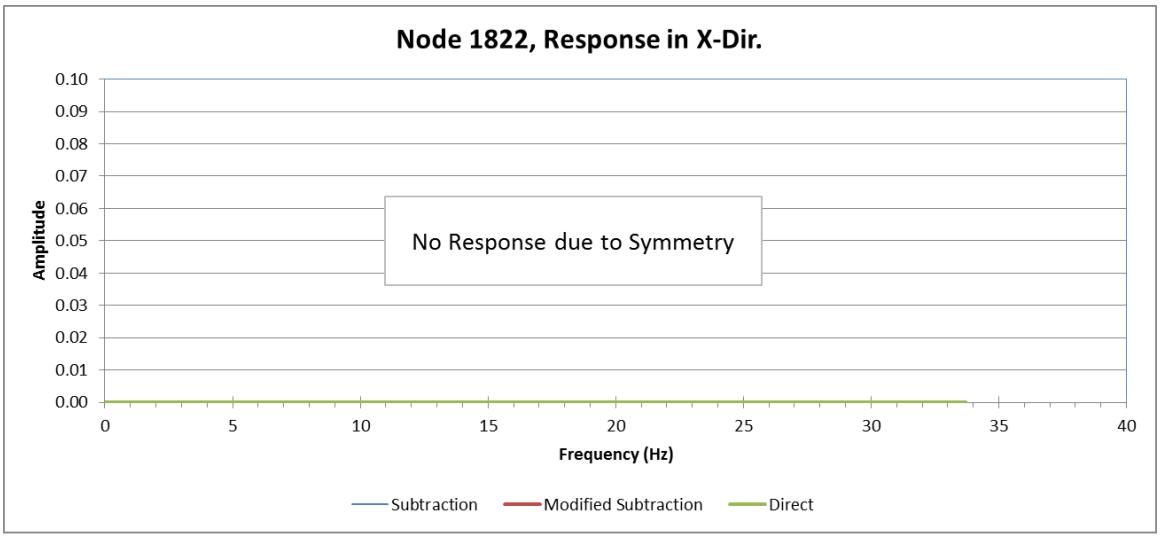
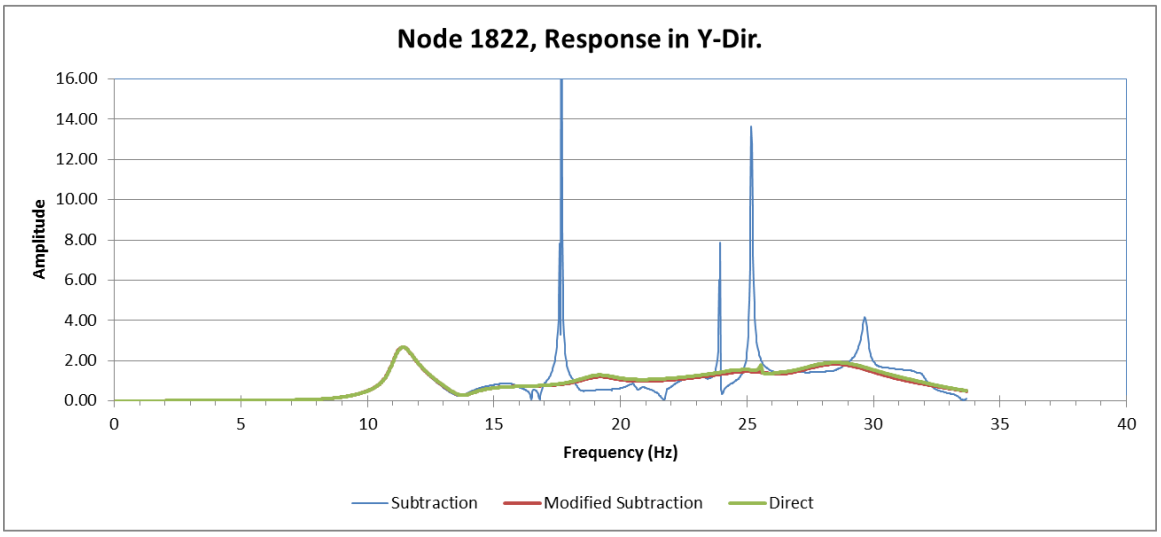


Figure 16: Comparison of Transfer Functions, Node 1822, Input in Y-Dir. - Standard Soil Site





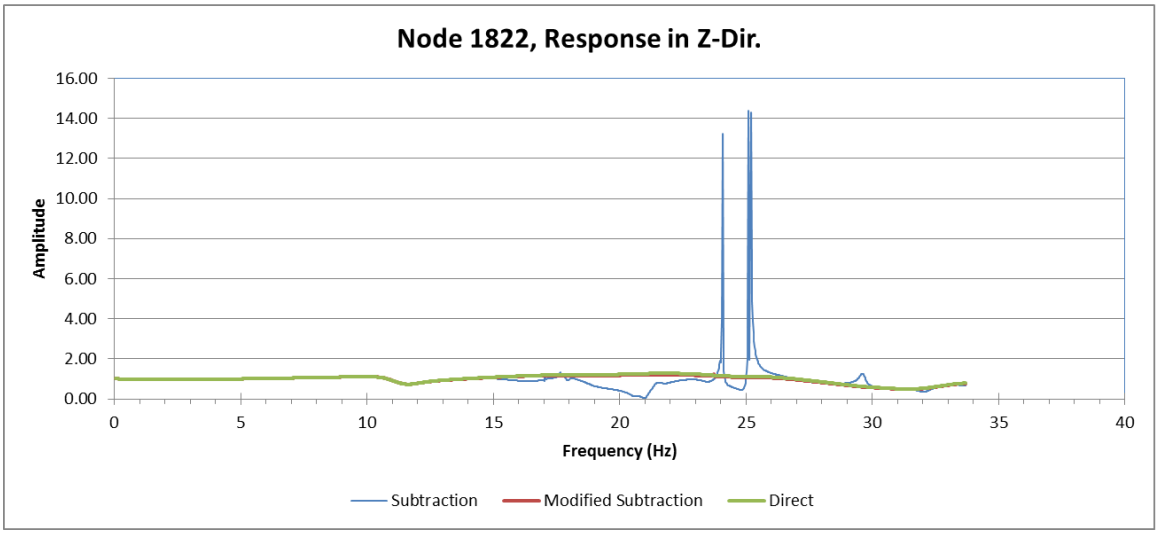
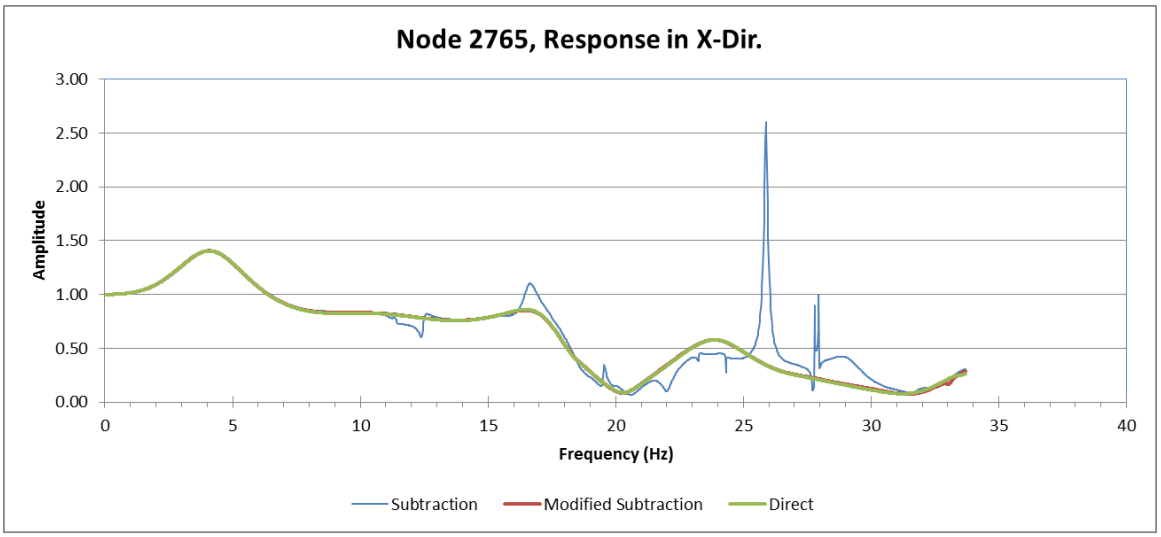
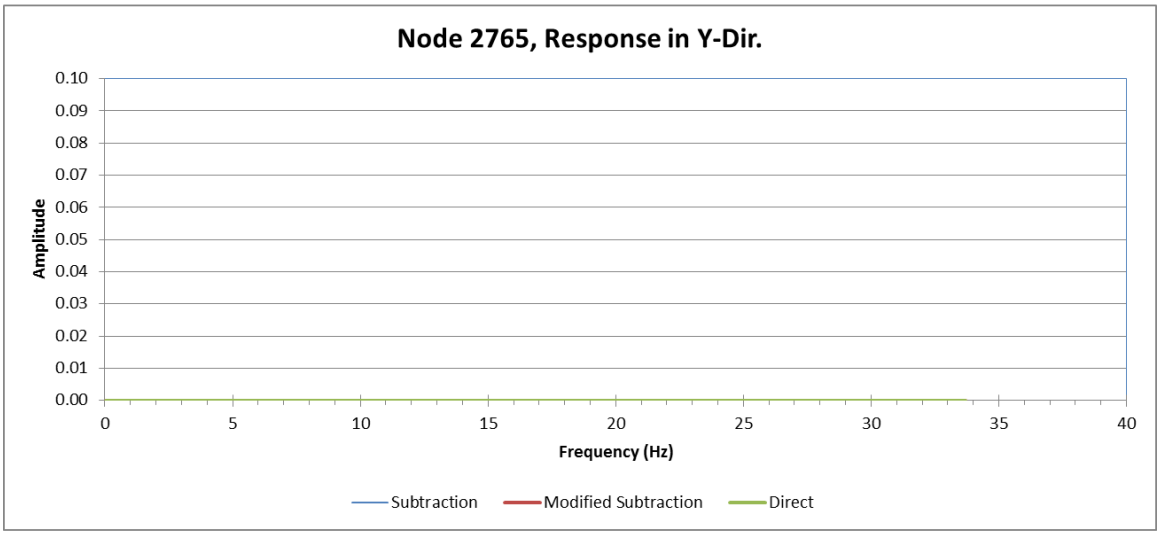


Figure 17: Comparison of Transfer Functions, Node 1822, Input in Z-Dir. - Standard Soil Site





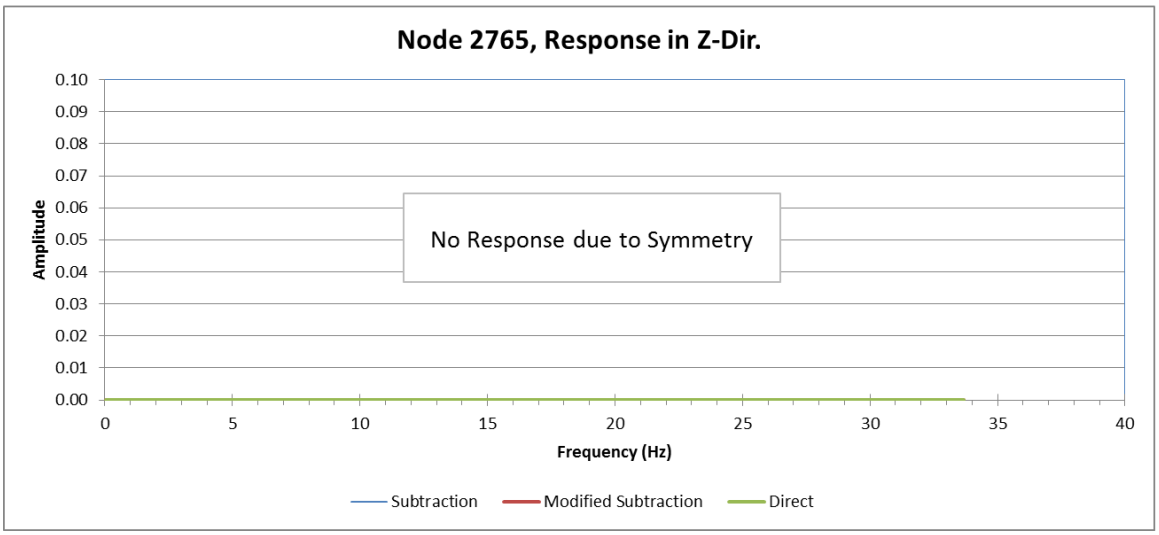
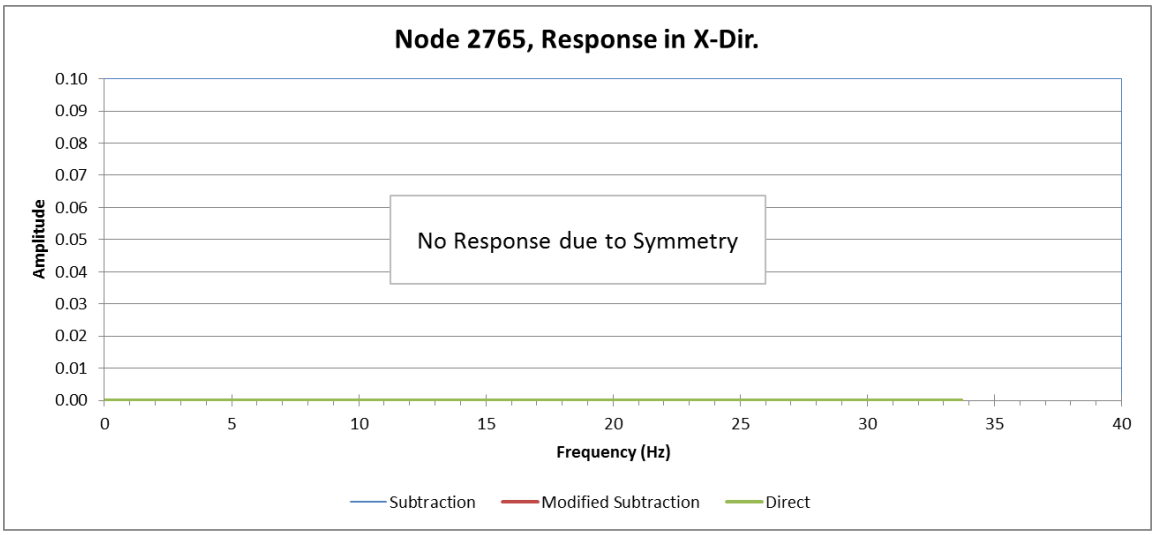
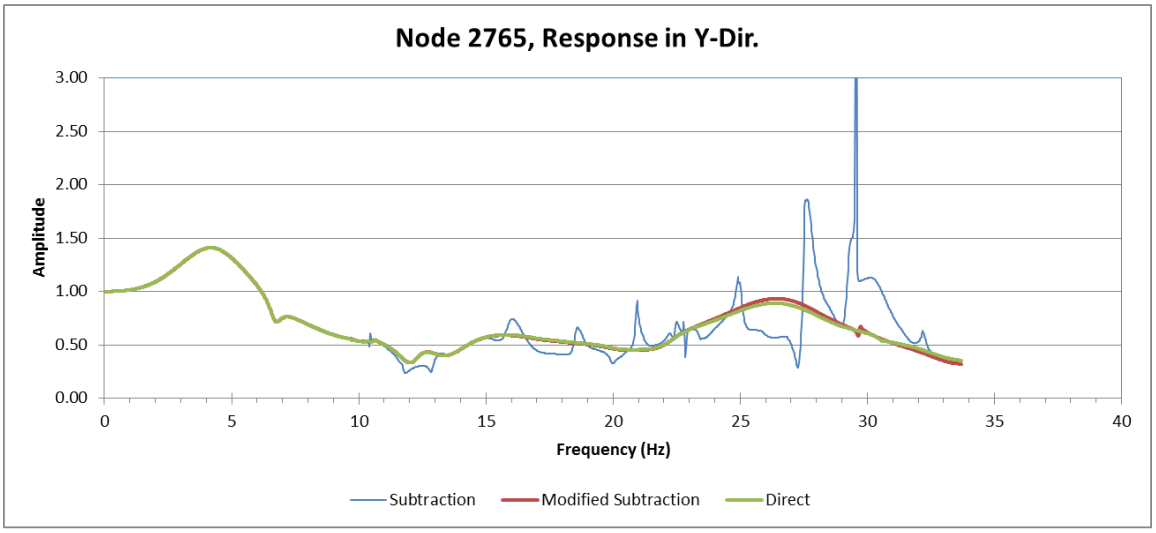


Figure 18: Comparison of Transfer Functions, Node 2765, Input in X-Dir. - Standard Soil Site





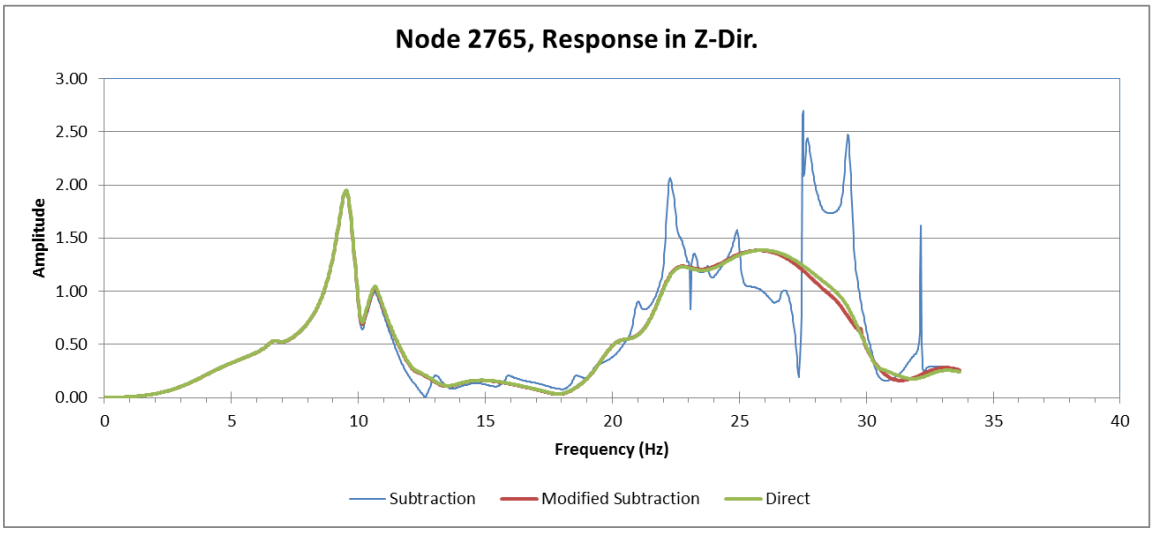
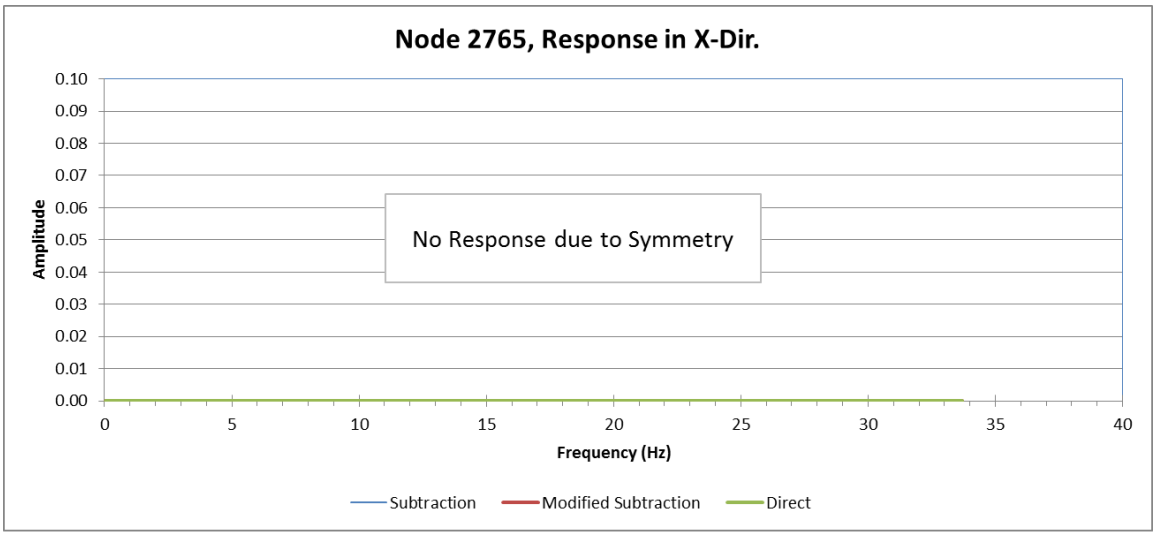
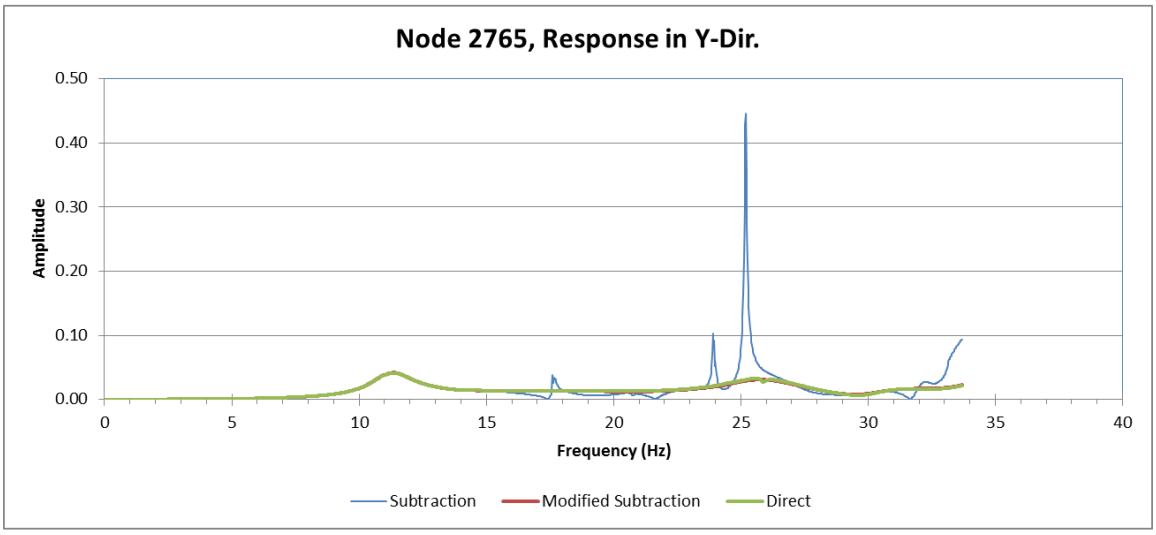


Figure 19: Comparison of Transfer Functions, Node 2765, Input in Y-Dir. - Standard Soil Site





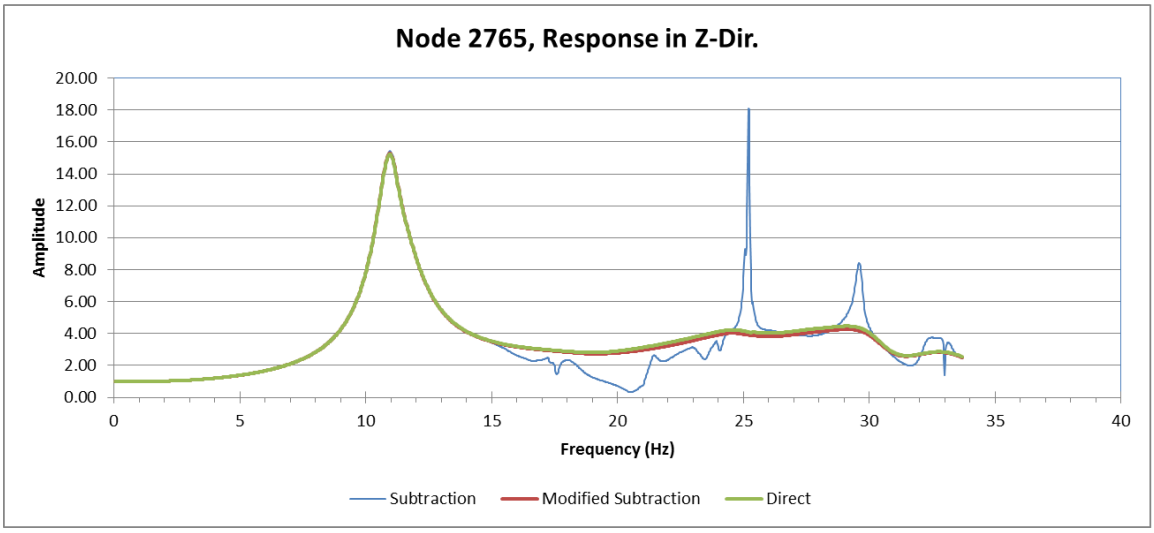
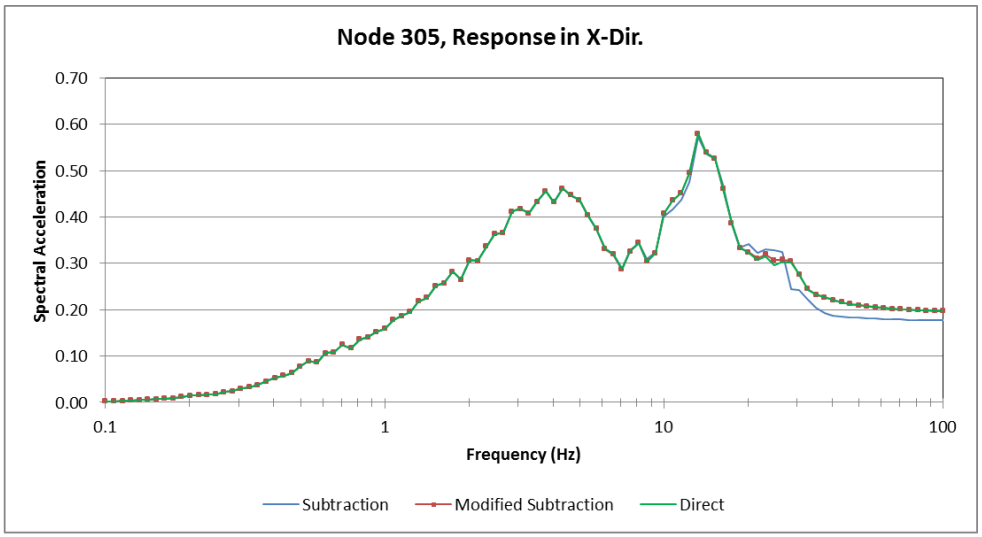
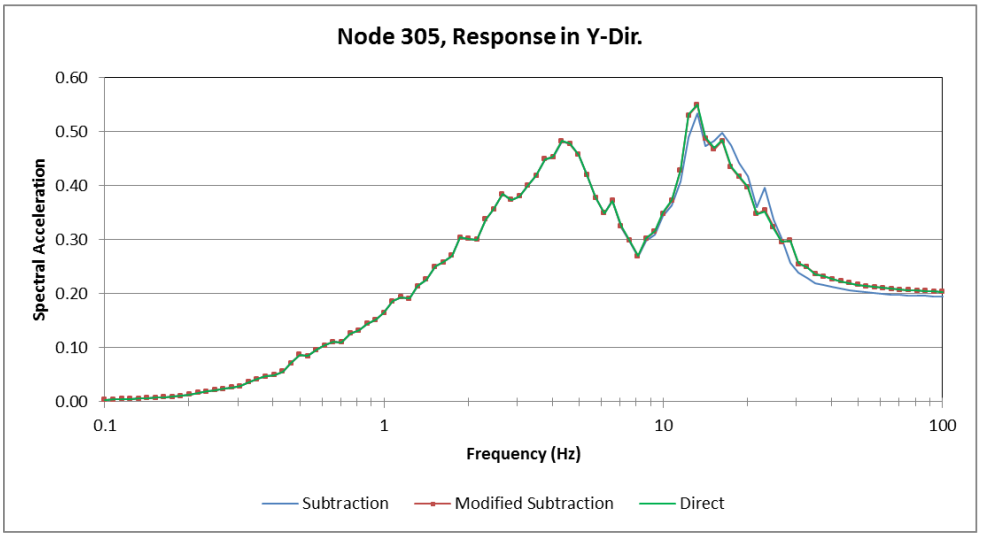


Figure 20: Comparison of Transfer Functions, Node 2765, Input in Z-Dir. - Standard Soil Site





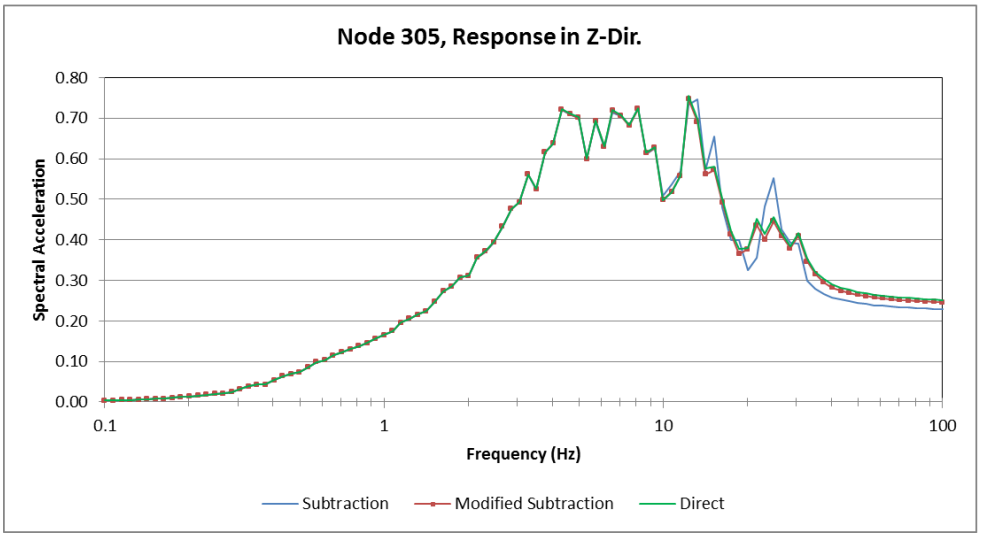
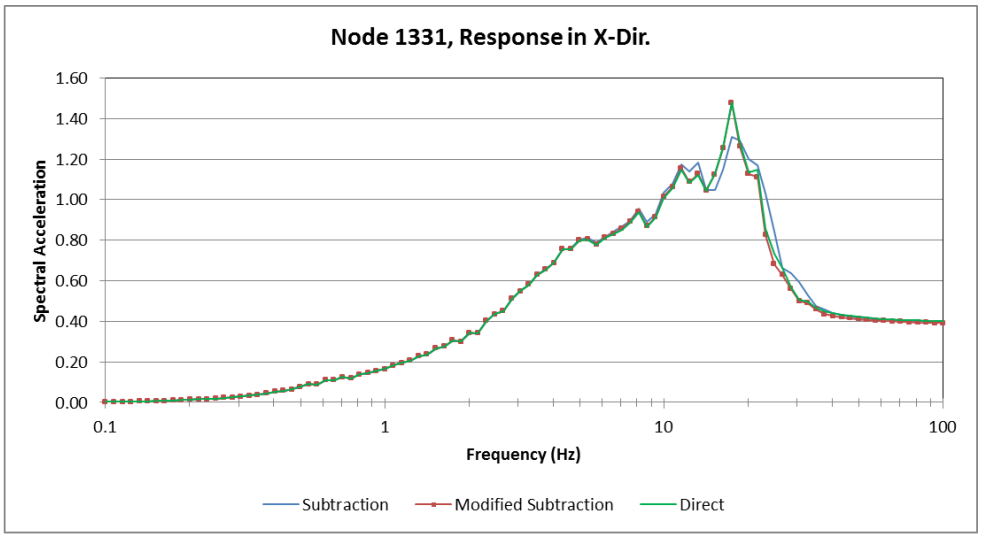
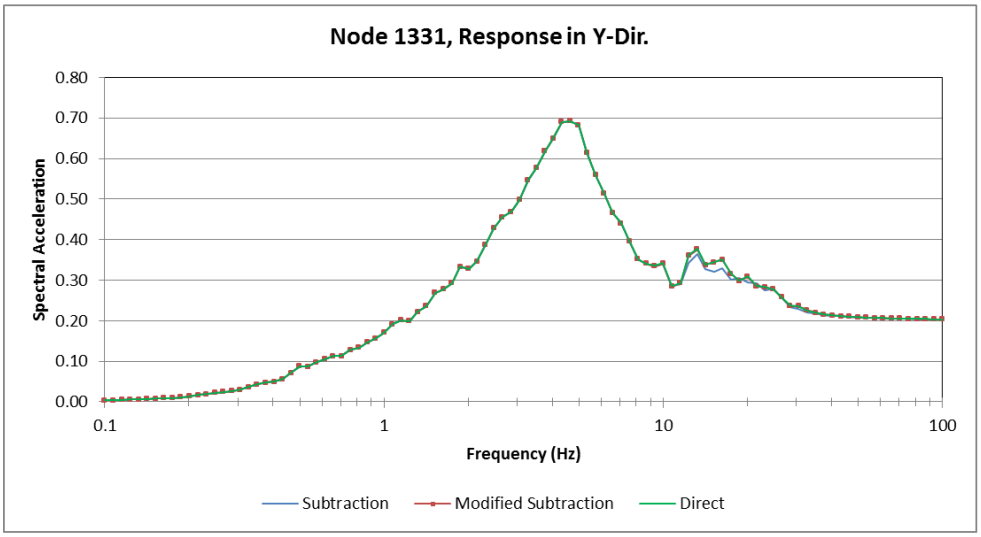


Figure 21: Comparison of 5%-Damped Response Spectra, Node 305 - Standard Soil Site





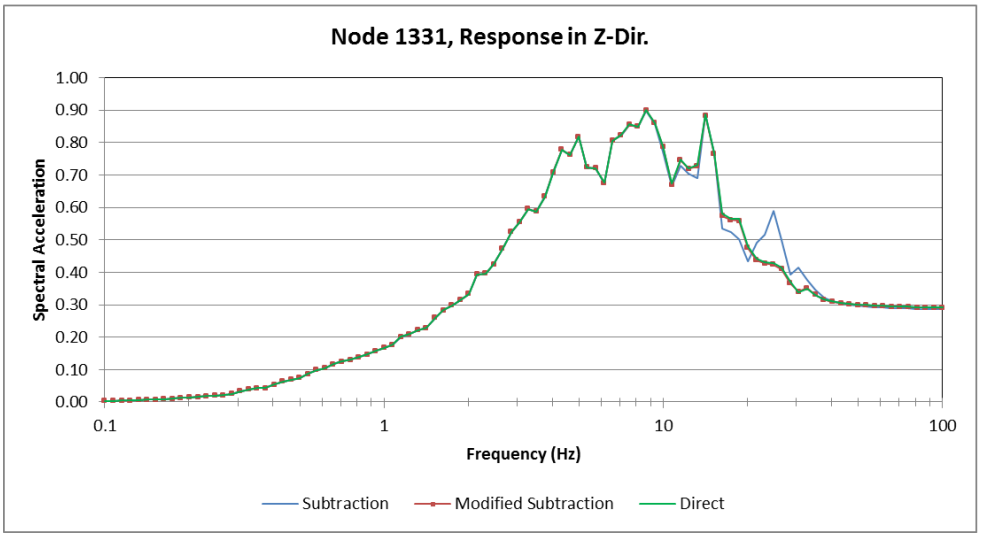
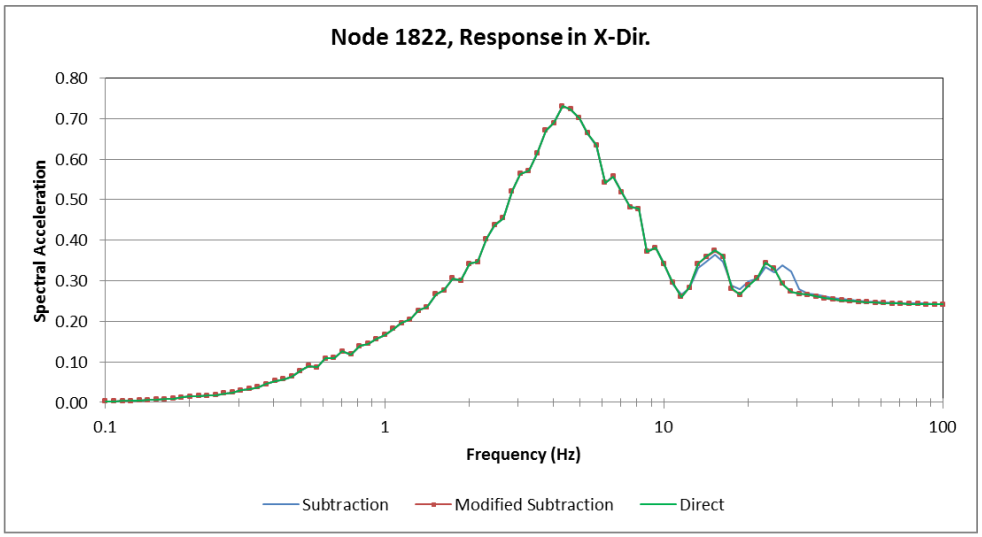
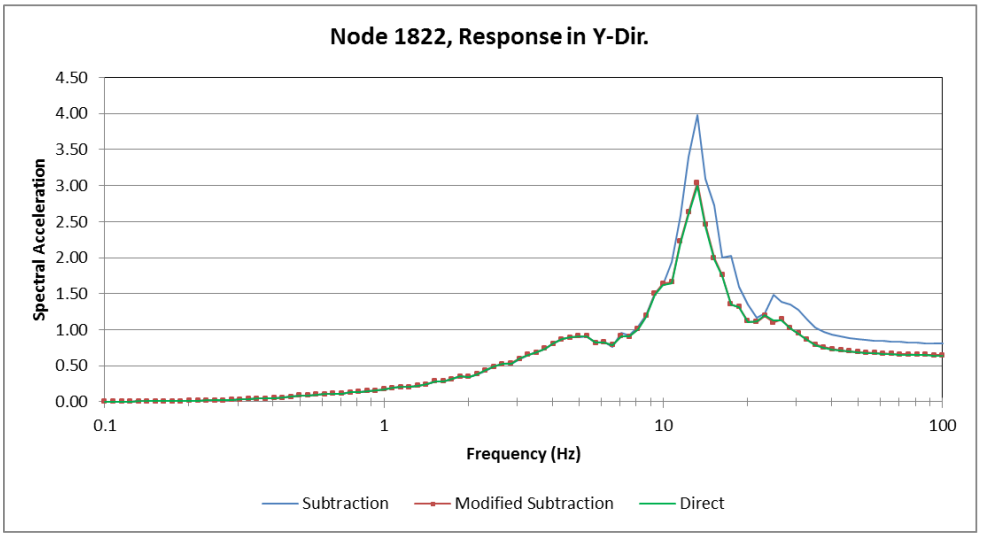


Figure 22: Comparison of 5%-Damped Response Spectra, Node 1331 - Standard Soil Site





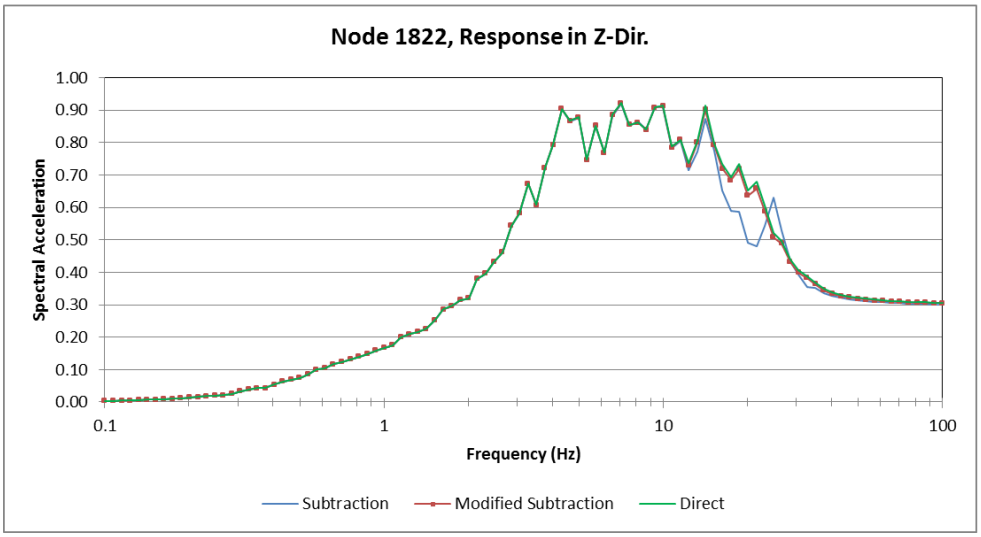
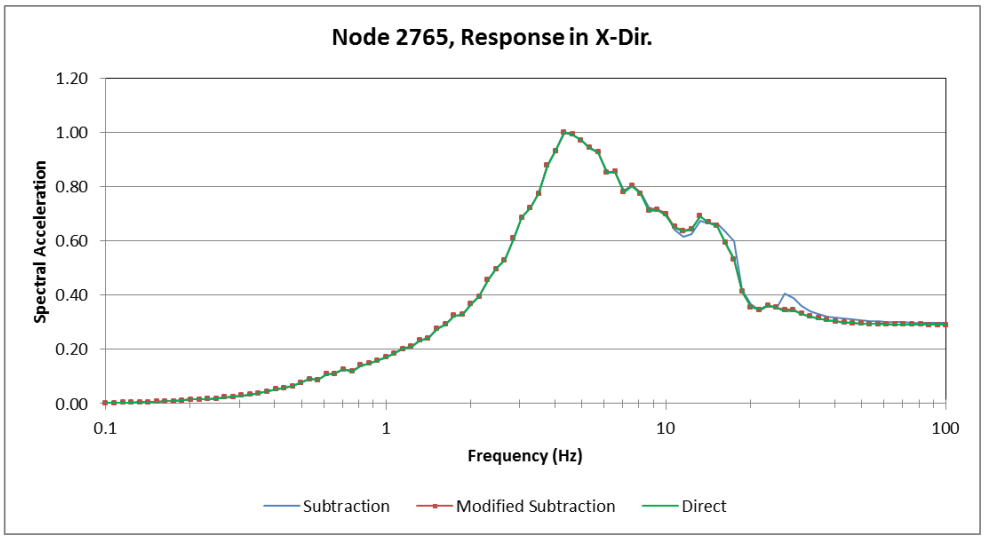
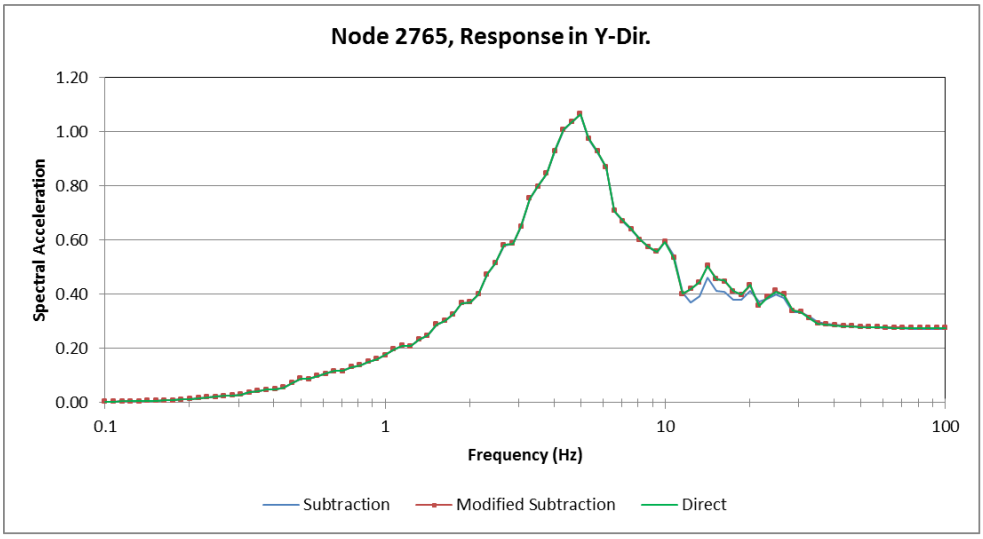


Figure 23: Comparison of 5%-Damped Response Spectra, Node 1822 - Standard Soil Site





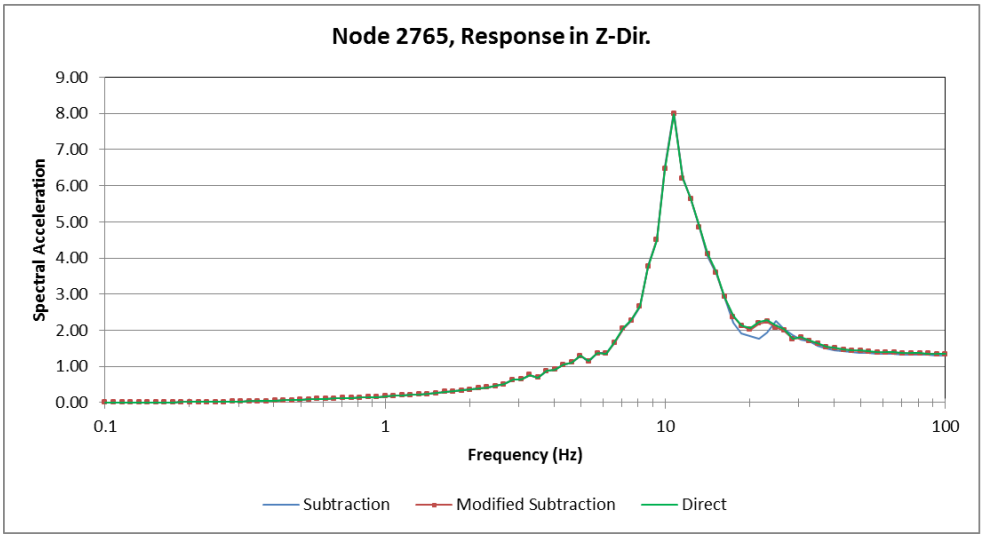
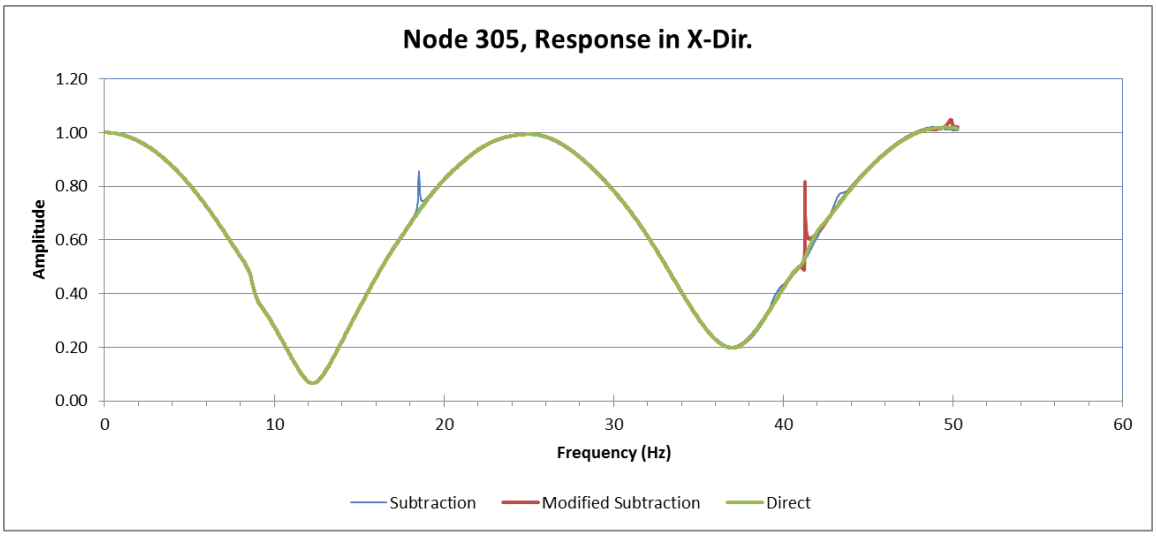
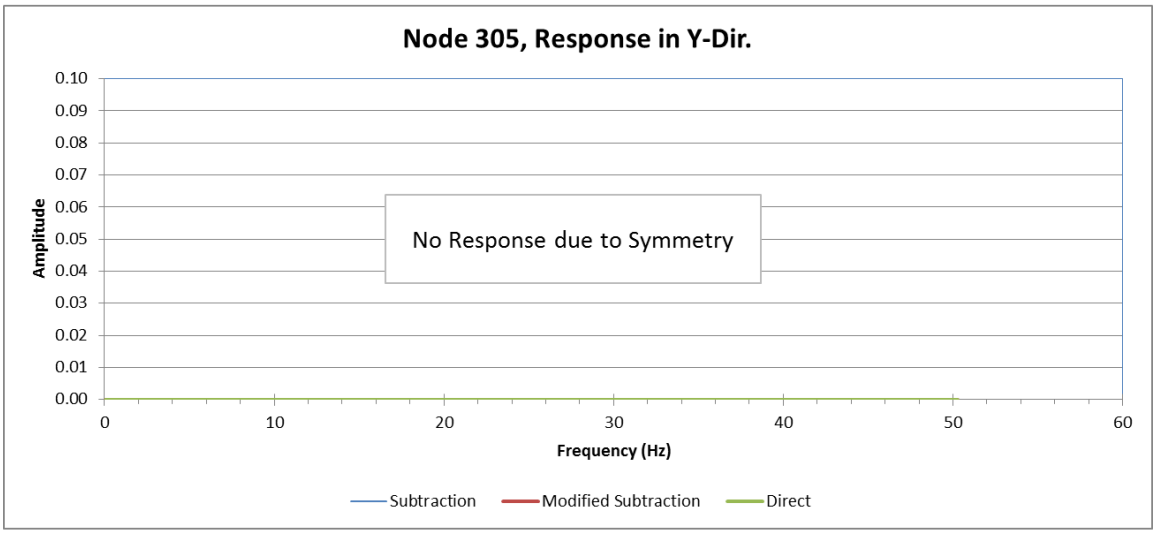


Figure 24: Comparison of 5%-Damped Response Spectra, Node 2765 - Standard Soil Site





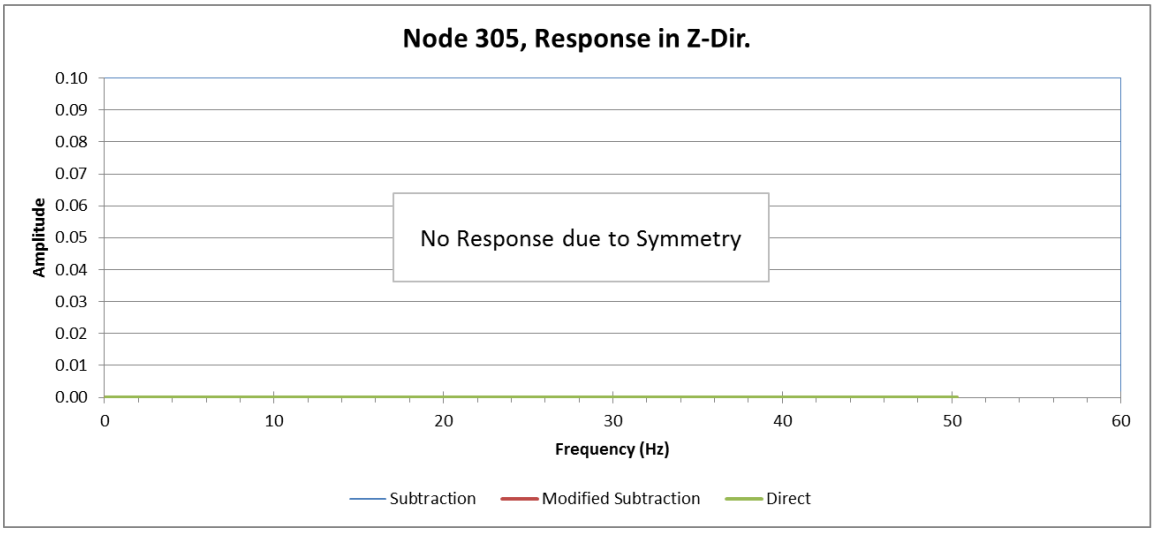
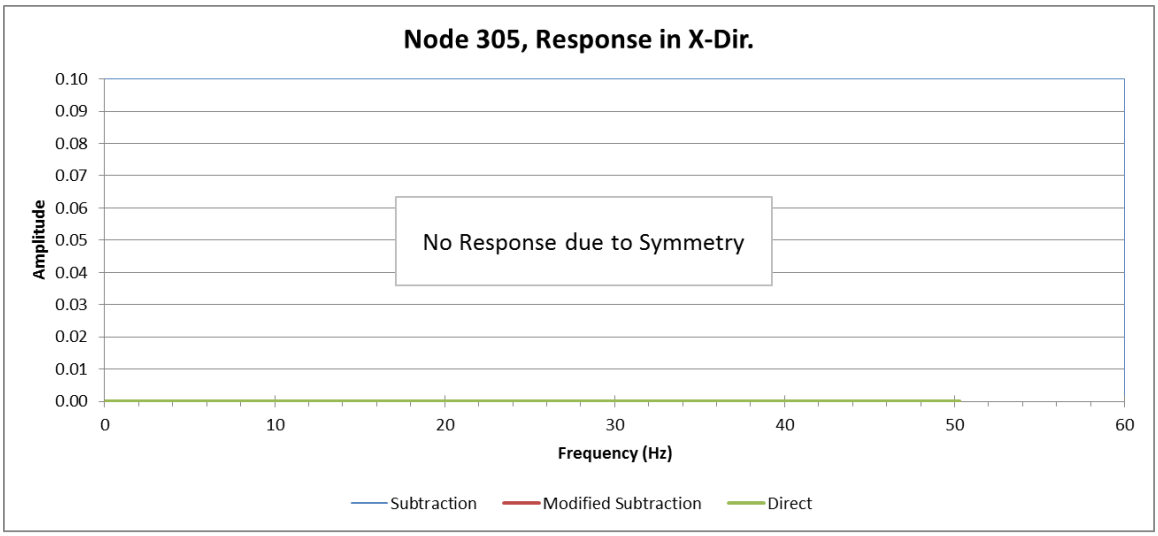
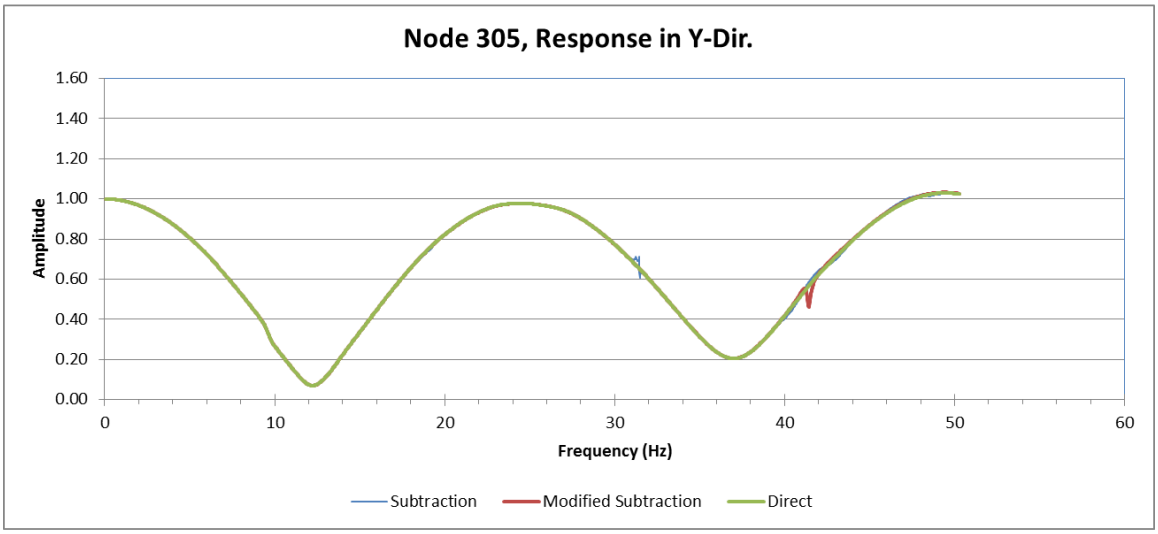


Figure 25: Comparison of Transfer Functions, Node 305, Input in X-Dir. - Hard Rock Site





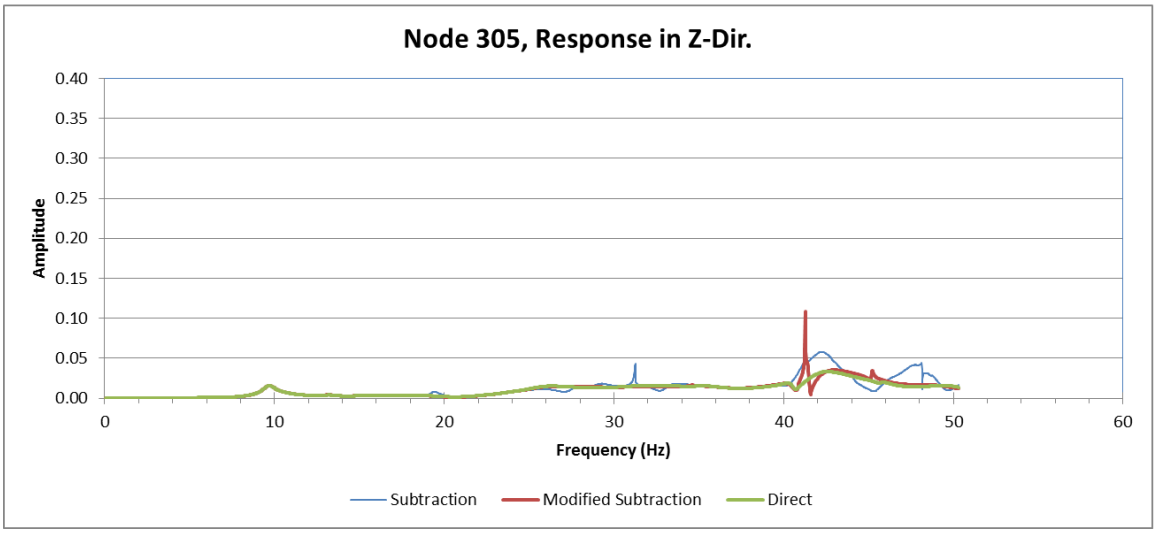
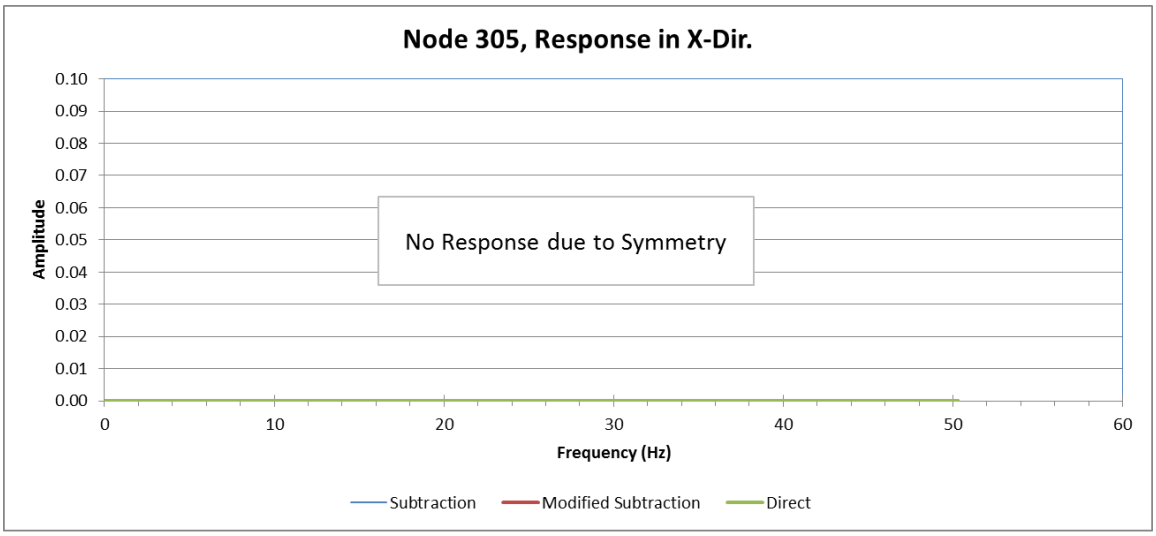
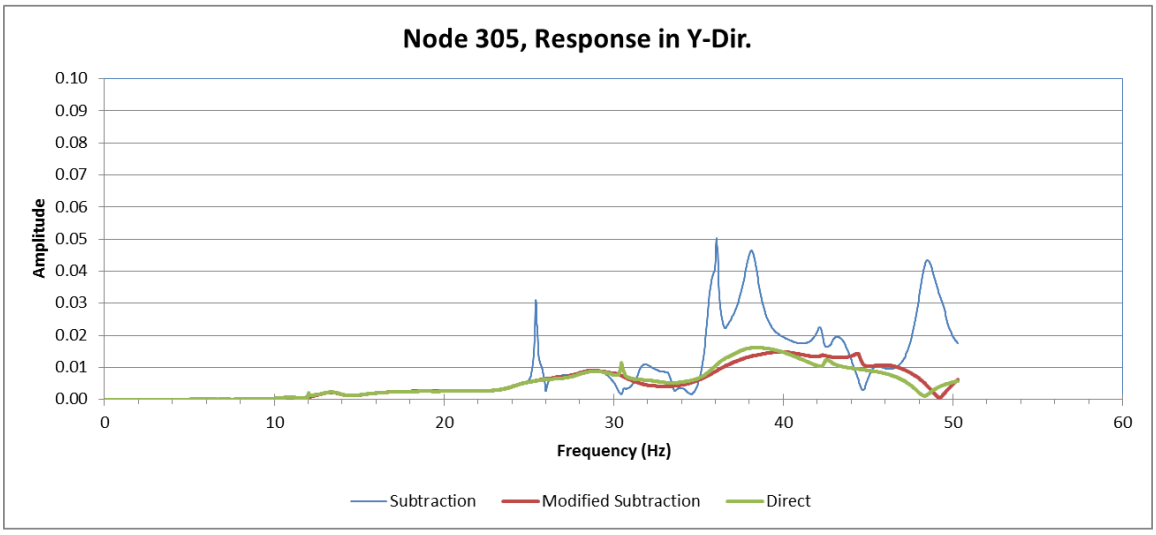


Figure 26: Comparison of Transfer Functions, Node 305, Input in Y-Dir. - Hard Rock Site





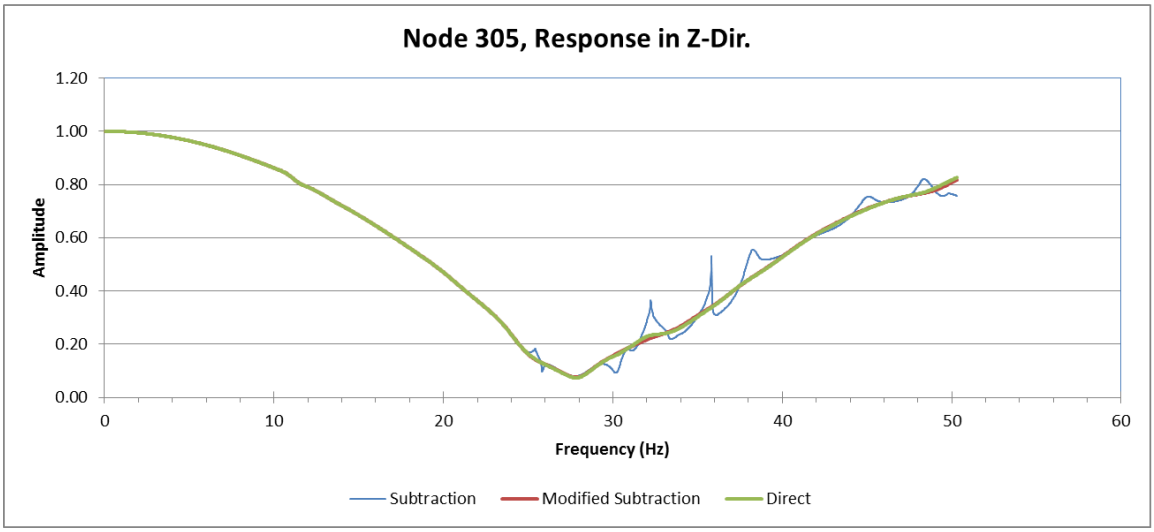
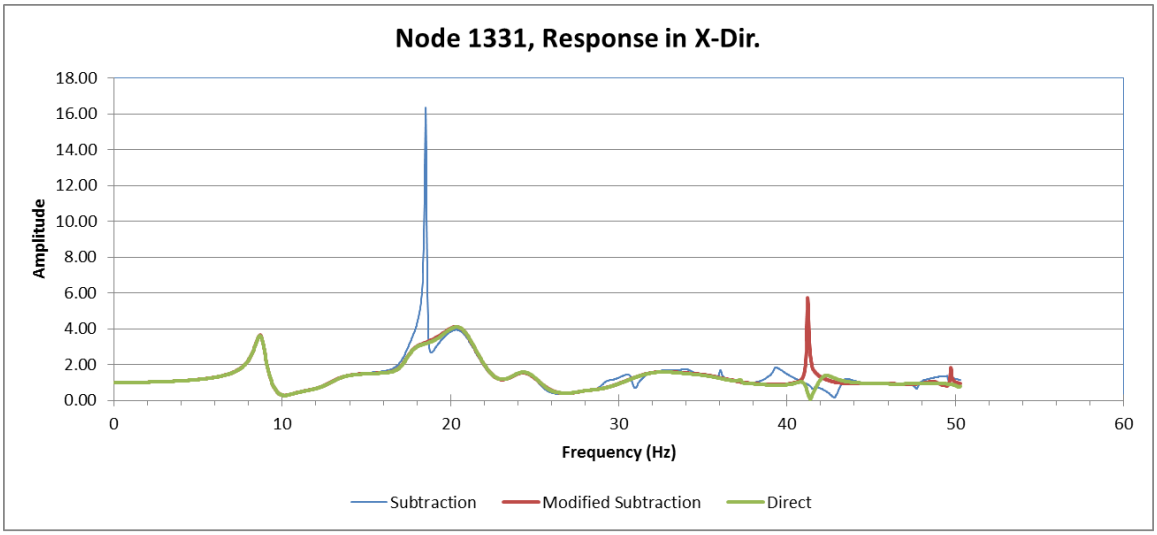
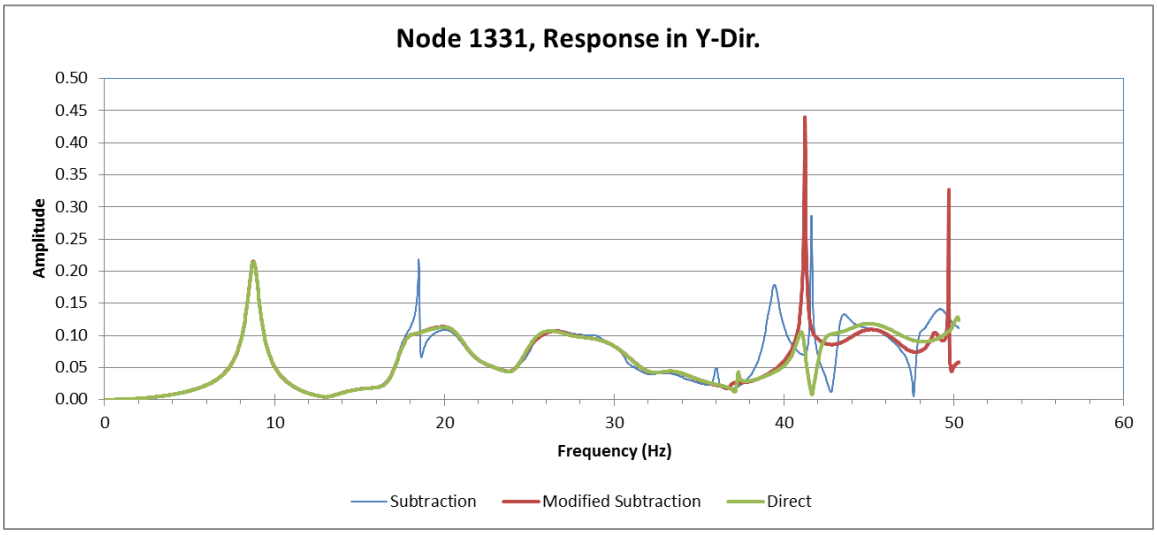


Figure 27: Comparison of Transfer Functions, Node 305, Input in Z-Dir. - Hard Rock Site





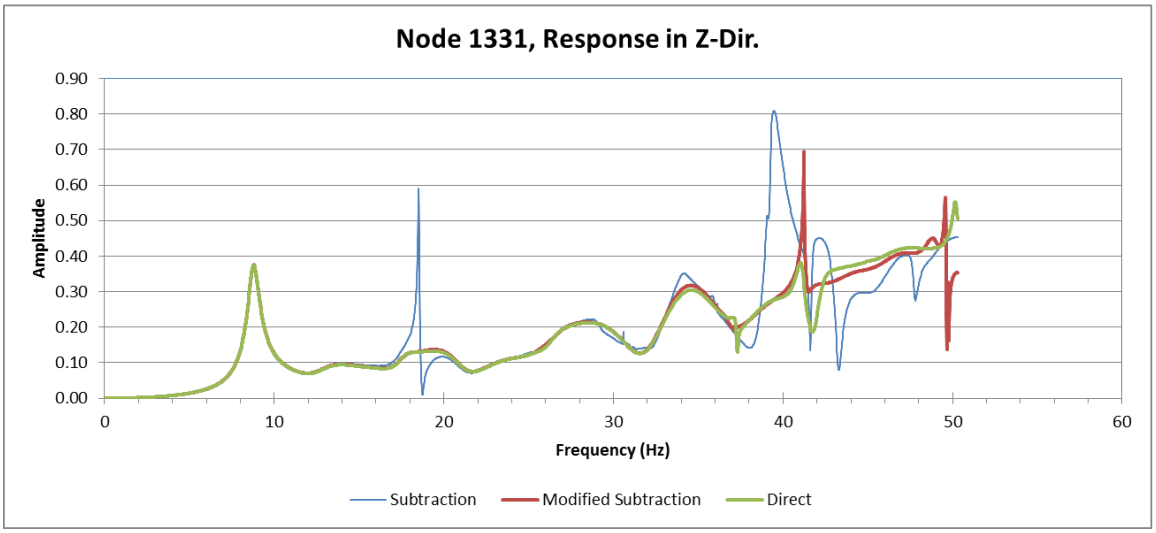
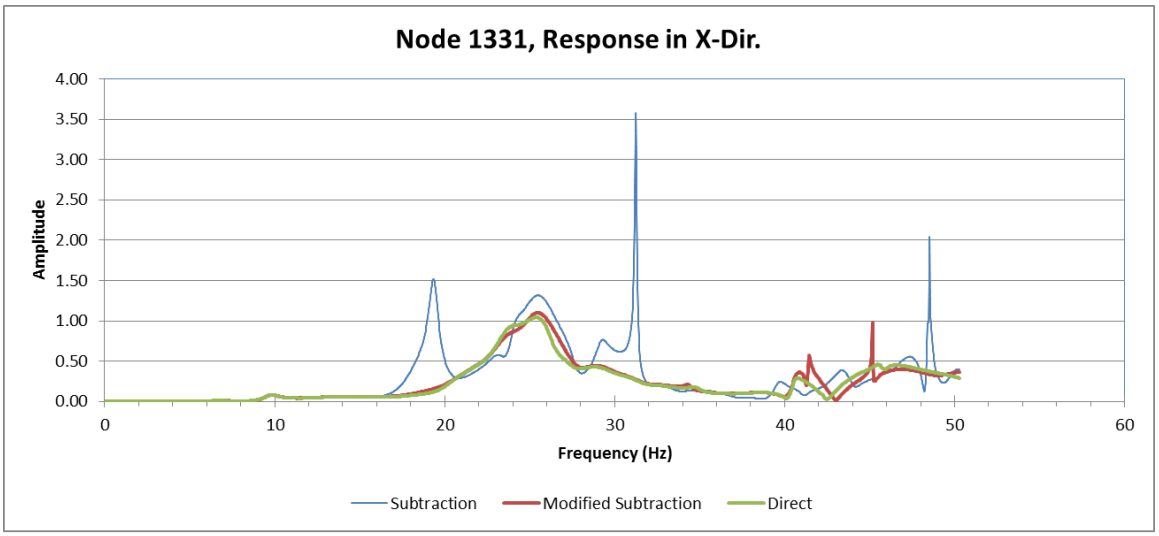
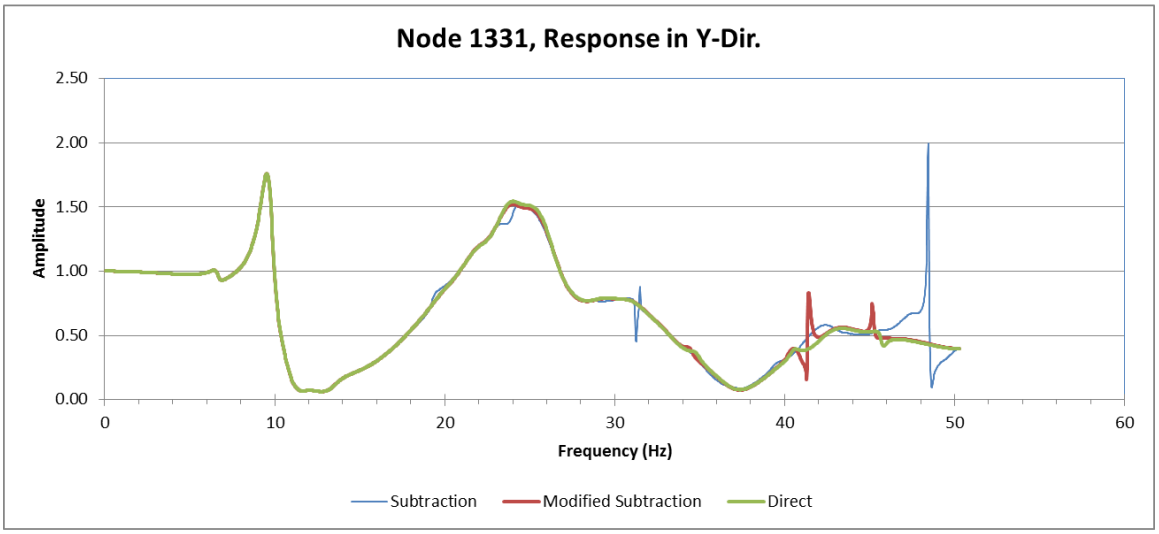


Figure 28: Comparison of Transfer Functions, Node 1331, Input in X-Dir. - Hard Rock Site





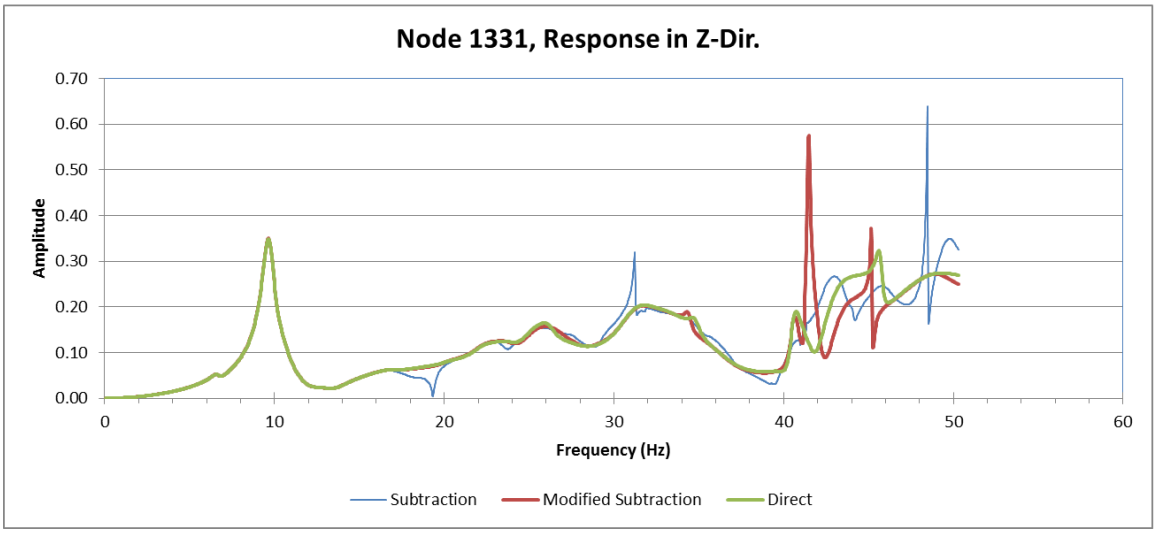
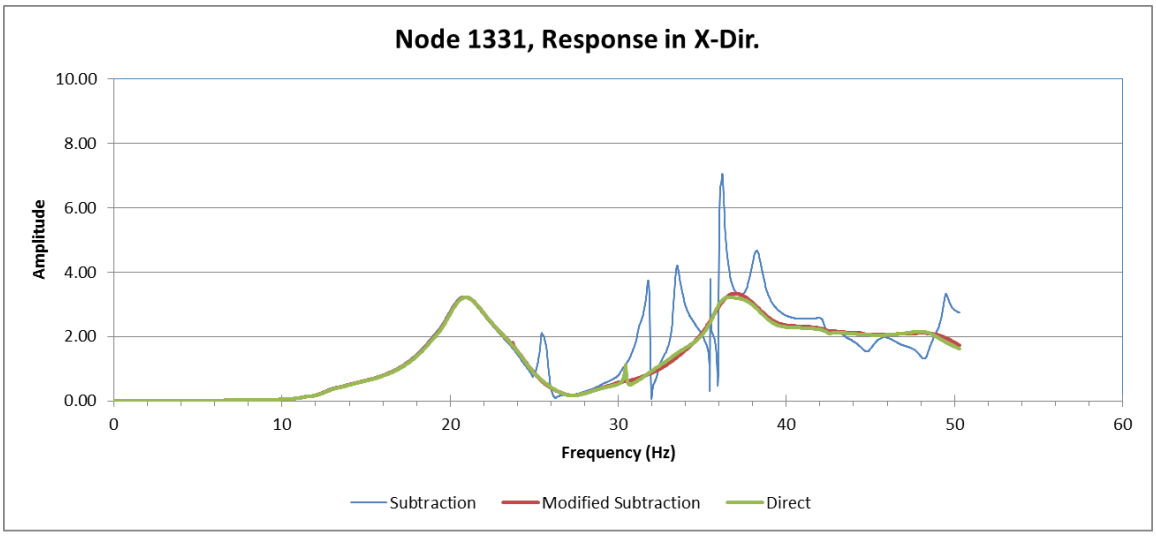
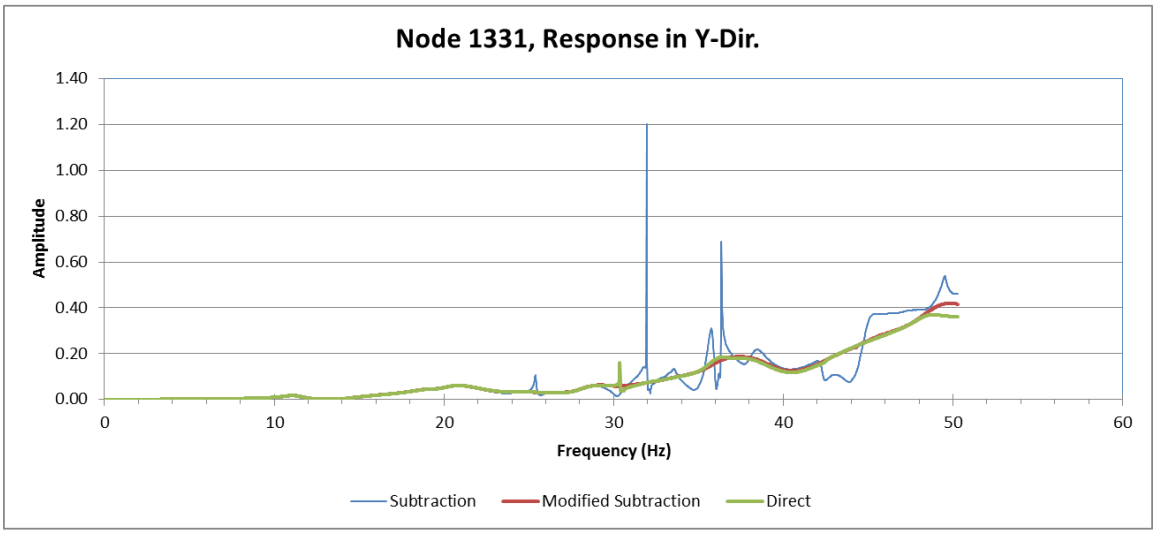


Figure 29: Comparison of Transfer Functions, Node 1331, Input in Y-Dir. - Hard Rock Site





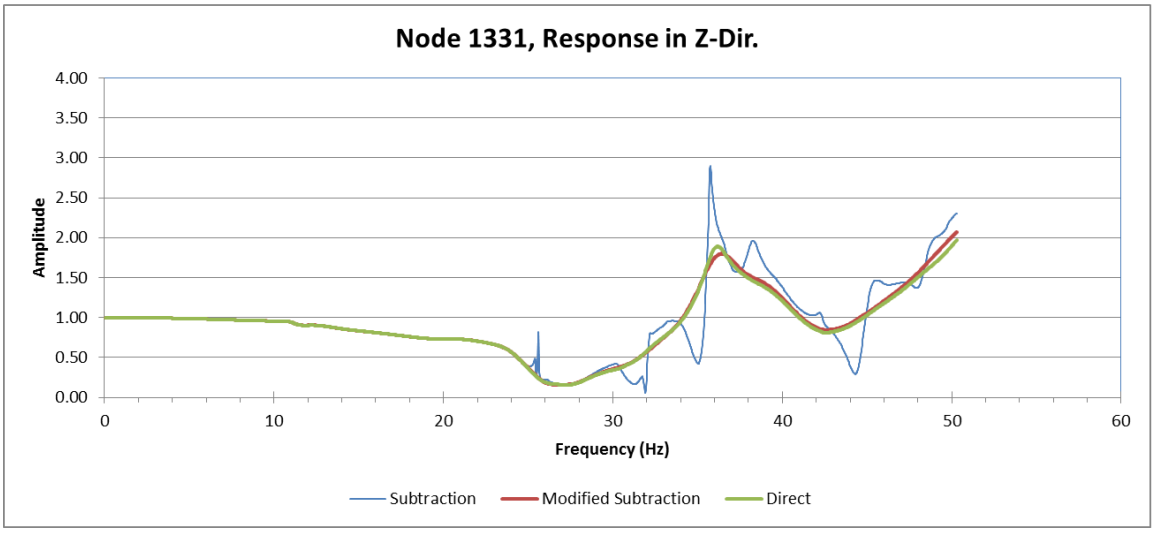
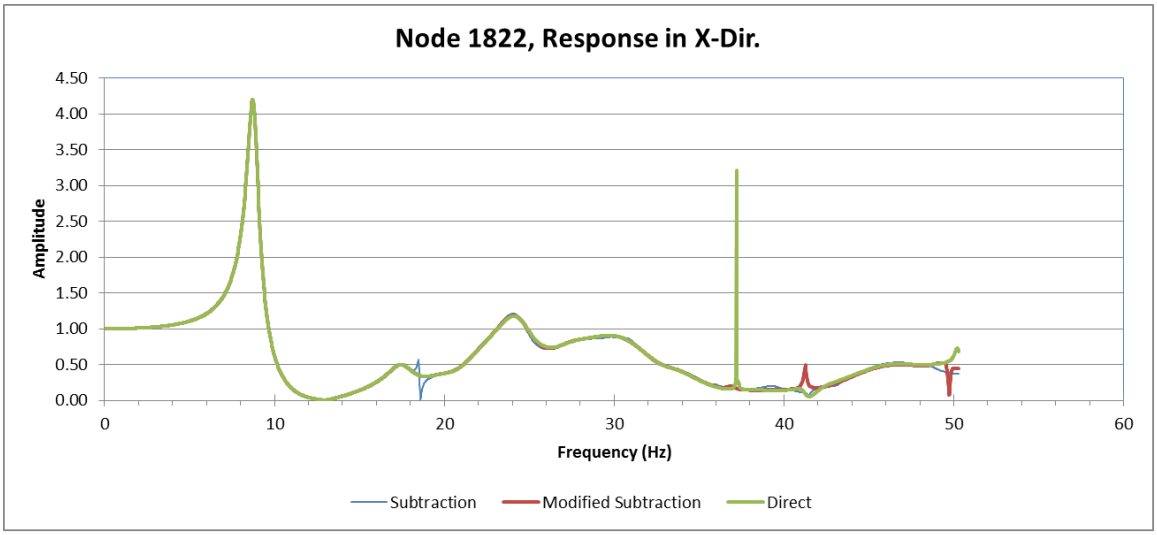
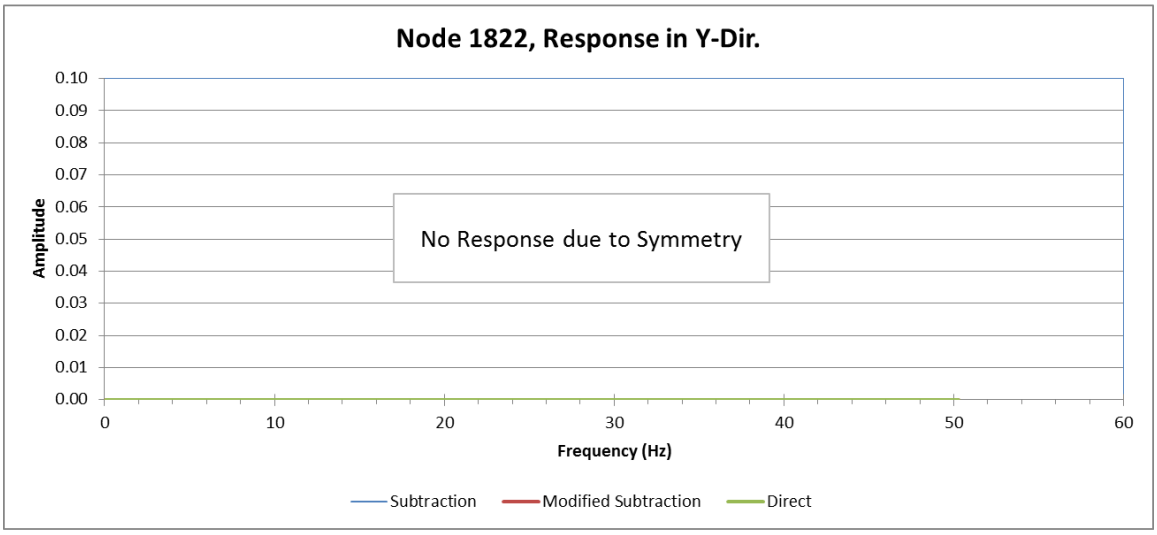


Figure 30: Comparison of Transfer Functions, Node 1331, Input in Z-Dir. - Hard Rock Site





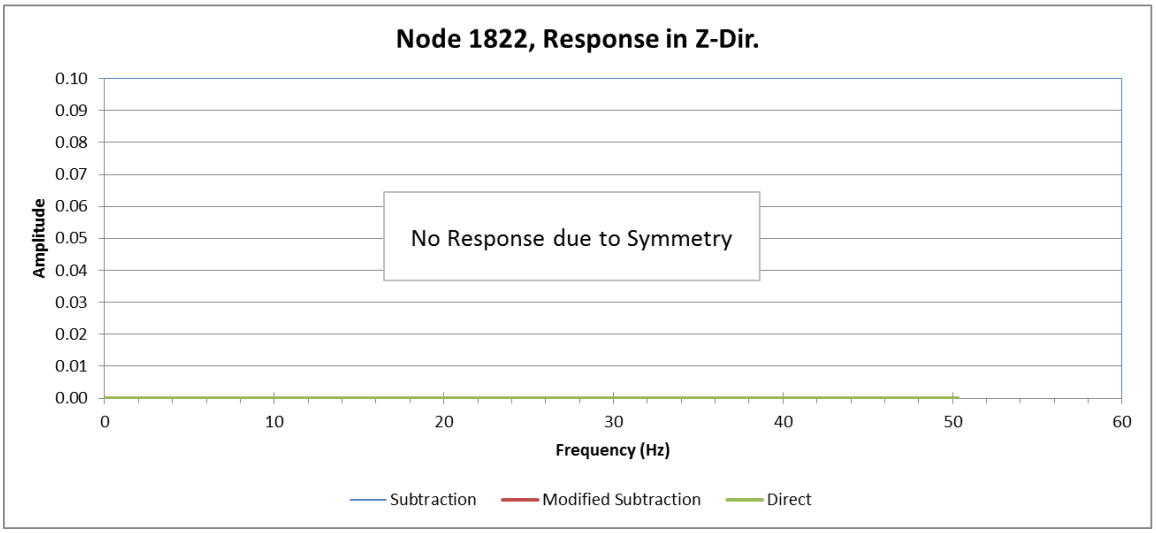
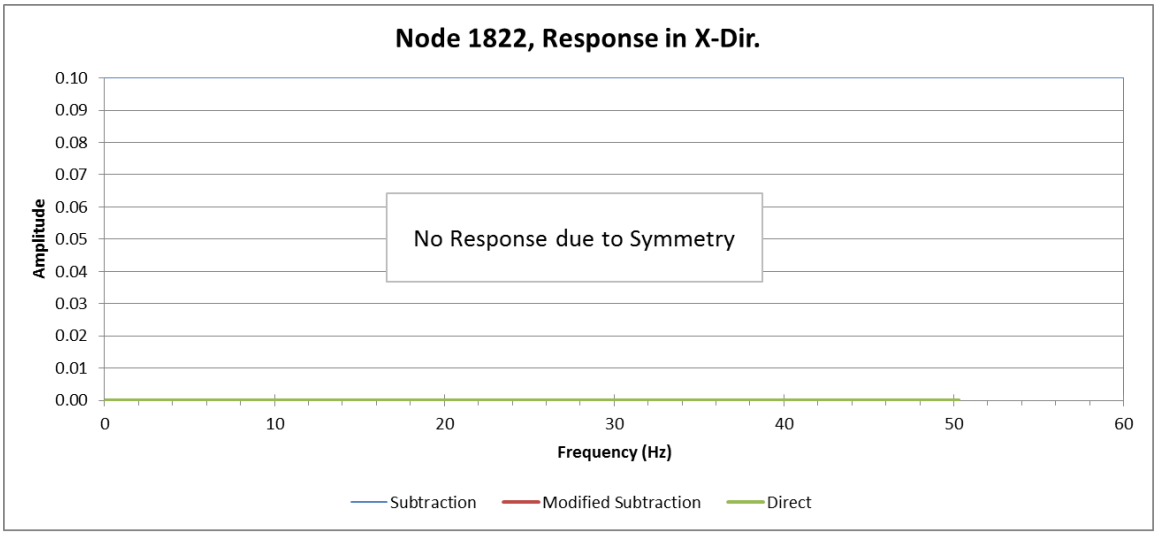
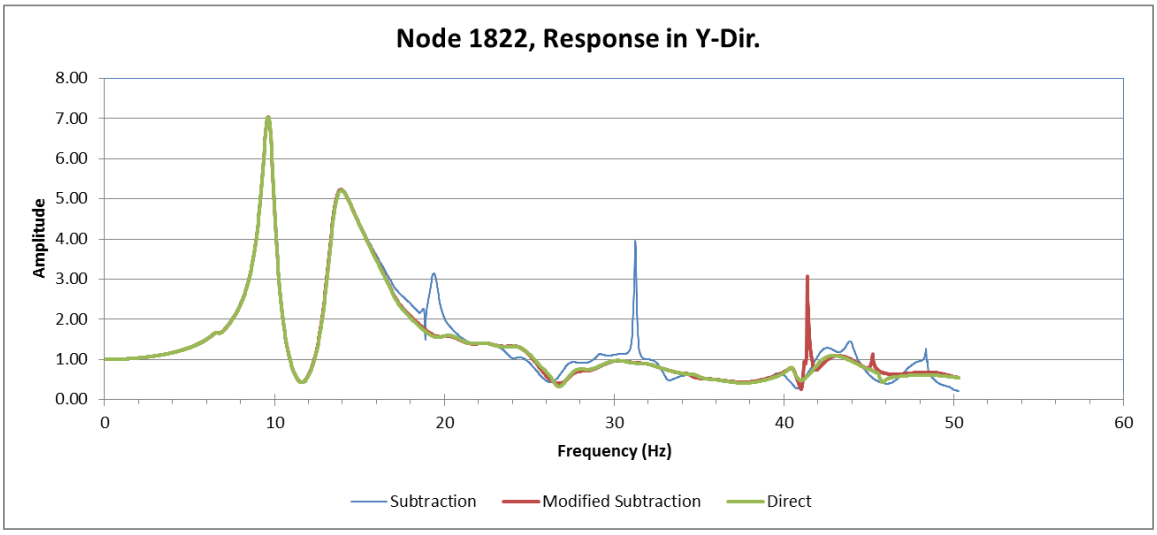


Figure 31: Comparison of Transfer Functions, Node 1822, Input in X-Dir. - Hard Rock Site





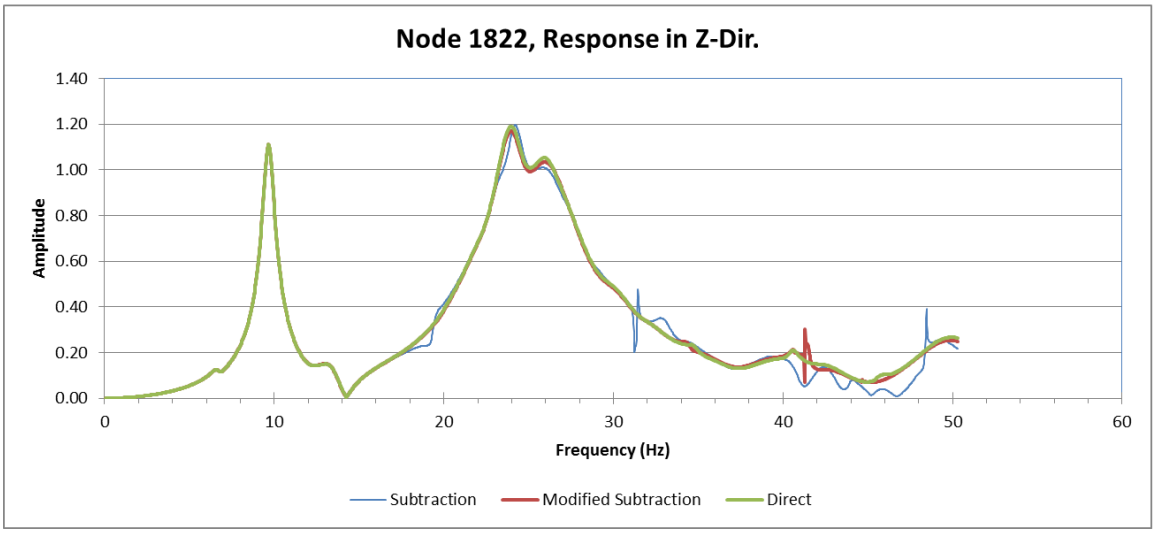
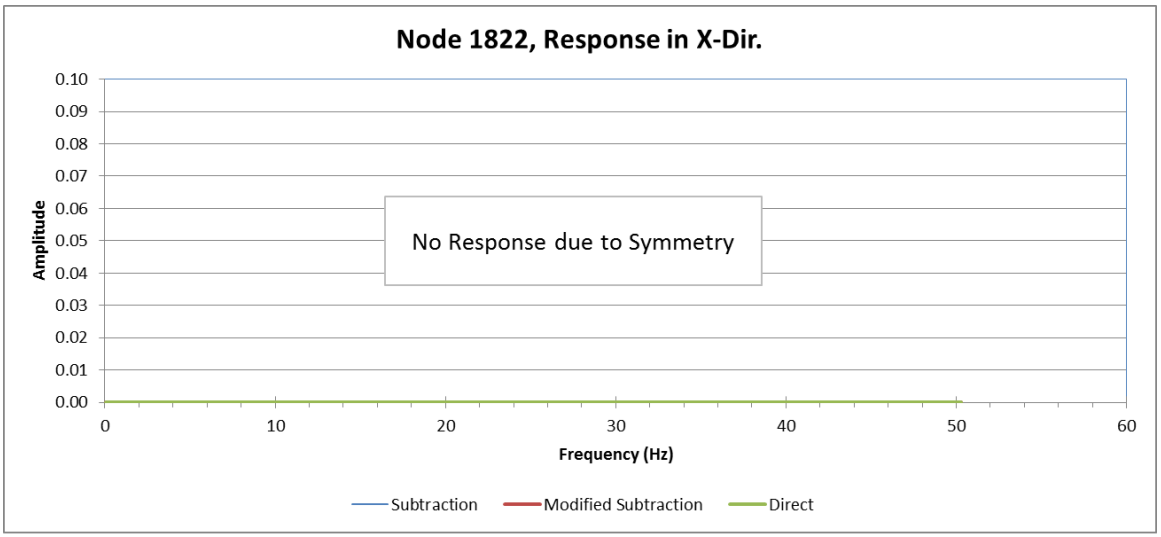
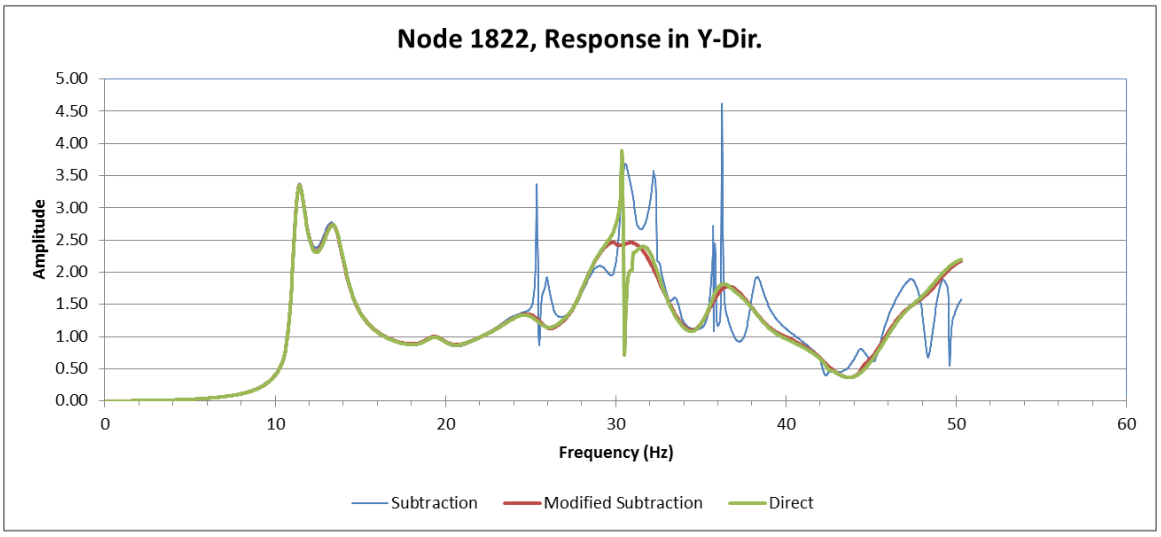


Figure 32: Comparison of Transfer Functions, Node 1822, Input in Y-Dir. - Hard Rock Site





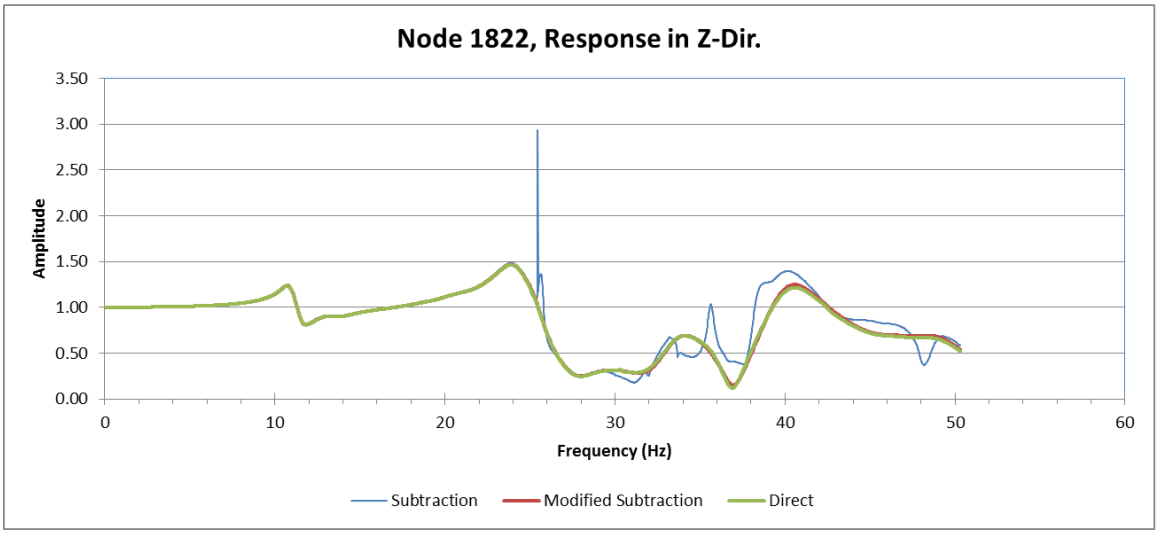
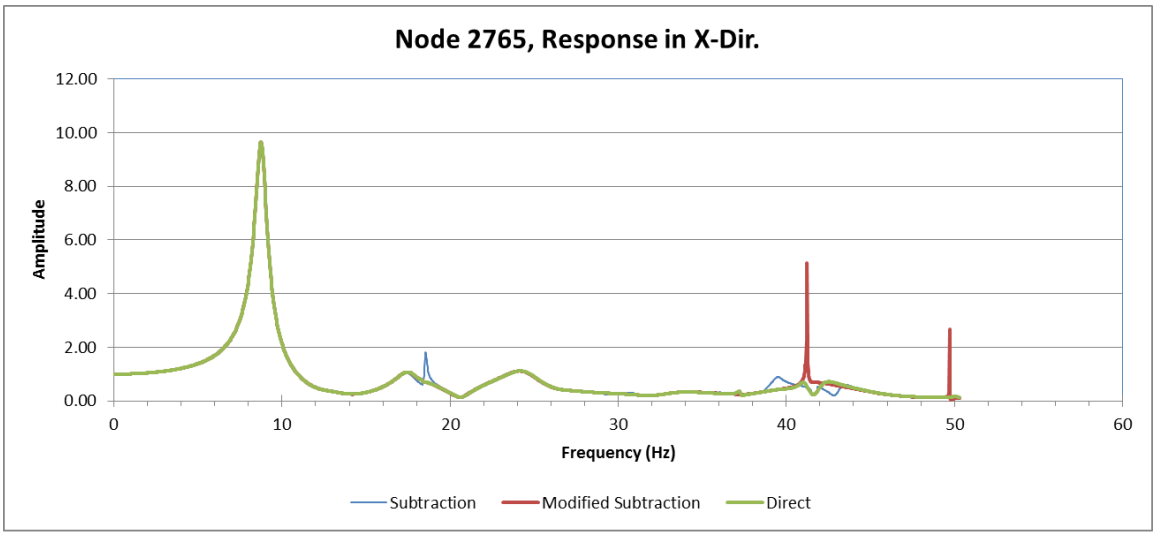
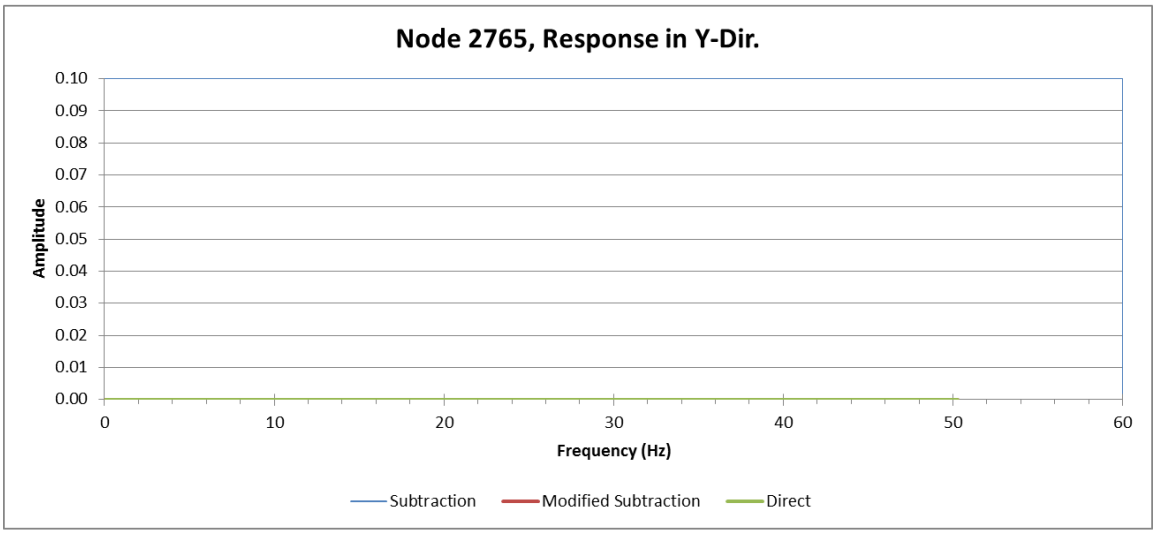


Figure 33: Comparison of Transfer Functions, Node 1822, Input in Z-Dir. - Hard Rock Site





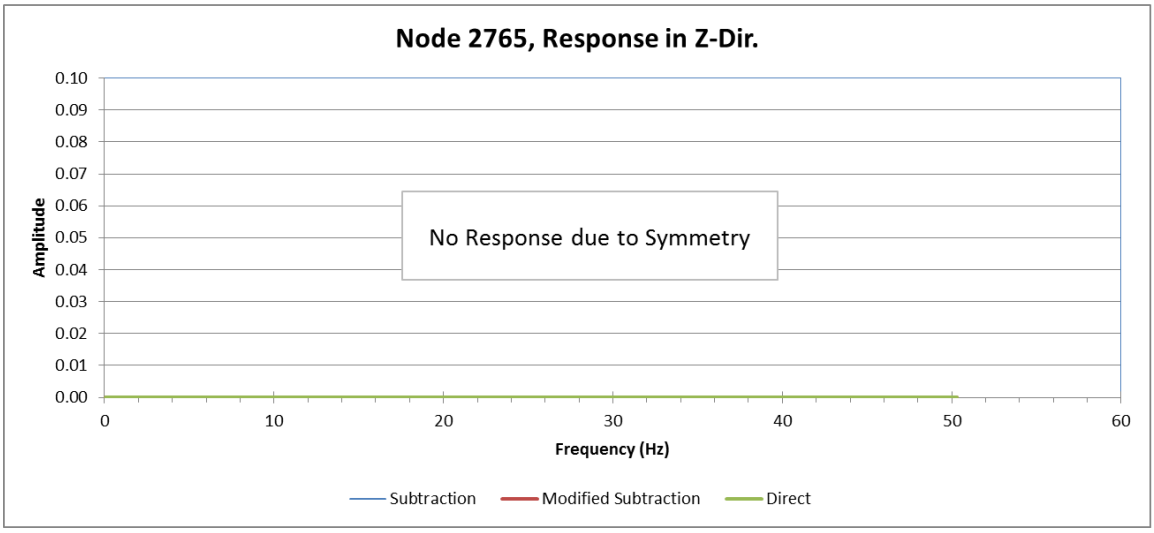
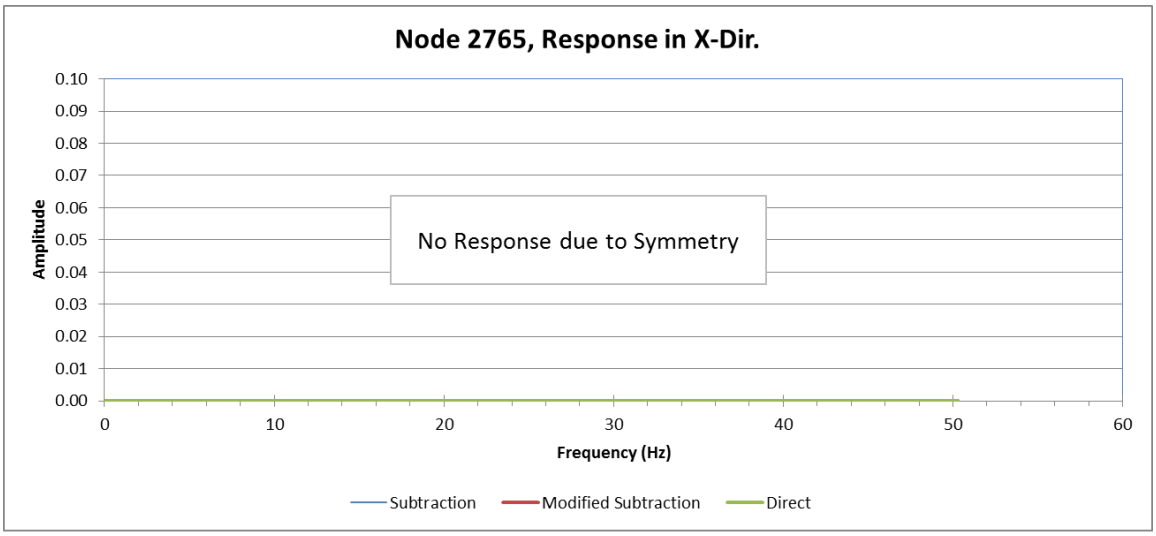
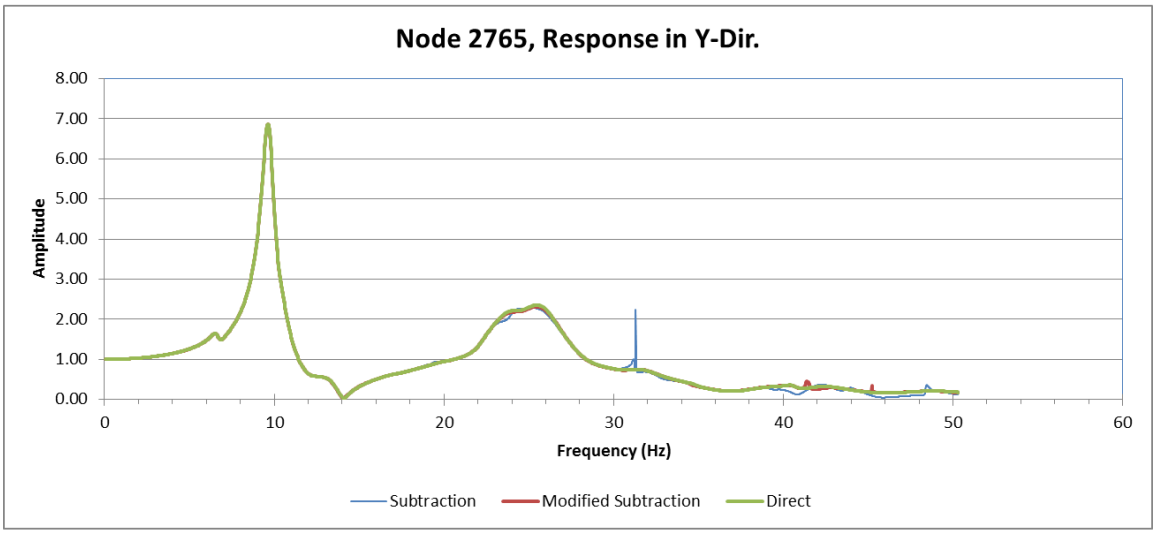


Figure 34: Comparison of Transfer Functions, Node 2765, Input in X-Dir. - Hard Rock Site





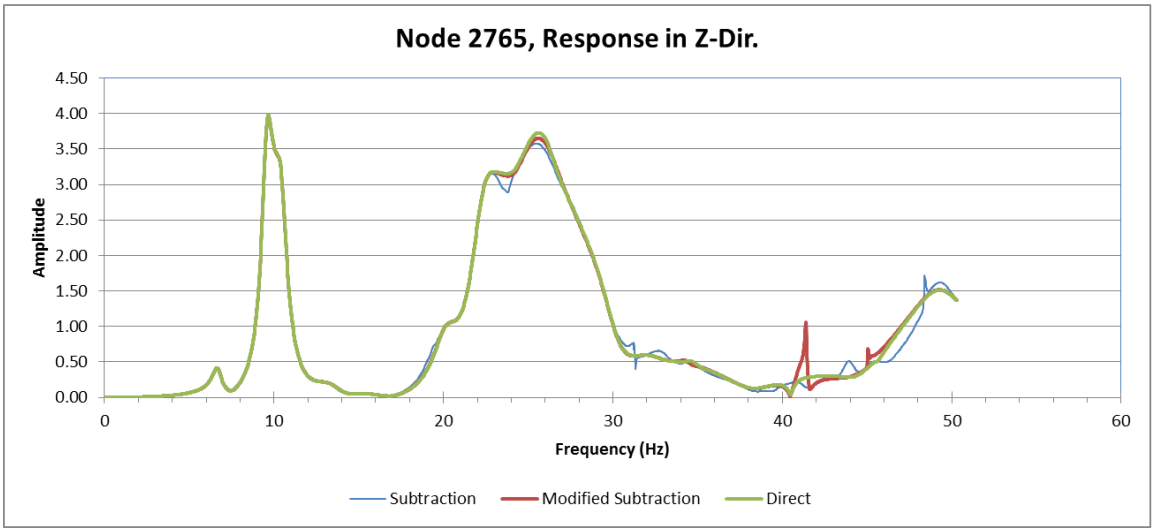
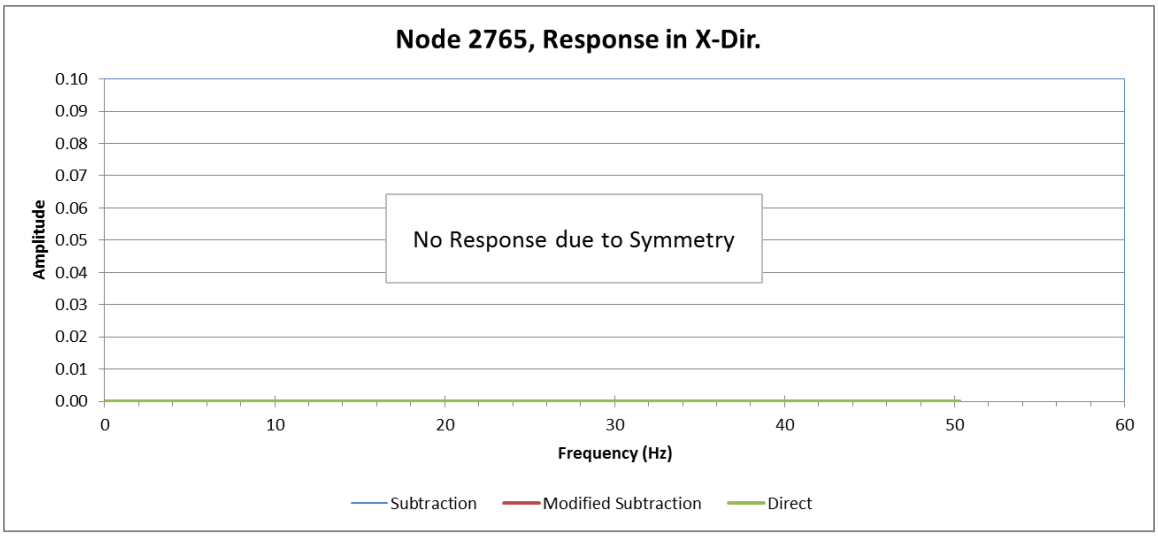
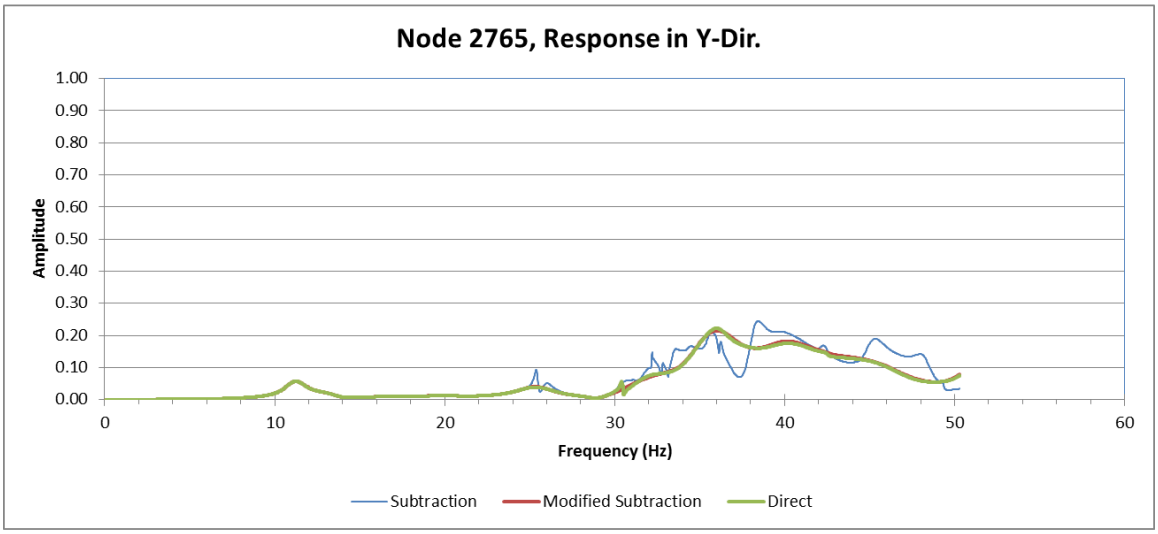


Figure 35: Comparison of Transfer Functions, Node 2765, Input in Y-Dir. - Hard Rock Site





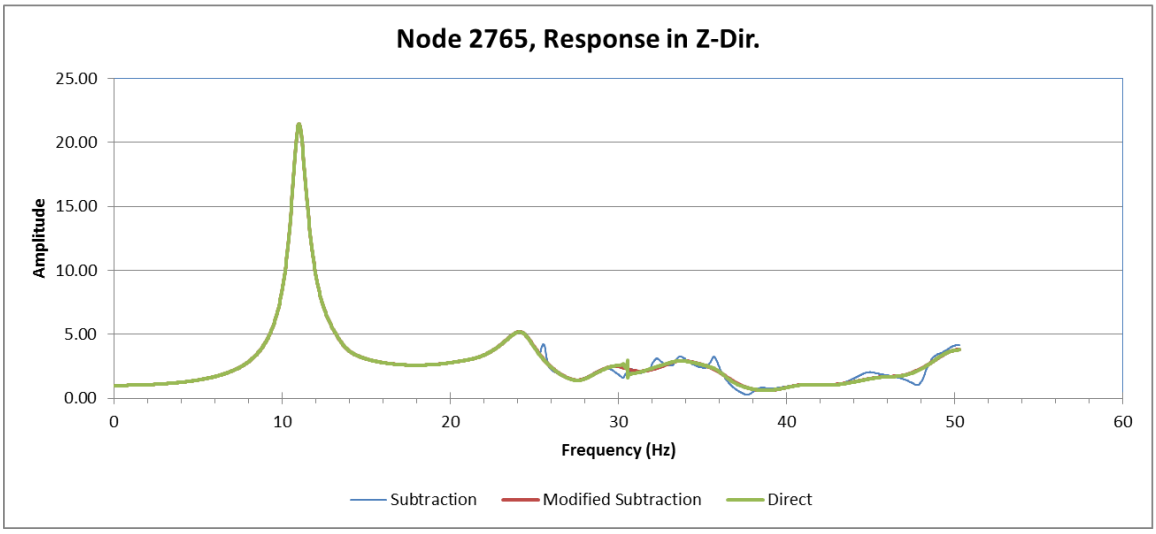
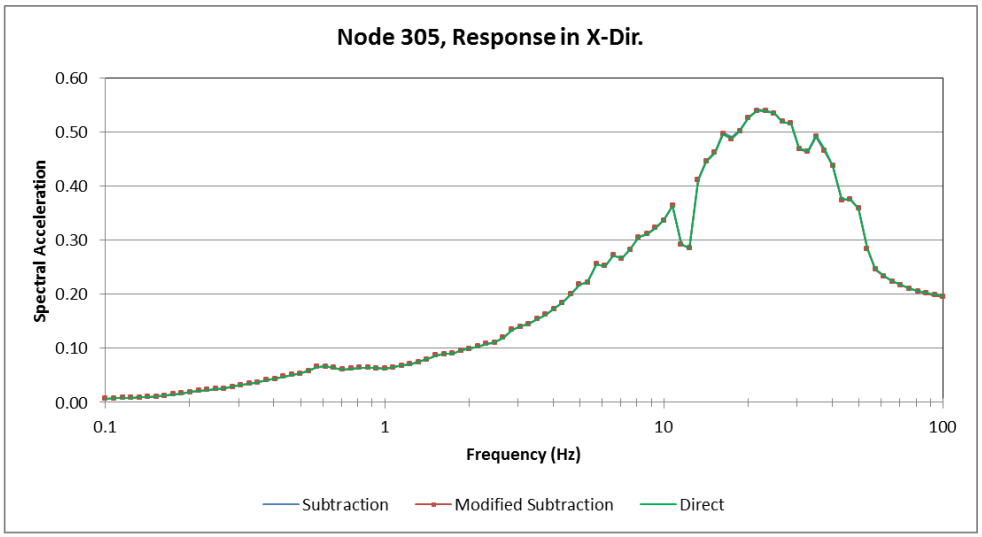
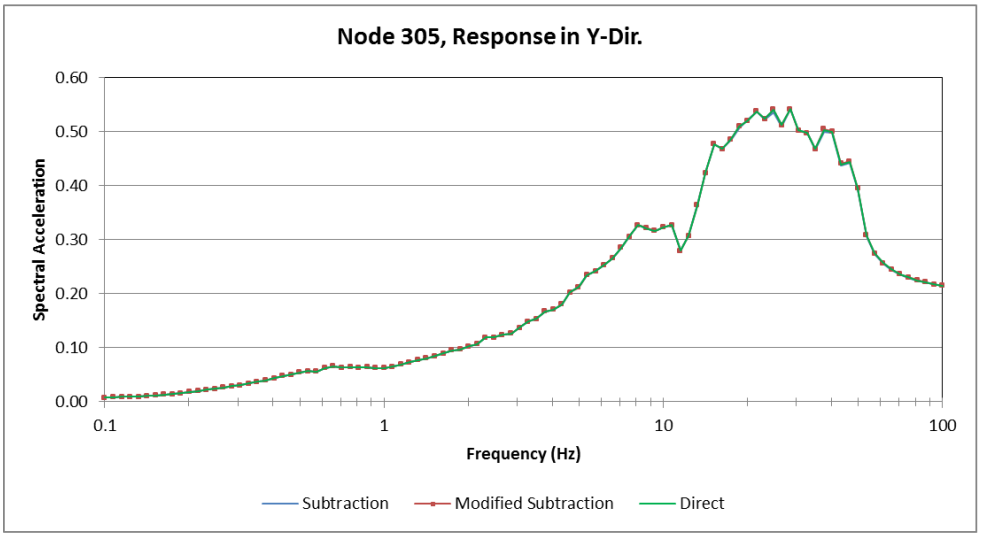


Figure 36: Comparison of Transfer Functions, Node 2765, Input in Z-Dir. - Hard Rock Site





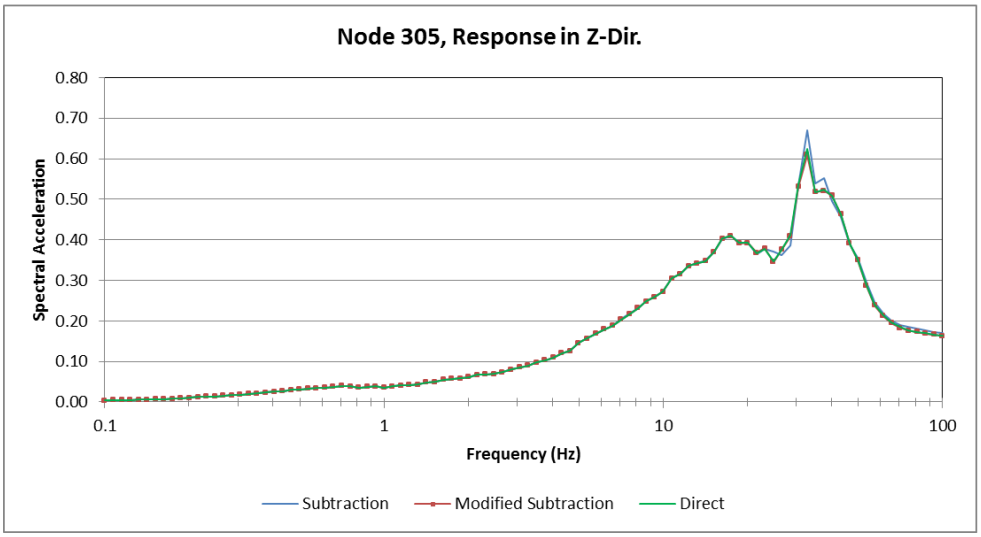
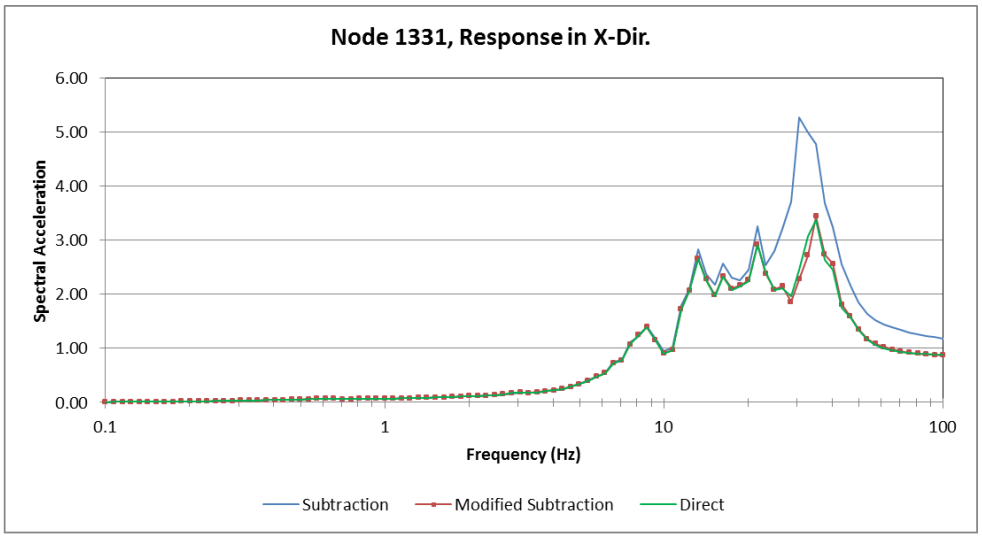
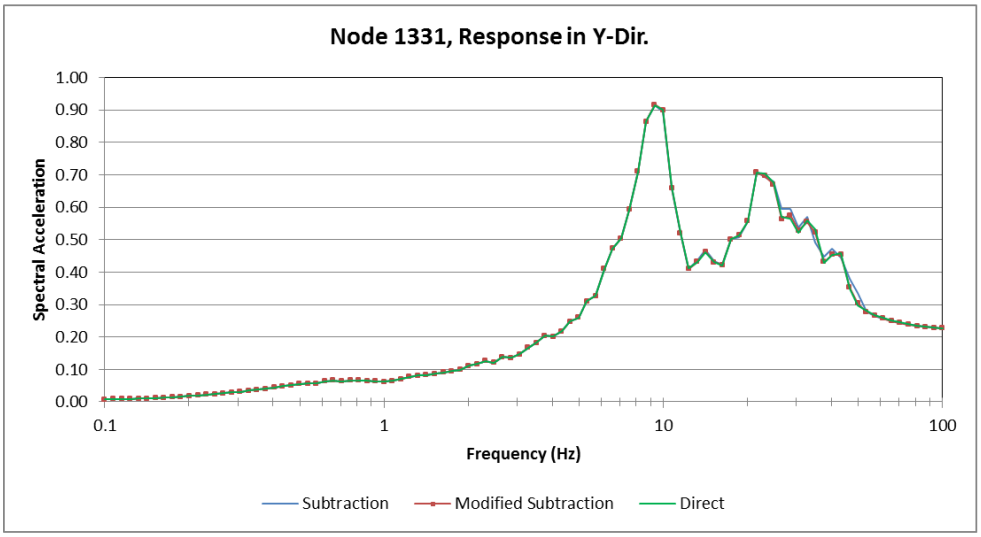


Figure 37: Comparison of 5%-Damped Response Spectra, Node 305 - Hard Rock Site





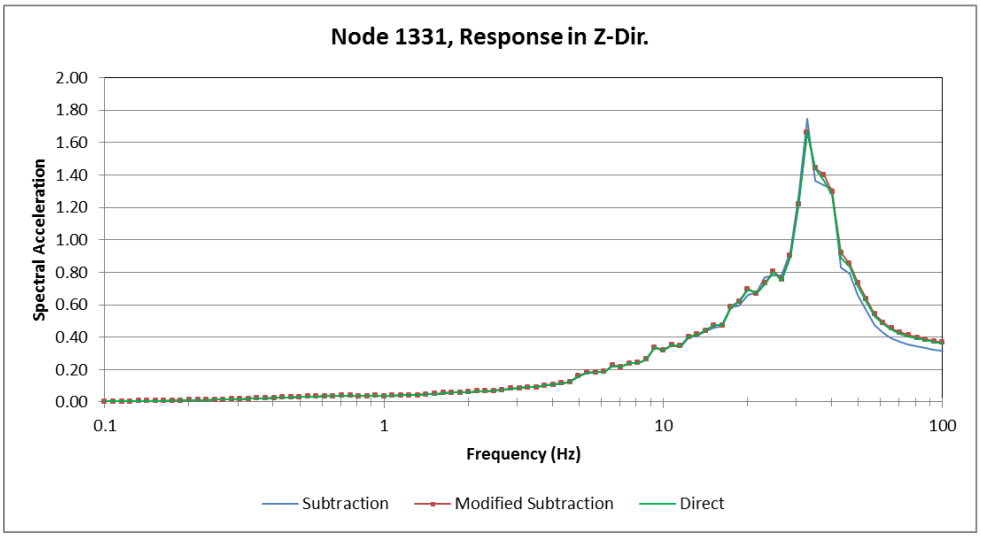
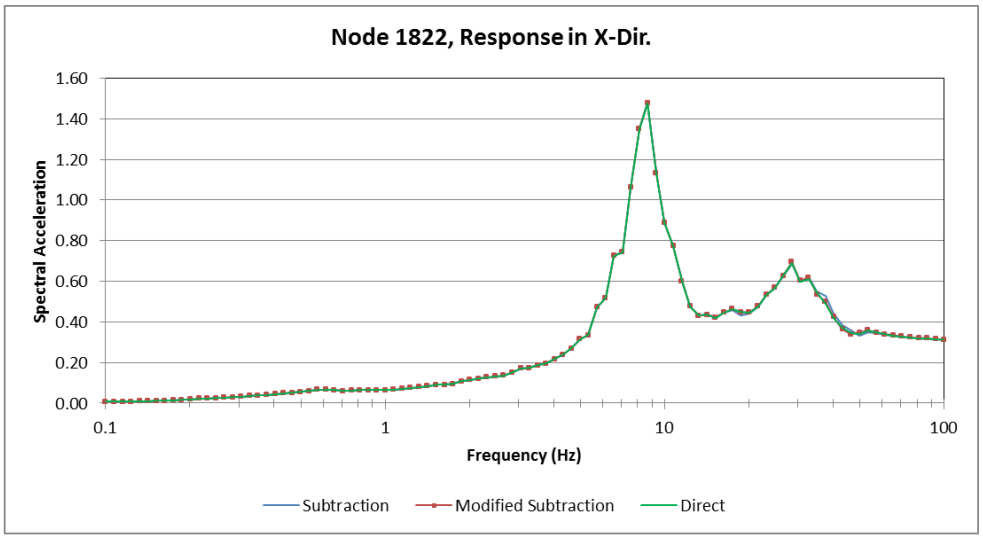
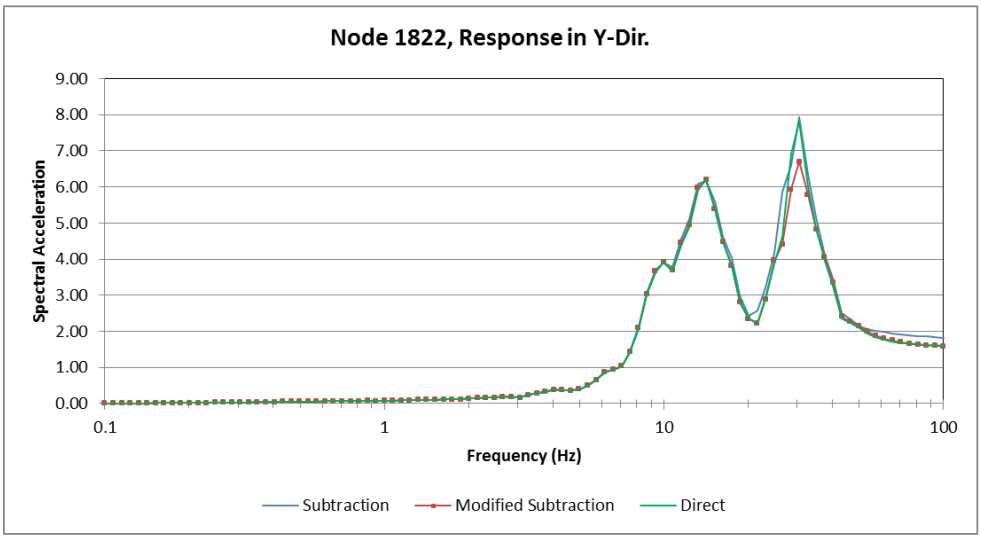


Figure 38: Comparison of 5%-Damped Response Spectra, Node 1331 - Hard Rock Site





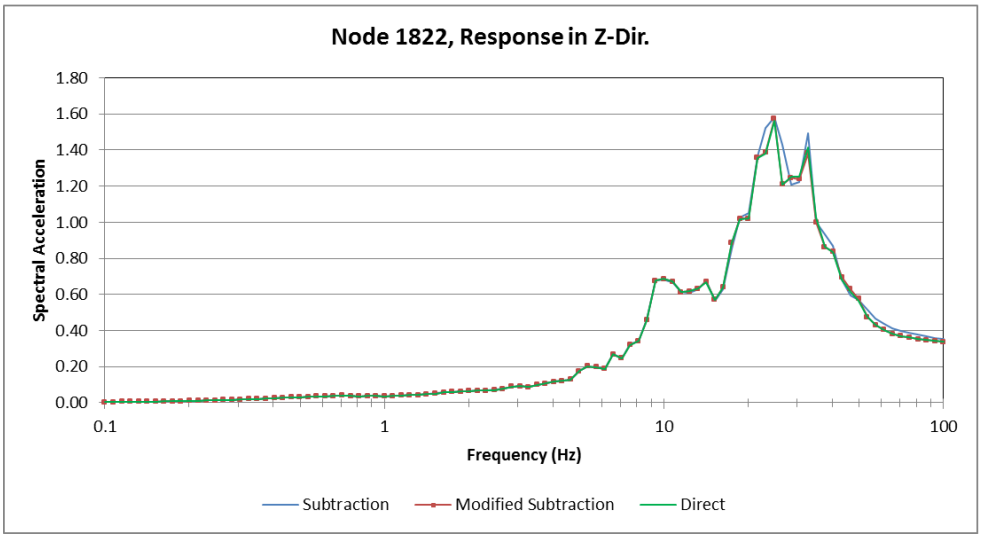
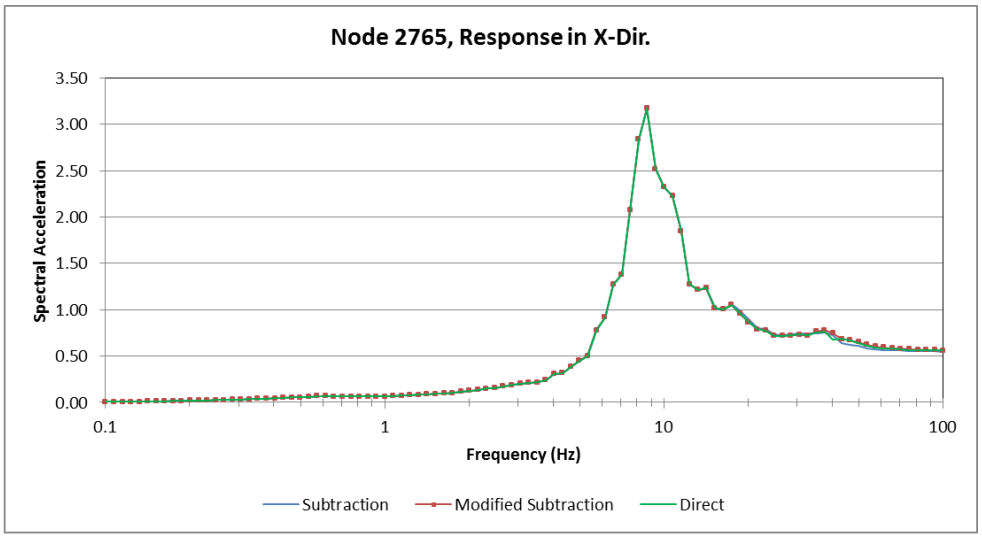
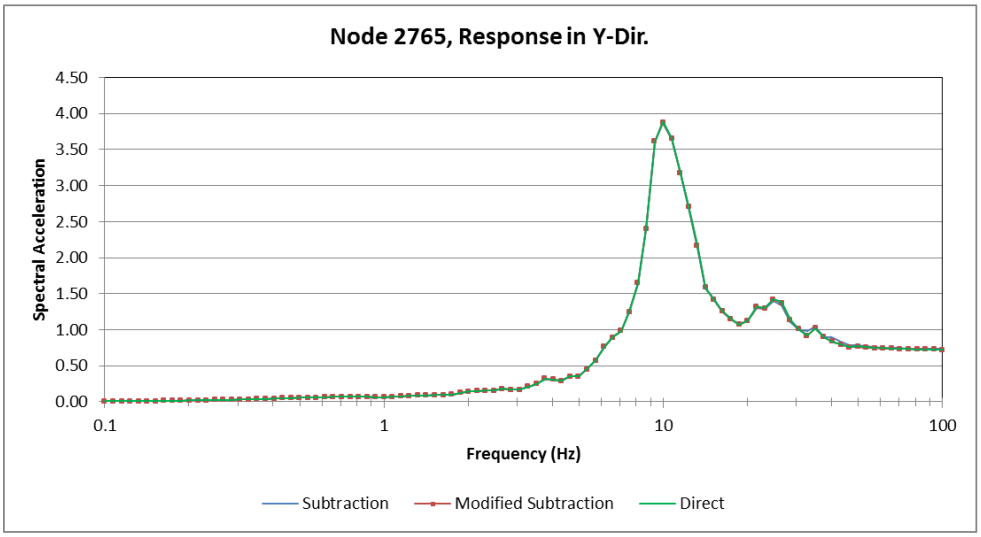


Figure 39: Comparison of 5%-Damped Response Spectra, Node 1822 - Hard Rock Site





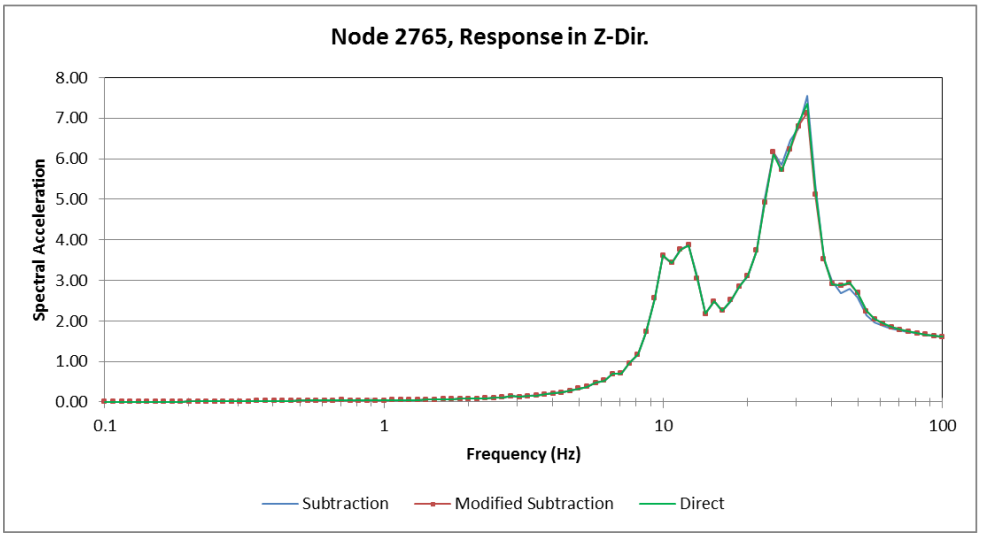


Figure 40: Comparison of 5%-Damped Response Spectra, Node 2765 - Hard Rock Site