Transactions, SMiRT-22
San Francisco, California, USA - August 18-23, 2013
Division V

VERIFICATION OF WTP SSI ANALYSIS RESULTS BY SASSI 2000 WITH SUBTRACTION METHOD

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ABSTRACT

The seismic soil-structure interaction (SSI) analysis is a vital part for the structural design and equipment seismic qualification of the Waste Treatment and Immobilization Plant (WTP) currently under construction at the DOE Hanford Site. The SSI analysis has been performed using the program SASSI2000 with the Subtraction Method, an internal option for fast impedance computations. A recent research report in the literature challenges the accuracy and applicable range of the Subtraction Method. This challenge initiated the verification study reported herein.

A hybrid finite element/stick model of the High Level Waste (HLW) Vitrification Building of WTP was adopted for the purpose of this study. The stick model dynamic properties were successfully reconciled with those of the detail finite element model as part of a separate study. Two parallel SSI analyses were performed using identical model and soil profile settings except one used the Subtraction Method, and the other used the Direct Method, the latter is recognized as accurate, but requiring much more computation effort. Both lower bound and upper bound soil conditions were considered in the study.

Results of the parallel analyses in terms of transfer functions (TF) and In-Structure Response Spectra (ISRS) are presented in this paper. Comparison of the results indicates that, within the frequency range used in the original design analysis, the results from analysis with Subtraction Method are essentially the same as the results with Direct Method. For responses that showed some differences between the two sets of results, the results using the Subtraction Method are in general in the conservative side. It is concluded that the SSI analysis results for WTP are adequate for the design purpose.

INTRODUCTION

The Waste Treatment and Immobilization Plant (WTP) currently being constructed at the DOE Hanford Site is the largest nuclear waste treatment plant in the world. The seismic soil structure interaction (SSI) analyses for the WTP Seismic Category I building structures were performed during the 2001 – 2005 period. The analyses were performed using the computer program SASSI2000 (Lysmer, et al, 1999) with the Subtraction Method, a built-in option in the program for fast computation of the impedance matrix. Results of the analyses form the basis of seismic design of the WTP building structures and seismic qualification of equipment.

Mertz, et al (2010) published a parametric study for SSI with SASSI2000, challenging the accuracy of the Subtraction Method for finite element models under extreme conditions. The publication of this report caused concerns in DOE management on the adequacy of the SSI work for WTP. It is the purpose of this paper to present the verification studies that we have done to confirm the adequacy and accuracy of WTP SSI work.

METHODOLOGY

In SASSI2000, two methods of impedance computations are implemented. The first method is called “direct” method which assumes the full volume of the excavated soil mass is participating in the interaction. This method was first developed in the original SASSI (1980) and is commonly accepted as sufficient in comparing with other methods, but is very computer resource-demanding and time-consuming. The second method, developed by Chin (1998) and first implemented in SASSI2000, is called “subtraction” method; which is an approximate method which assumes the interactions occur only at the boundaries of the excavated soil mass. This method runs much faster than the Direct Method for problems of same size, but involves more assumptions and its applicable range is strictly limited by the 1/5λ rule for element size in a SASSI model as well as the dimensionless frequency ratio in the order of 3. The limitation of the Subtraction Method and its improvement by using an extended Subtraction Method are now fully described in the new version of SASSI called SASSI2010. To assess the adequacy and accuracy of the Subtraction Method as utilized in the WTP SSI work, it is determined that the most straight forward way is to perform the analysis with both methods and compare the results from the two.

FINITE ELEMENT MODEL

The hybrid finite element/stick model that was first constructed to demonstrate the accuracy of SSI analyses results calculated for WTP is used in this study. This hybrid model consists of the below grade exterior walls and basemat of the full finite element model of the High Level Waste (HLW) Vitrification Building, as did in the design SSI analysis, but the interior structure below grade and the upper structure above grade are simplified as a beam-lumped mass assembly. Figure 1 shows the hybrid model. Figure 2 shows the details of the upper-structure sticks. The dynamic properties of the stick model were closely reconciled with those a detailed finite element model for the purpose of several studies including the study reported herein.

The extreme soil profiles used in the design SSI analysis, the lower bound (LB) and upper bound (UB) soil profiles are considered in this study. Figure 3 shows the strain compatible shear wave velocity distributions of LB and UB profiles. The corresponding damping profiles are not shown here due to space limitations.

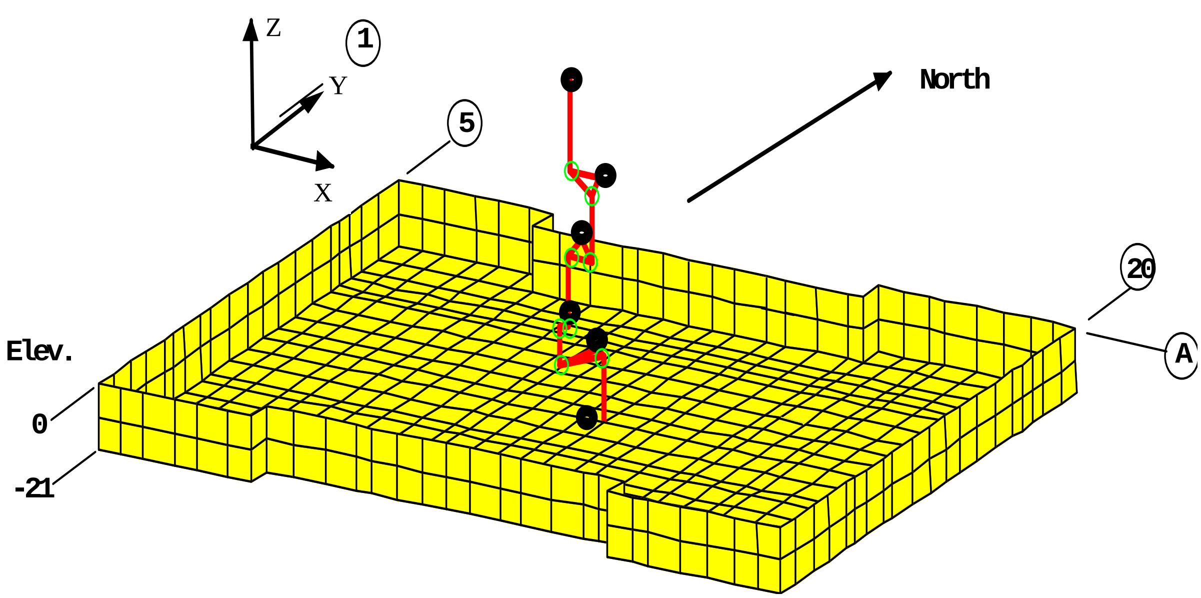


Figure 1 The Hybrid Finite Element Model for SASSI Verification

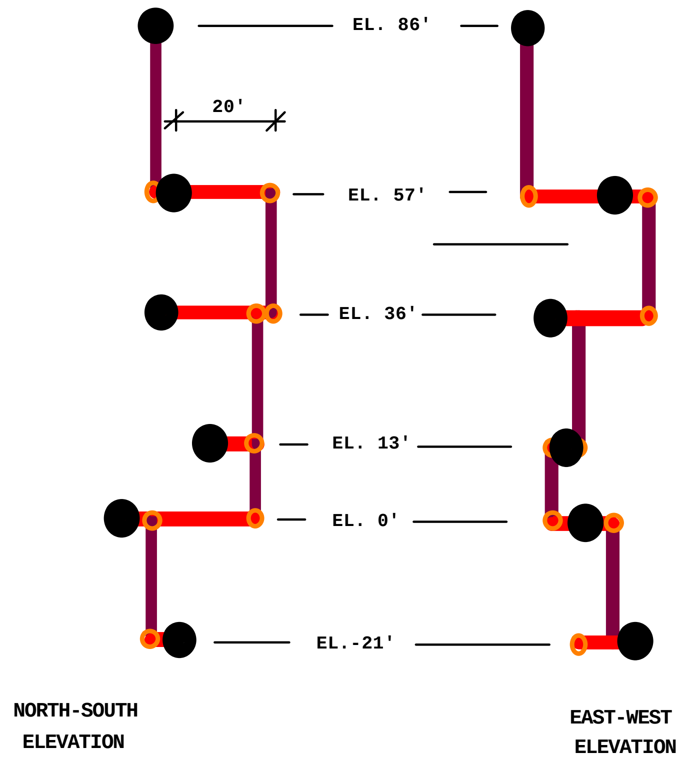


Figure 2 Details of the Beam-Lumped Mass Model

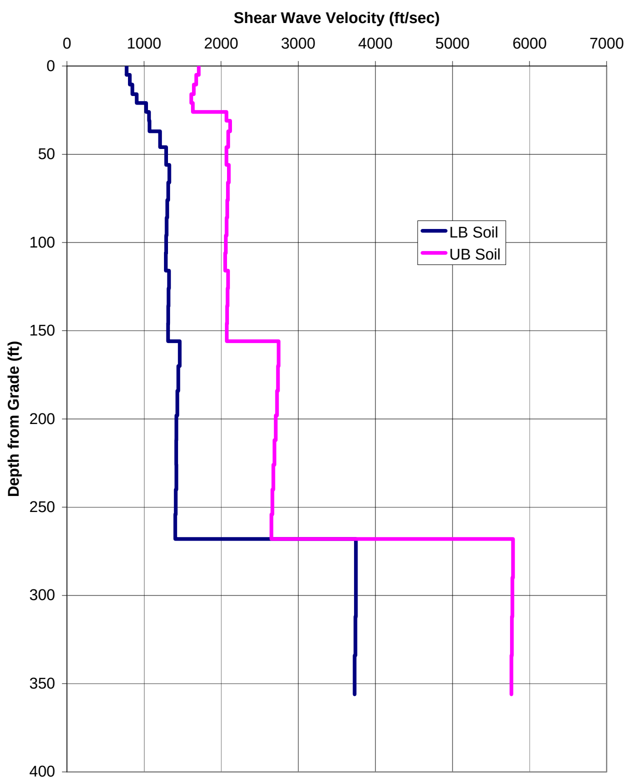


Figure 3 Strain-Compatible Vs Distribution for LB and UB Soil Profiles

RESULTS OF ANALYSIS

Two SSI analyses were performed on the same model shown in Figures 1 and 2 using both Direct Method and Subtraction Method. The cutoff frequencies for the LB and UB soil cases are 10.5 Hz and 22 Hz, respectively. The frequency increment is 0.5 Hz. Additional frequencies are added to remove interpolation-related spikes.

Results of analysis in terms of transfer functions (TF) and 5% damped acceleration response spectra (ARS) in x-, y- and z-directions are computed. The output at basemat and roof of the model are presented below. In each figure, the results by subtraction and direct methods are plotted together for comparison. Comparisons at other locations are comparable, but are not shown herein due to space limitation.

Figure 4 shows the TF and ARS in X-direction at Node 7001, the basemat, for the LB profile. ARS were calculated with 5% damping ratio.

Figure 5 shows the TF and ARS in Y-direction at Node 7001, the basemat, for the LB profile. ARS were calculated with 5% damping ratio.

Figure 6 shows the TF and ARS in Z-direction at Node 7001, the basemat, for the LB profile. ARS were calculated with 5% damping ratio.

Figure 7 shows the TF and ARS in X-direction at Node 7015, the roof, for the LB profile. ARS were calculated with 5% damping ratio.

Figure 8 shows the TF and ARS in Y-direction at Node 7015, the roof, for the LB profile. ARS were calculated with 5% damping ratio.

Figure 9 shows the TF and ARS in Z-direction at Node 7015, the roof, for the LB profile. ARS were calculated with 5% damping ratio.

Figure 10 shows the TF and ARS in X-direction at Node 7001, the basemat, for the UB profile. ARS were calculated with 5% damping ratio.

Figure 11 shows the TF and ARS in Y-direction at Node 7001, the basemat, for the UB profile. ARS were calculated with 5% damping ratio.

Figure 12 shows the TF and ARS in Z-direction at Node 7001, the basemat, for the UB profile. ARS were calculated with 5% damping ratio.

Figure 13 shows the TF and ARS in X-direction at Node 7015, the roof, for the UB profile. ARS were calculated with 5% damping ratio.

Figure 14 shows the TF and ARS in Y-direction at Node 7015, the roof, for the UB profile. ARS were calculated with 5% damping ratio.

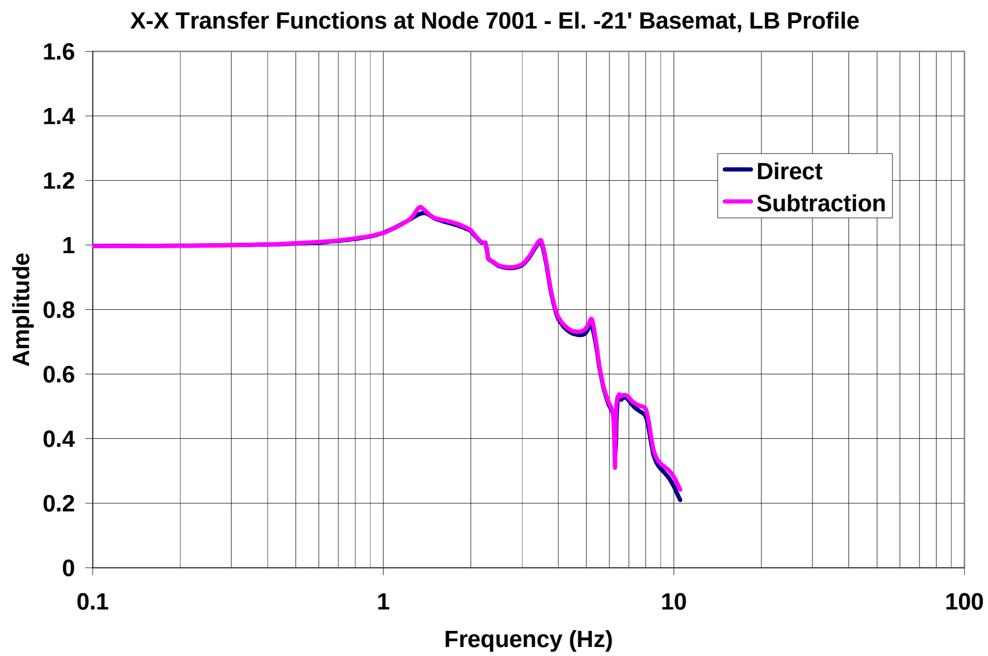
Figure 15 shows the TF and ARS in Z-direction at Node 7015, the roof, for the UB profile. ARS were calculated with 5% damping ratio.

OBSERVATIONS

The results of analysis for the hybrid model show that, in both LB and UB cases, the transfer functions from the two methods do have some minor differences at higher frequency range close to the cut-off frequencies used in WTP SSI analysis work, as opposed to the lower frequency range wherein excellent agreement between the methods was apparent However, in terms of the design quantities of interest such as the acceleration response spectra, the more important quantity in engineering practice and the basis of the seismic design and equipment qualification, the differences are insignificant and bear no consequence. The conclusion, therefore, is that the SSI analysis results for the WTP structures using the Subtraction Method are essentially as accurate as would be by using the Direct Method, and they are adequate for the seismic design and equipment qualification purposes.

REFERENCES

1. Chin, C.-C. (1998). "Substructure Subtraction Method and Dynamic Analysis of Pile Foundations." PhD Dissertation, University of California at Berkeley, California, USA
2. Lysmer, J., et al (1981). "SASSI – A System for Analysis of Soil-Structure Interaction," Report No. UCB/GT/81-02, Geotechnical Engineering, University of California, Berkeley. California, USA. April.
3. Lysmer, J., Ostadan, F. and Chin, C.-C. (1999), "SASSI2000 – A System for Analysis of Soil-Structure Interaction." Version 1.0, University of California, Berkeley. California, USA
4. Mertz, G., et al (2010) "Seismic Response of Embedded Facilities Using the SASSI Subtraction Method", Los Alamos National Laboratory Report LA-UR10-05302.



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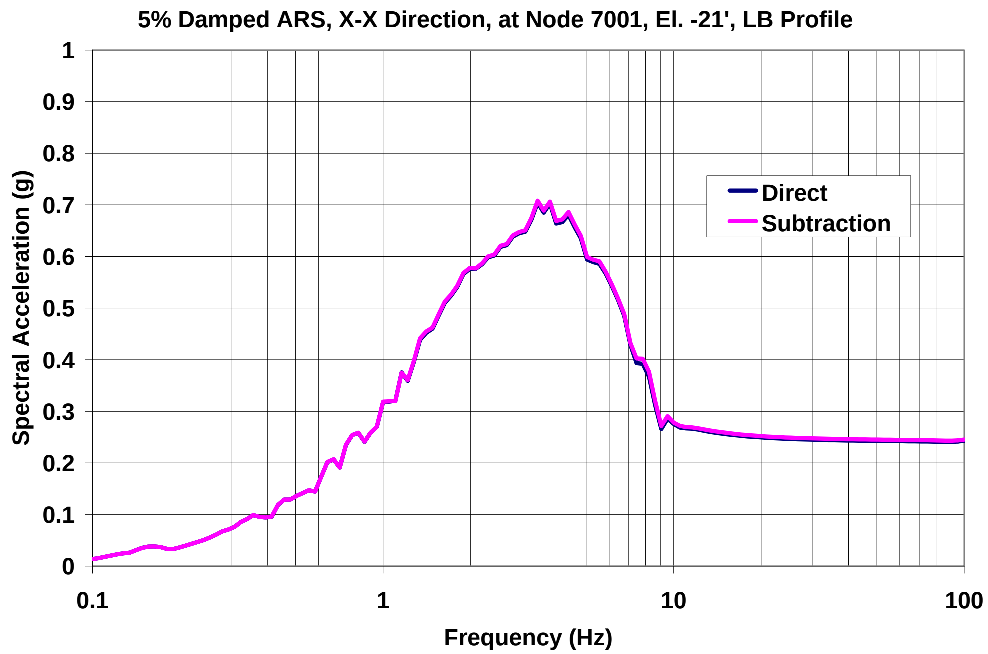
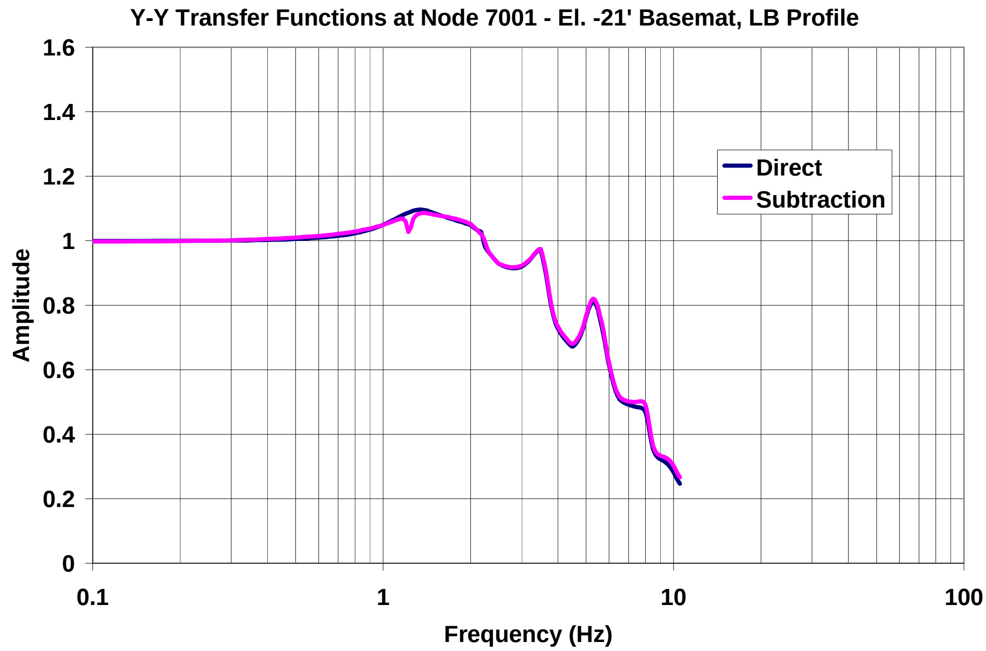


(b) Acceleration Response Spectra (ARS)

Figure 4 TF and ARS in X-direction at Node 7001, LB profile



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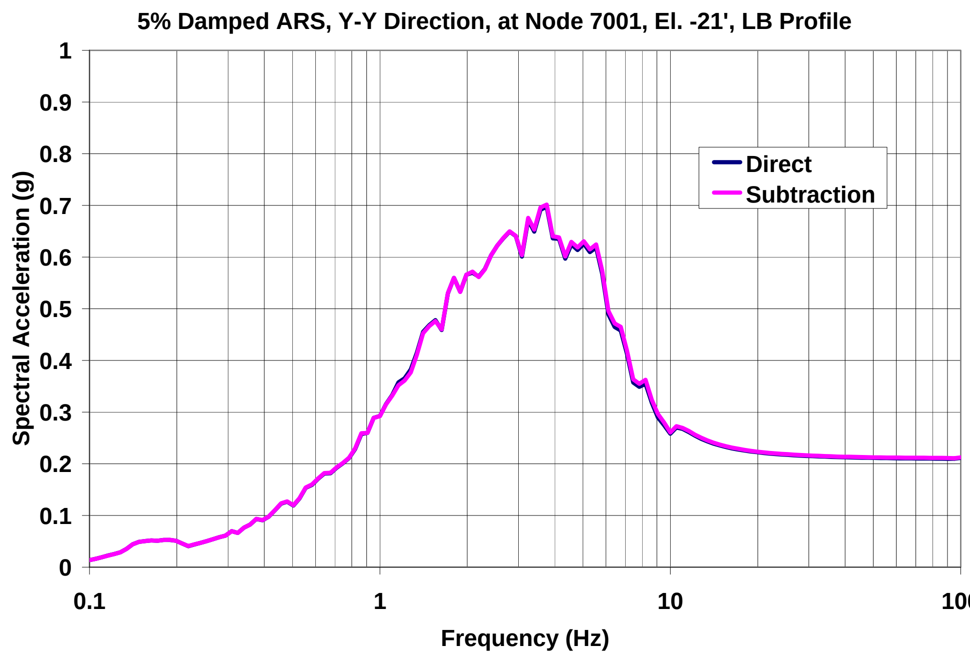
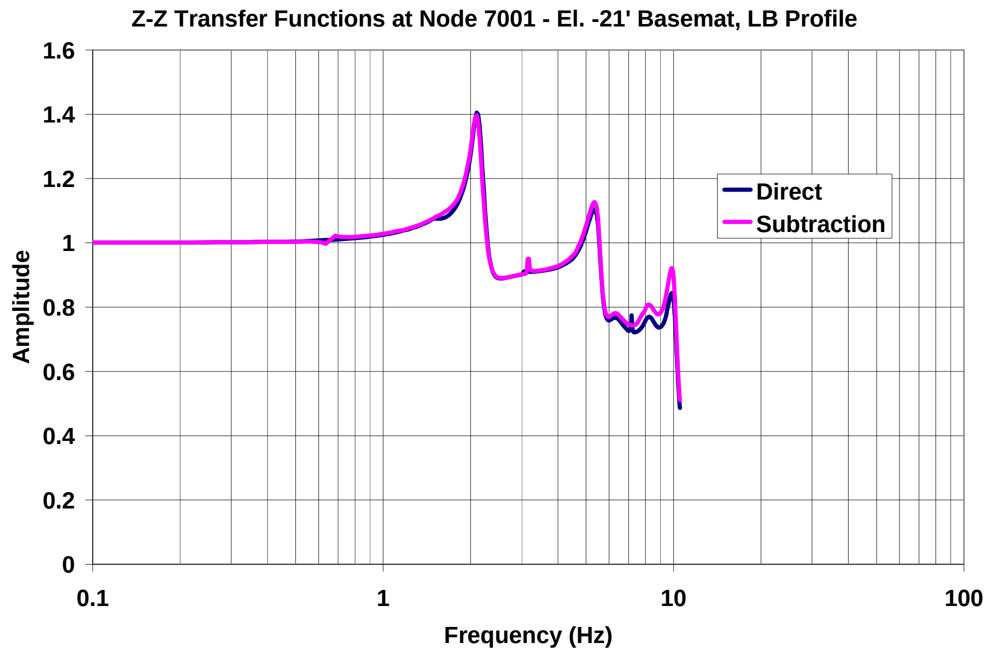


(b) Acceleration Response Spectra (ARS)

Figure 5 TF and ARS in Y-direction at Node 7001, LB profile



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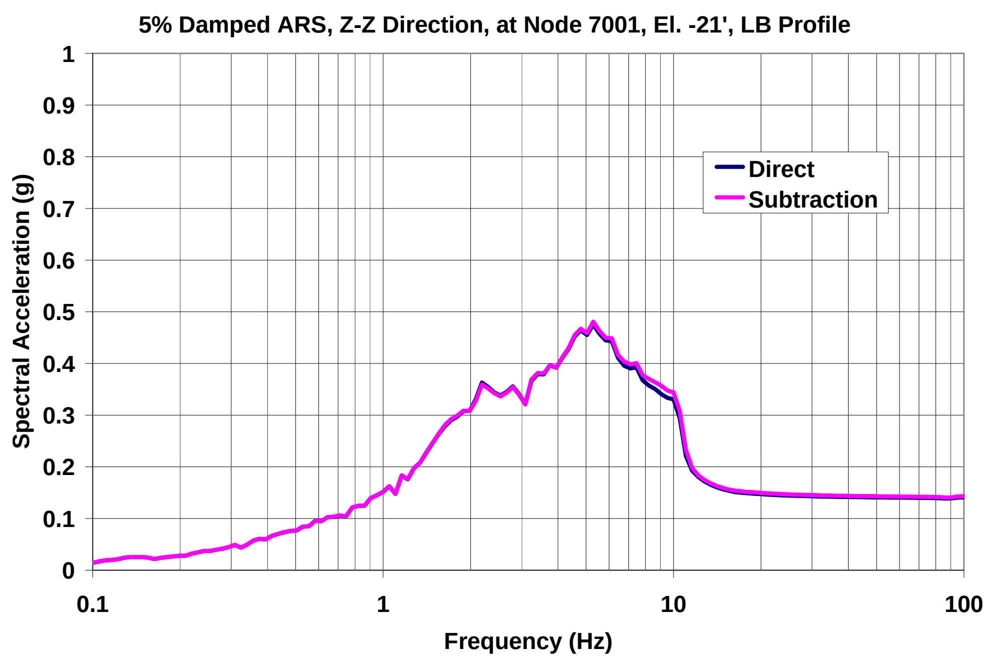
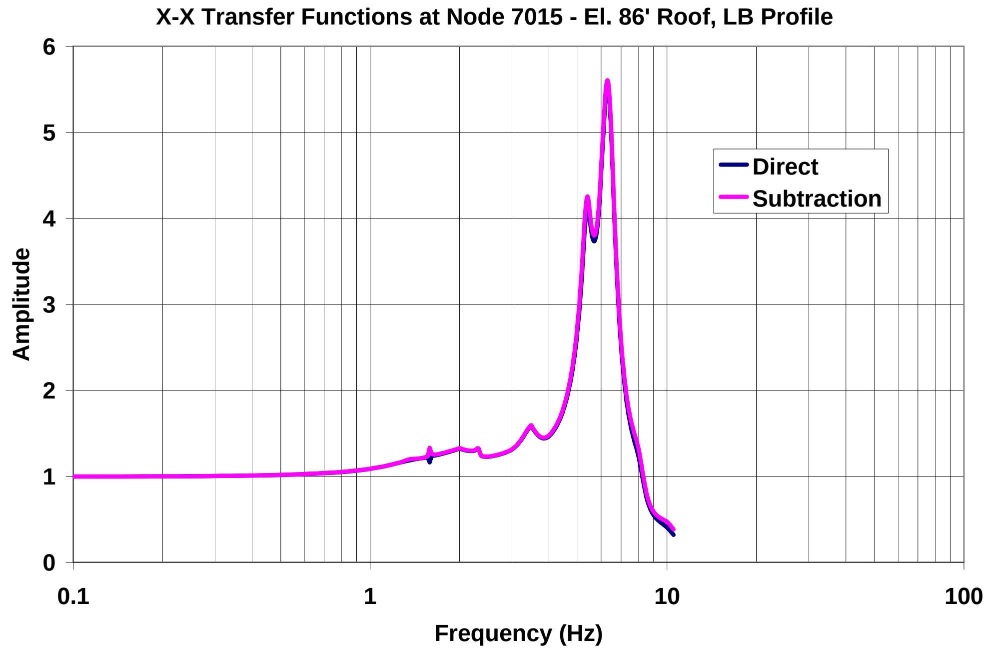


(b) Acceleration Response Spectra (ARS)

Figure 6 TF and ARS in Z-direction at Node 7001, LB profile



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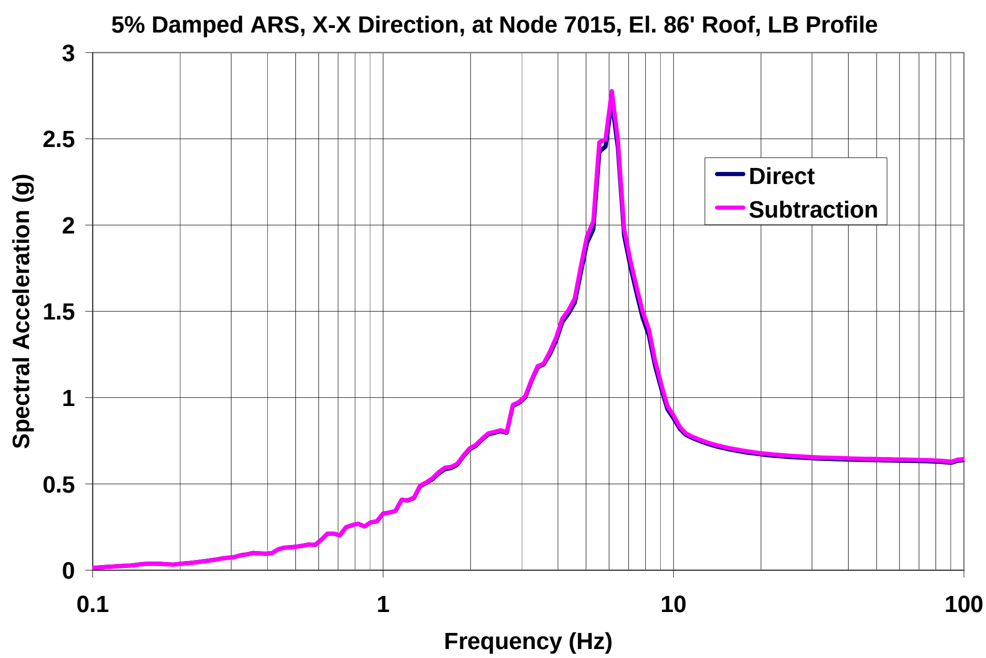
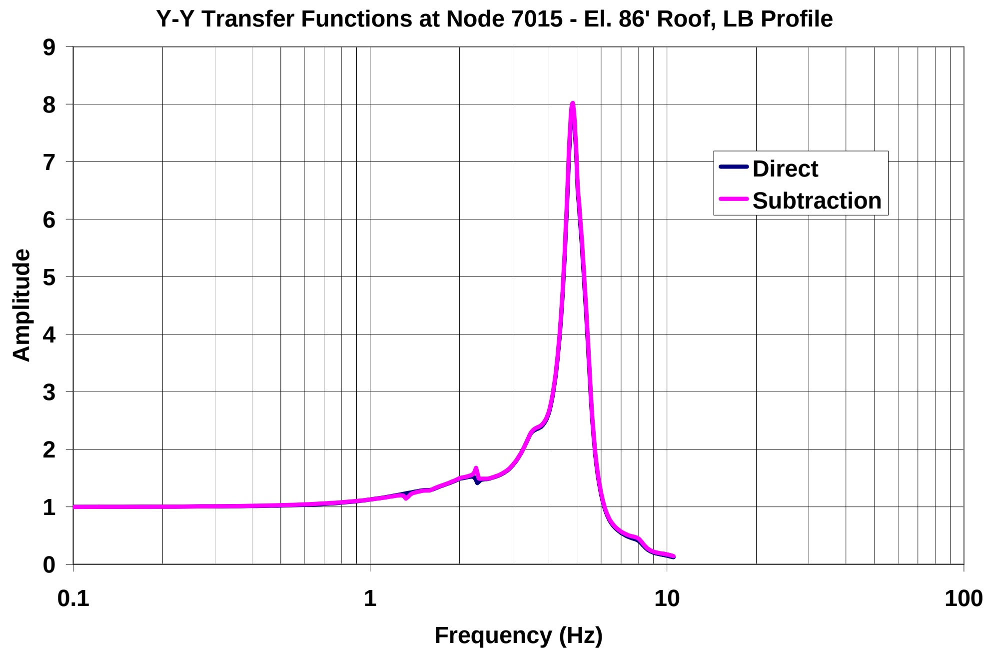
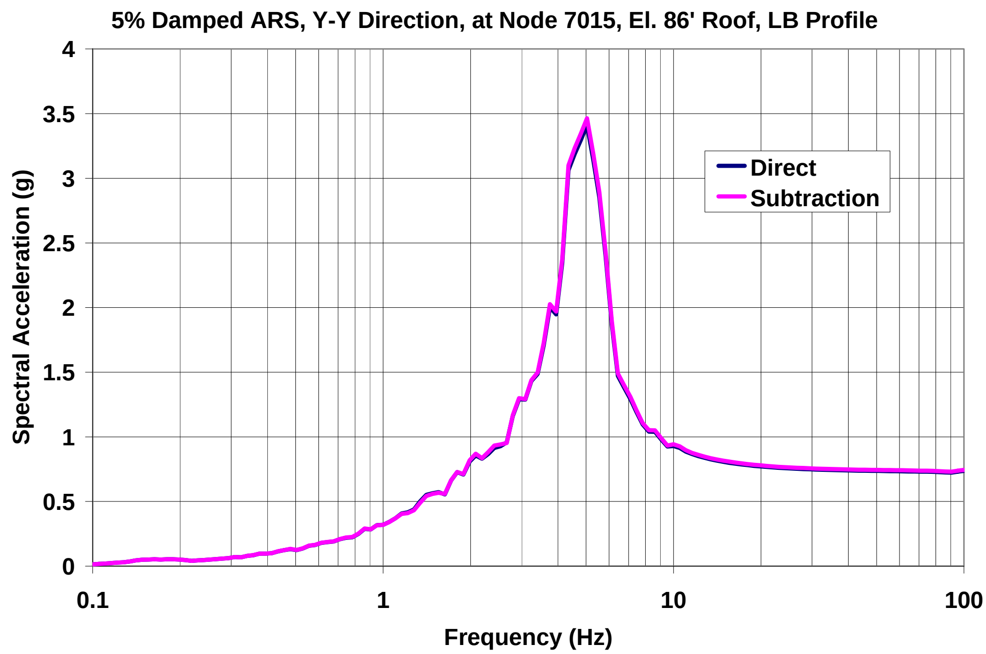


(b) Acceleration Response Spectra (ARS)

Figure 7 TF and ARS in X-direction at Node 7015, LB profile

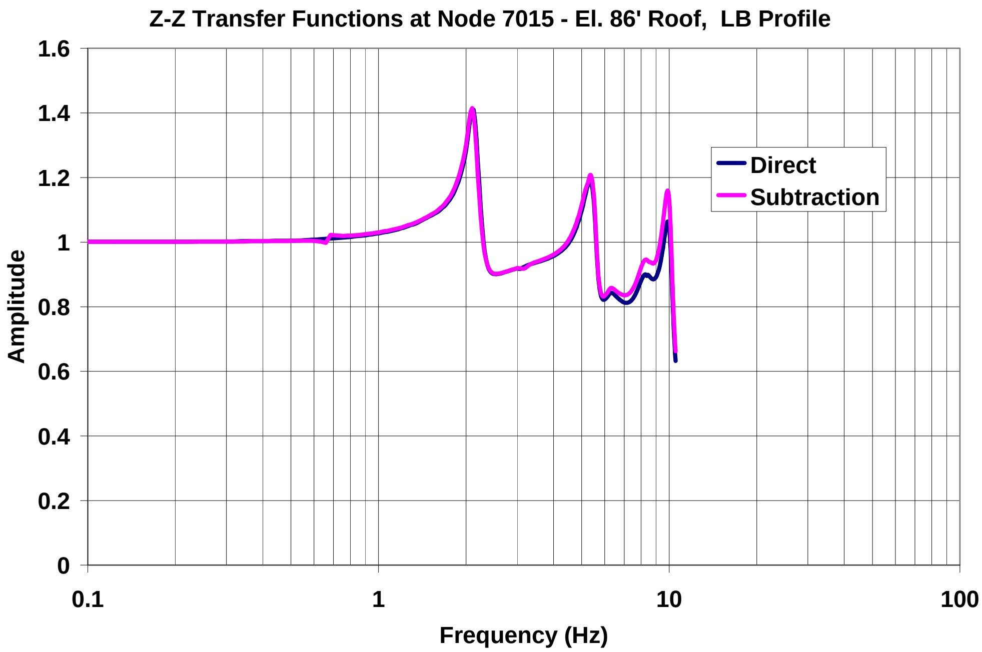


(a) Transfer Function (TF)



(b) Acceleration Response Spectra (ARS)

Figure 8 TF and ARS in Y-direction at Node 7015, LB profile



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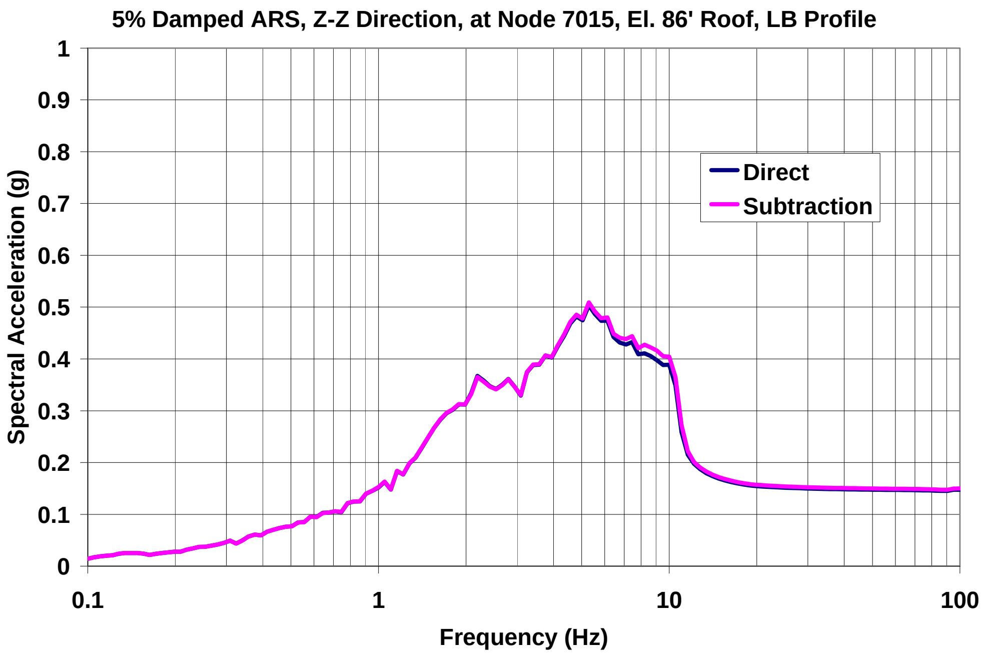
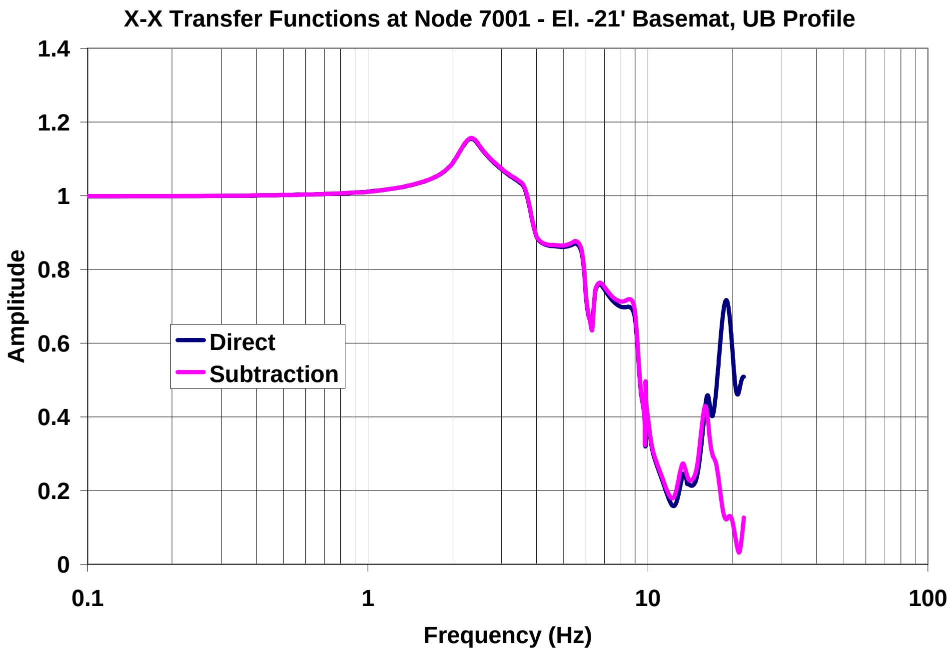


(b) Acceleration Response Spectra (ARS)

Figure 9 TF and ARS in Z-direction at Node 7015, LB profile



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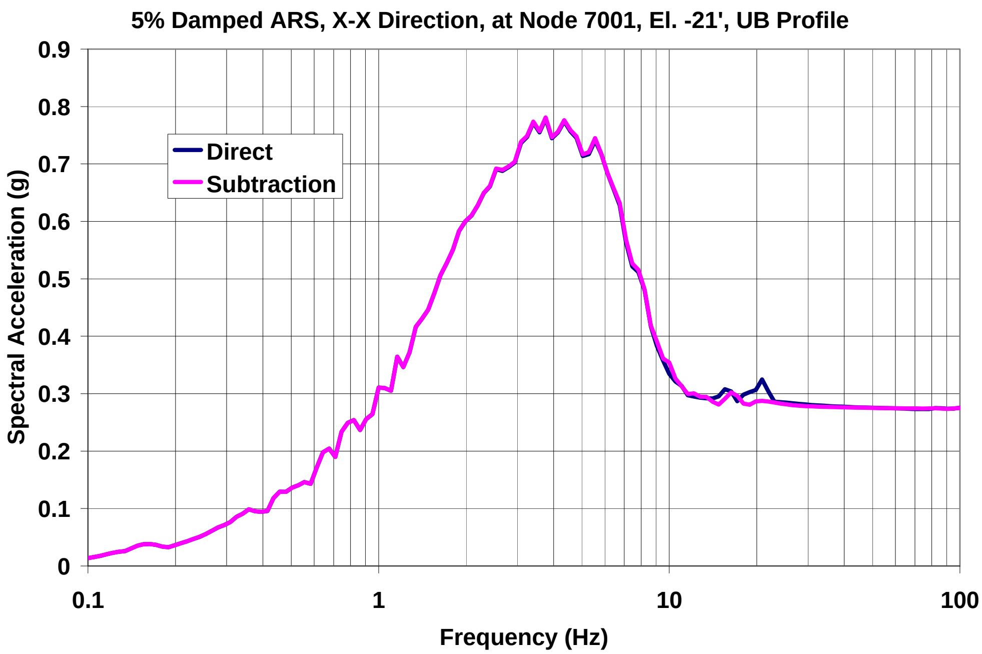
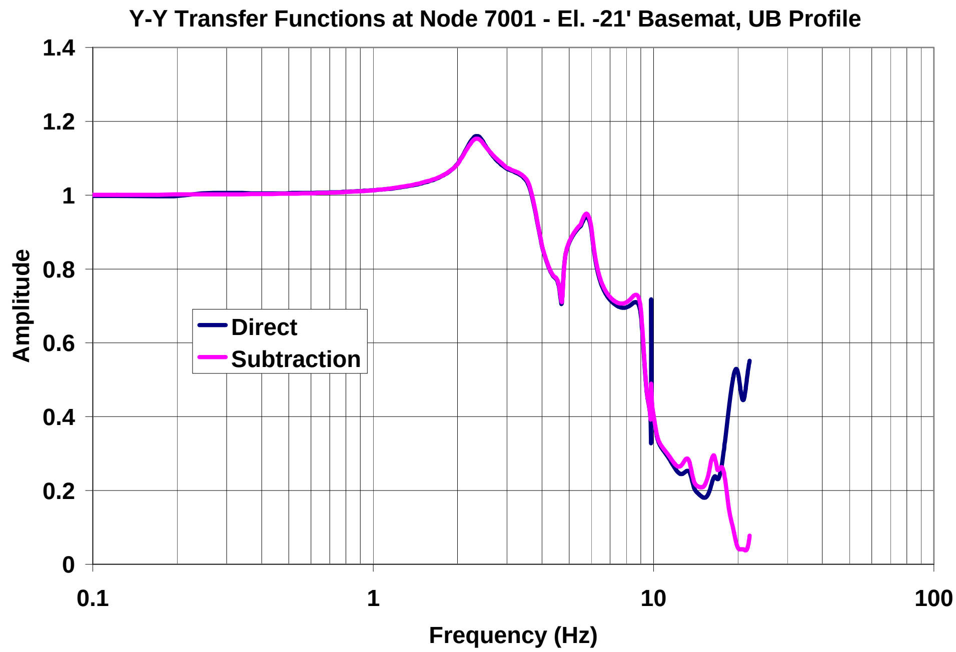


(b) Acceleration Response Spectra (ARS)

Figure 10 TF and ARS in X-direction at Node 7001, UB profile



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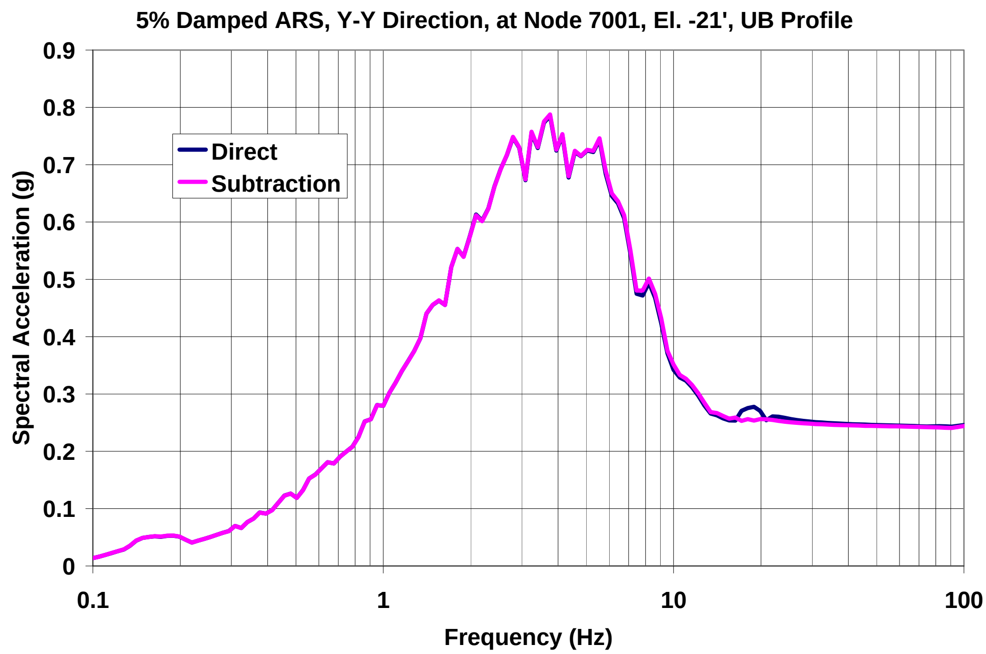
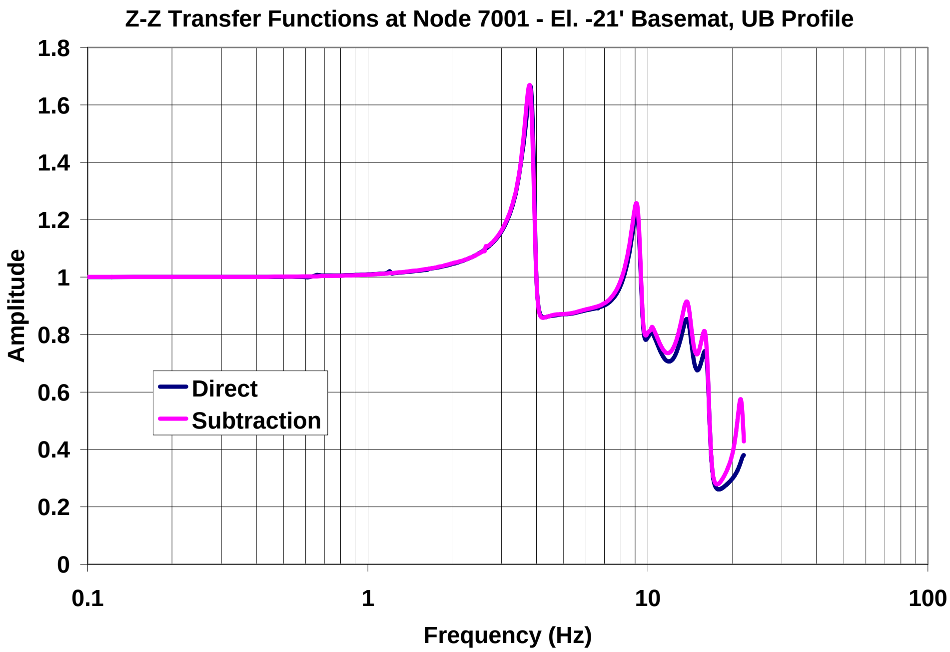


(b) Acceleration Response Spectra (ARS)

Figure 11 TF and ARS in Y-direction at Node 7001, UB profile



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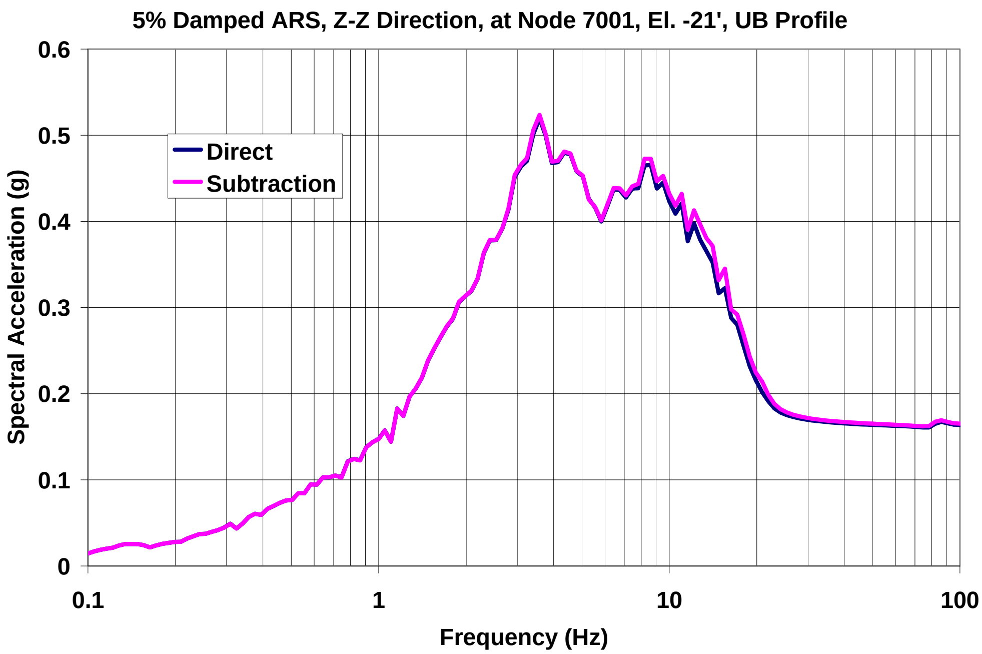
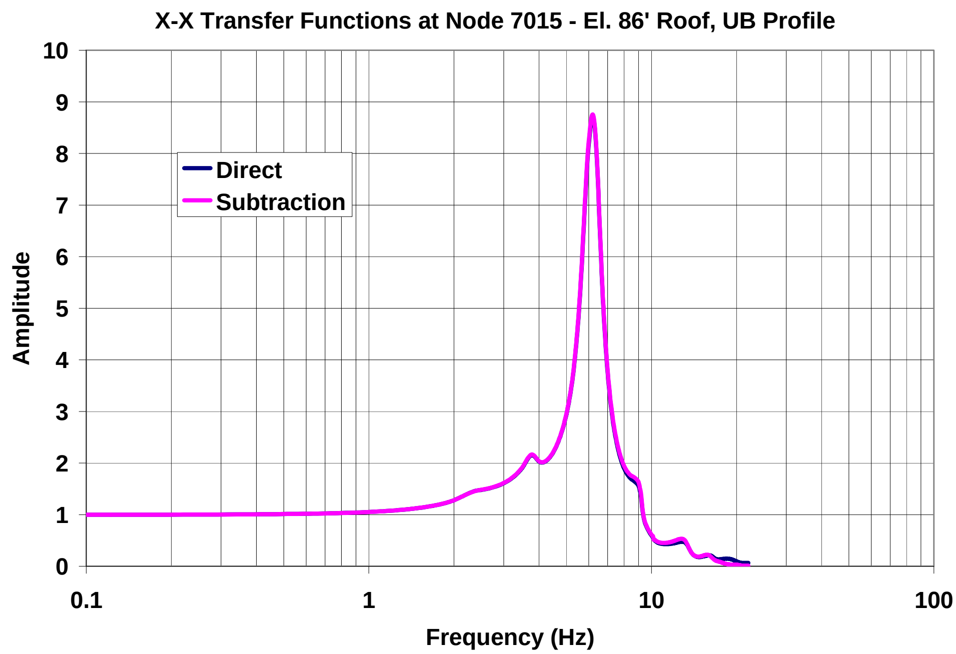


(b) Acceleration Response Spectra (ARS)

Figure 12 TF and ARS in Z-direction at Node 7001, UB profile



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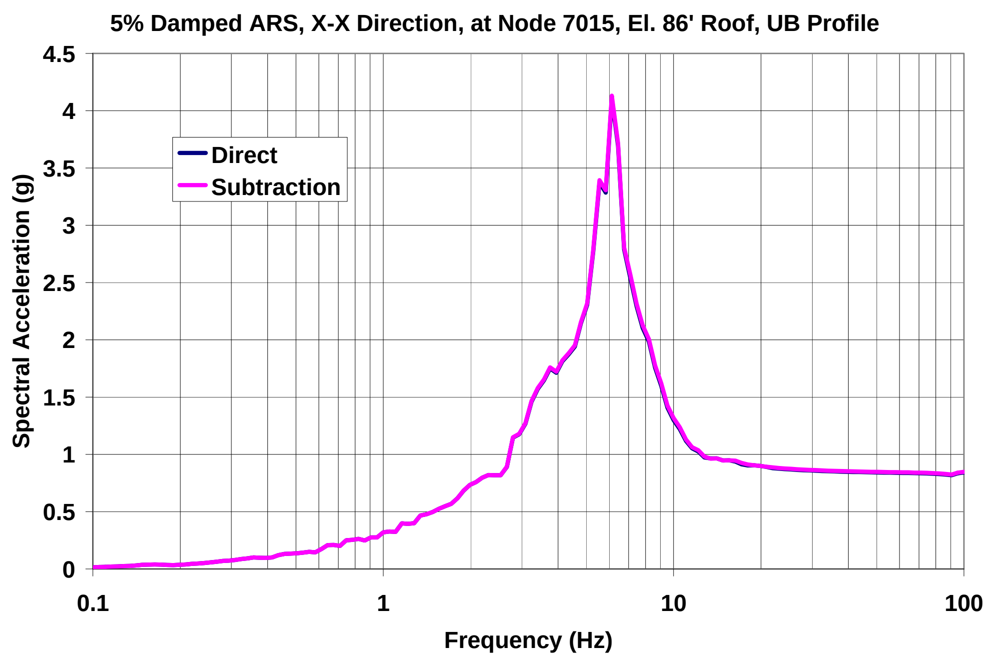
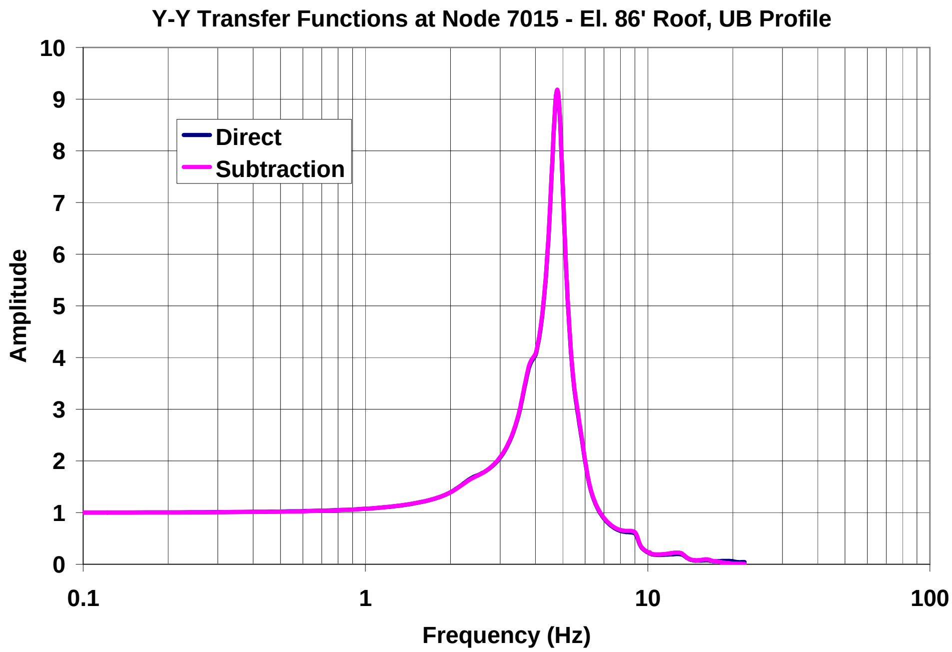


(b) Acceleration Response Spectra (ARS)

Figure 13 TF and ARS in X-direction at Node 7015, UB profile



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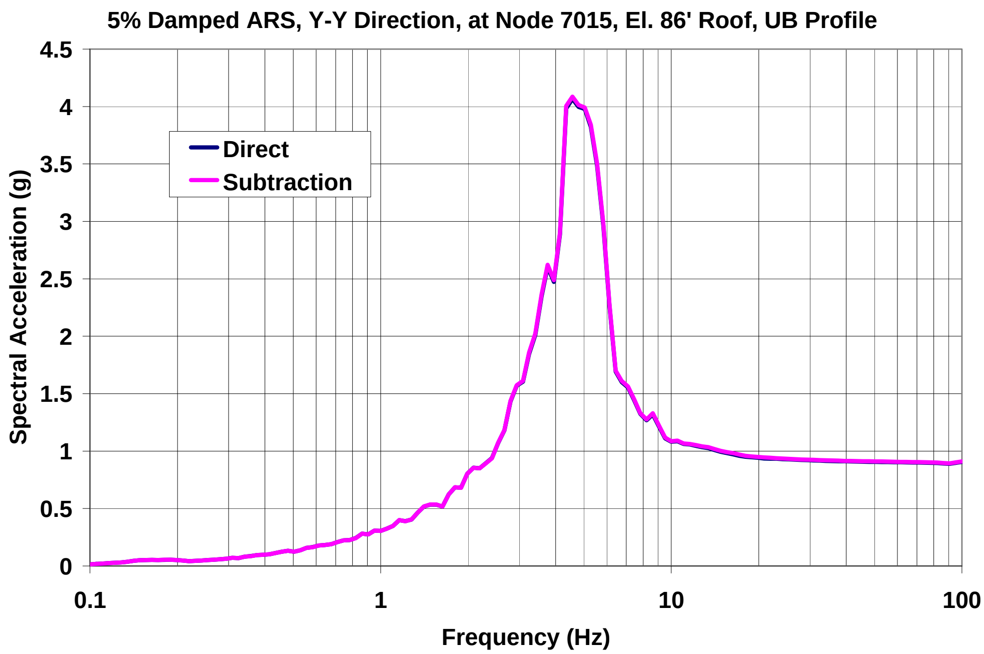
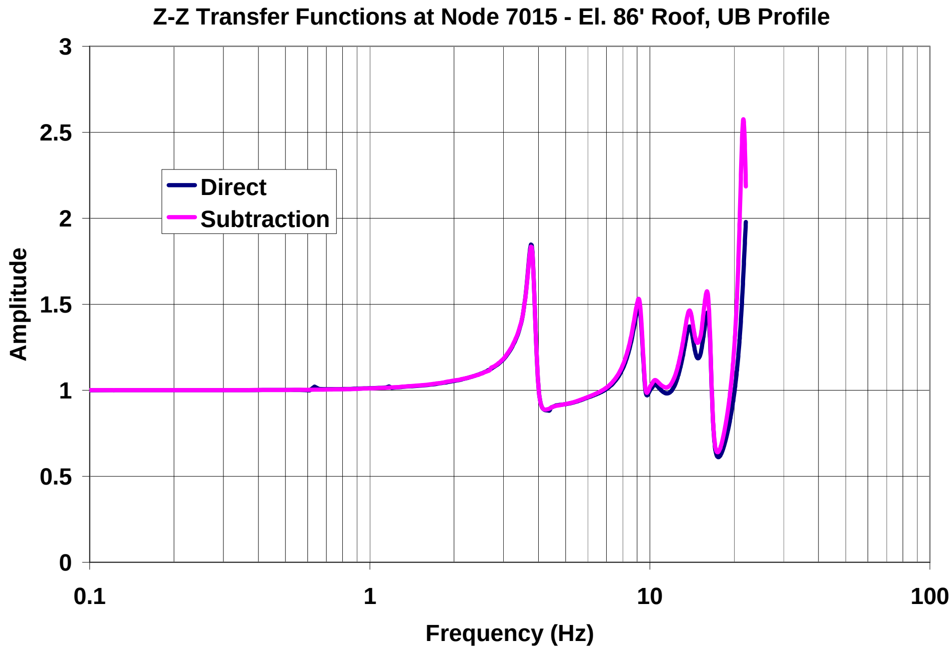


(b) Acceleration Response Spectra (ARS)

Figure 14 TF and ARS in Y-direction at Node 7015, UB profile



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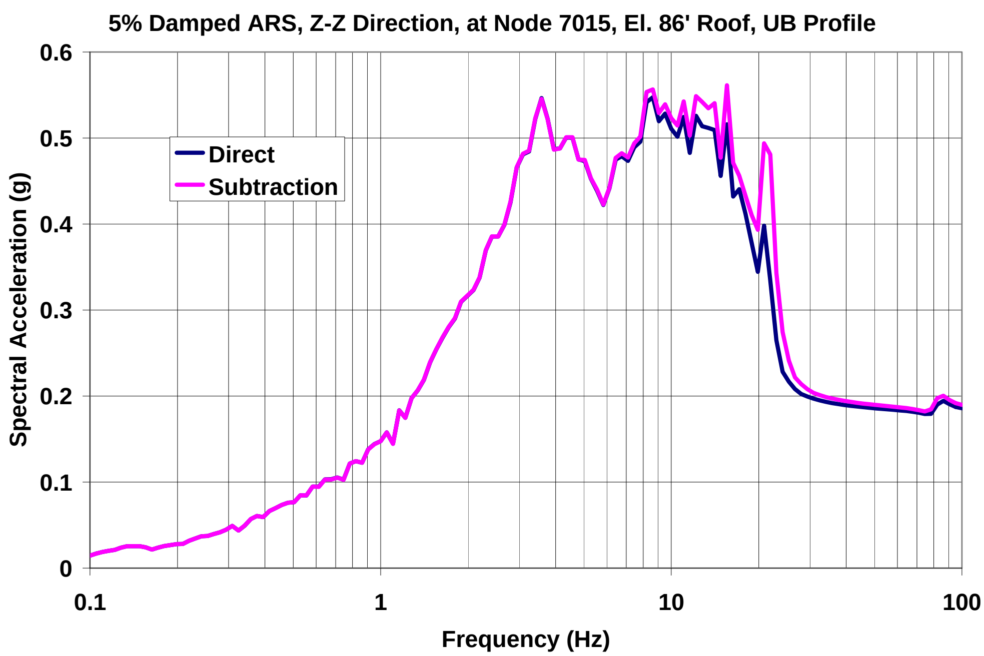

(b) Acceleration Response Spectra (ARS)

Figure 15 TF and ARS in Z-direction at Node 7015, UB profile