CLASSI-SASSI Validation for Incoherent Ground Motion

Dec. 20-21, 2006 NRC Meeting @ EPRI

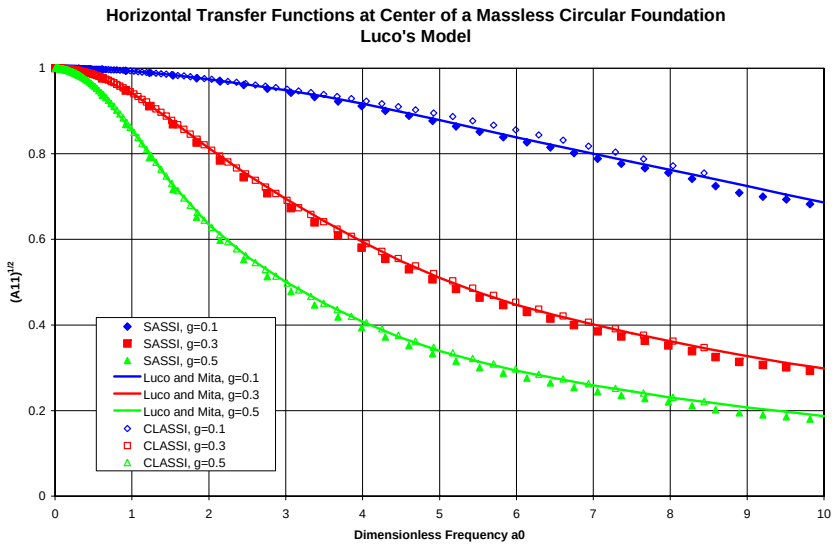
- CLASSI was validated for use in analysis of incoherent ground motion by comparison to analytical solutions from published literature
  - Luco & Mita, 1987; Veletsos & Prasad, 1989; Luco & Wong, 1986
- Action Items
  - Validate SASSI
    - ARES Team (ACS SASSI)
    - Bechtel (Bechtel SASSI)
  - Produce user guidance document

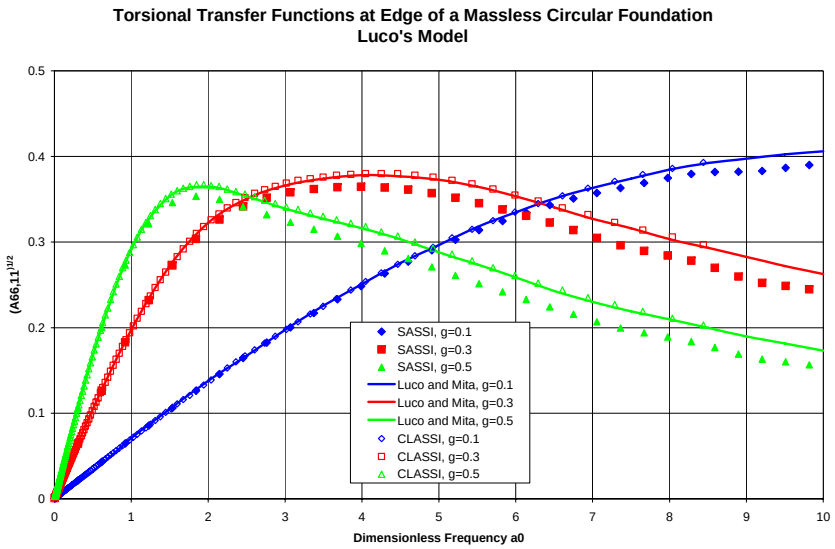
SASSI-CLASSI Validation

Rigid Massless Circular Foundation

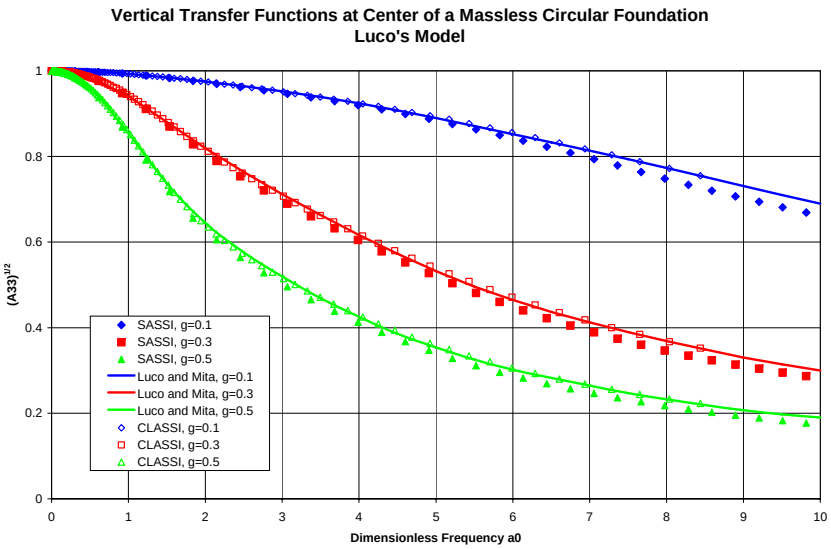
Luco and Mita (1987), Response of Circular Foundation to Spatially Random Ground Motion
ASME, Vol. 133, No. 1, January 1987

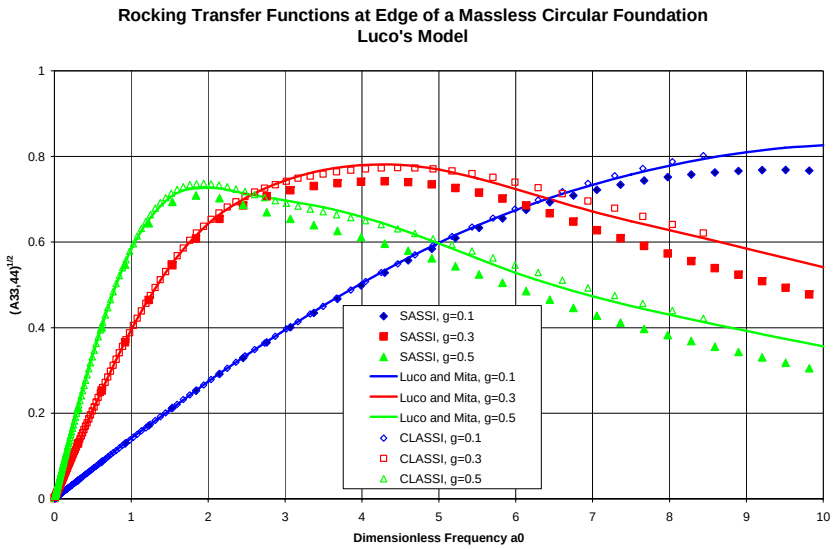
Horizontal Shaking





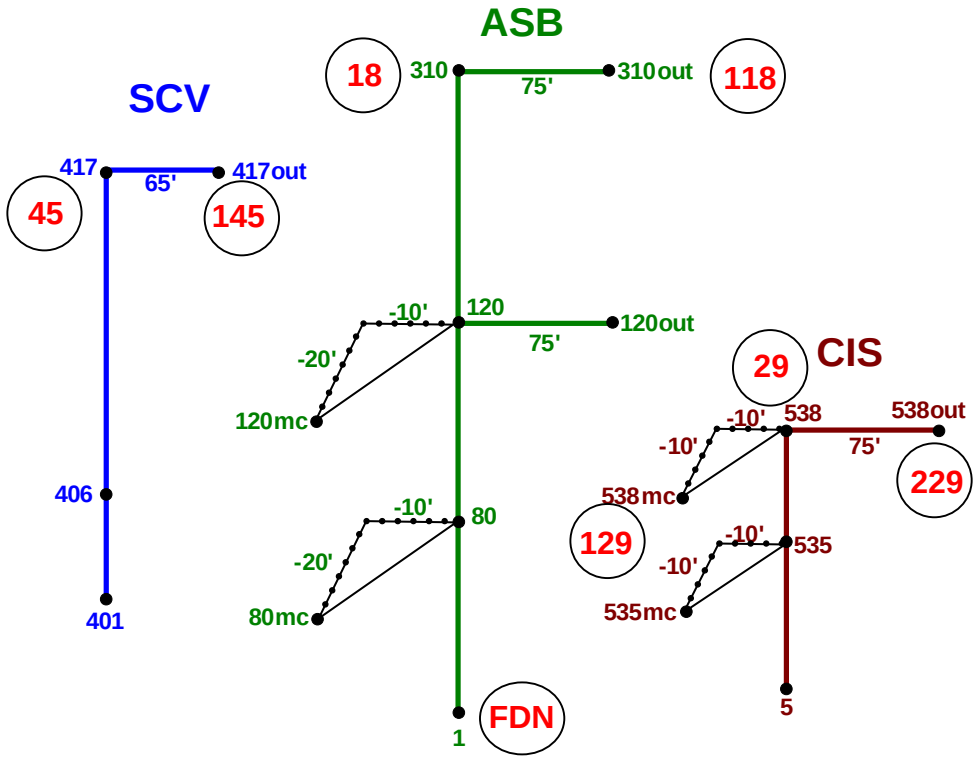
Vertical Shaking

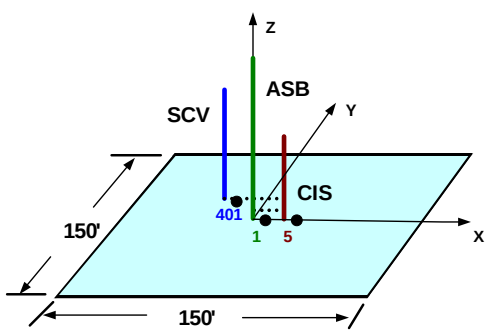




SSI Program Validation

- SSI computer programs were previously validated for incoherent ground motion in EPRI 1013504 for concentric structure model
  - CLASSI
  - ACS SASSI
  - Bechtel SASSI
- Additional validation for non-concentric structure model has been performed to assure that incoherence rotations are captured
- A surface founded nuclear power plant stick model is used to compare in-structure response spectra and foundation transfer functions





Node Number	Location
401	Base of Steel Containment Vessel
406	Low on Steel Containment Vessel
417	Top of Steel Containment Vessel
417out	Steel Containment Vessel Outrigger
1	Foundation of Auxiliary Shield Building
80	Low on Auxiliary Shield Building
80mc	Low on Auxiliary Shield Building Mass Center
120	Top of Auxiliary Building
120out	Top of Auxiliary Building Outrigger
120mc	Top of Auxiliary Building Mass Center
310	Top of Shield Building
310out	Shield Building Outrigger
5	Base of Containment Internal Structure
535	Low on Containment Internal Structure
535mc	Low on Containment Internal Structure Mass Center
538	Top of Containment Internal Structure
538out	Top of Containment Internal Structure Outrigger
538mc	Top of Containment Internal Structure Mass Center

Analysis Parameters

- 3 stick structure model
  - ASB-3.2 Hz; SCV-5.5 Hz;CIS-13.3 Hz fixed base
- Layered rock site
- High frequency CEUS earthquake motion
- Abrahamson 2005 coherency function
- Response locations known to have significant incoherence induced rotation response
  - Y response of ASB & SCV outriggers (nodes 118 & 145)
  - Z response of the CIS outrigger (node 229)

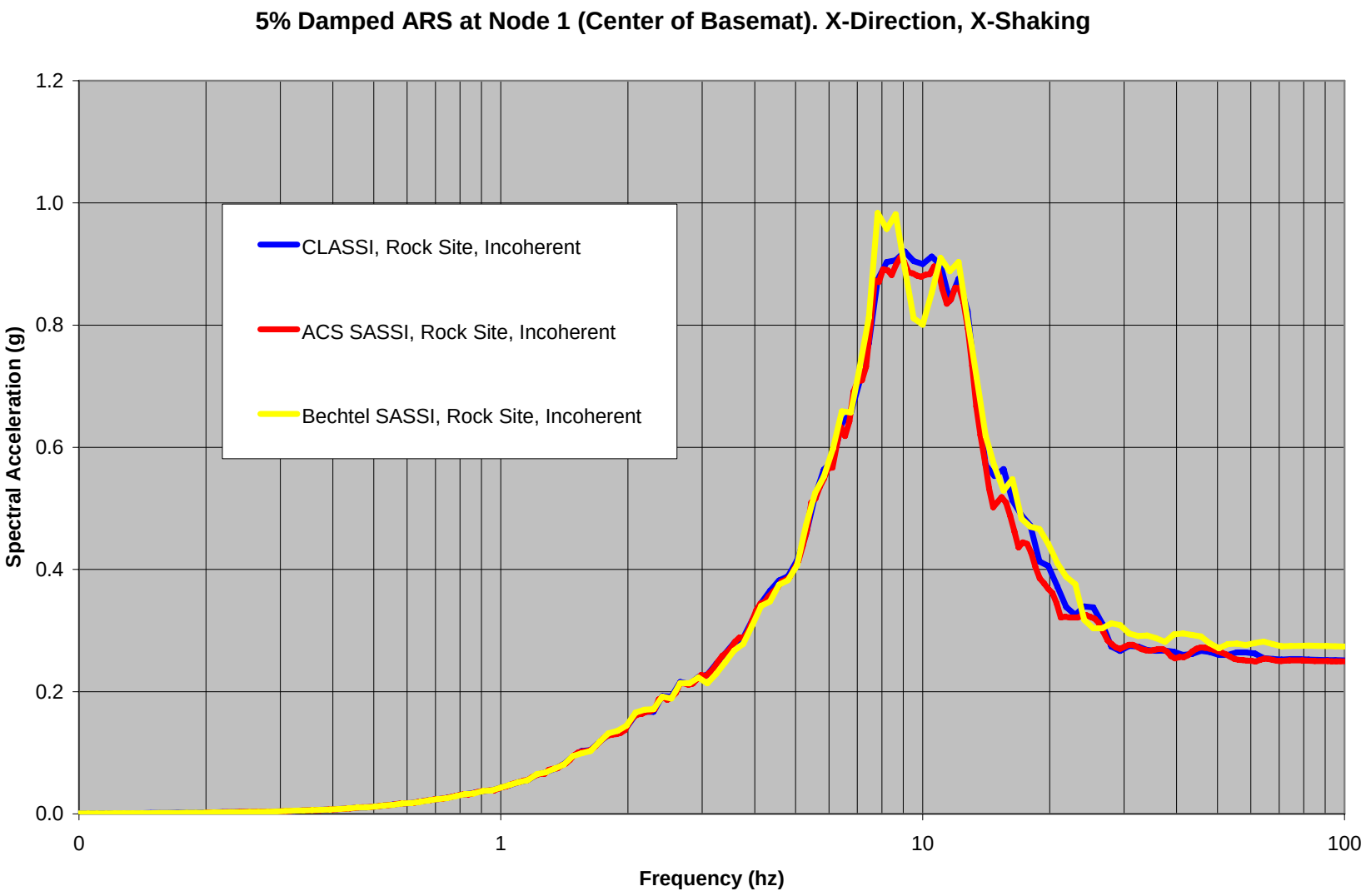
Conclusions

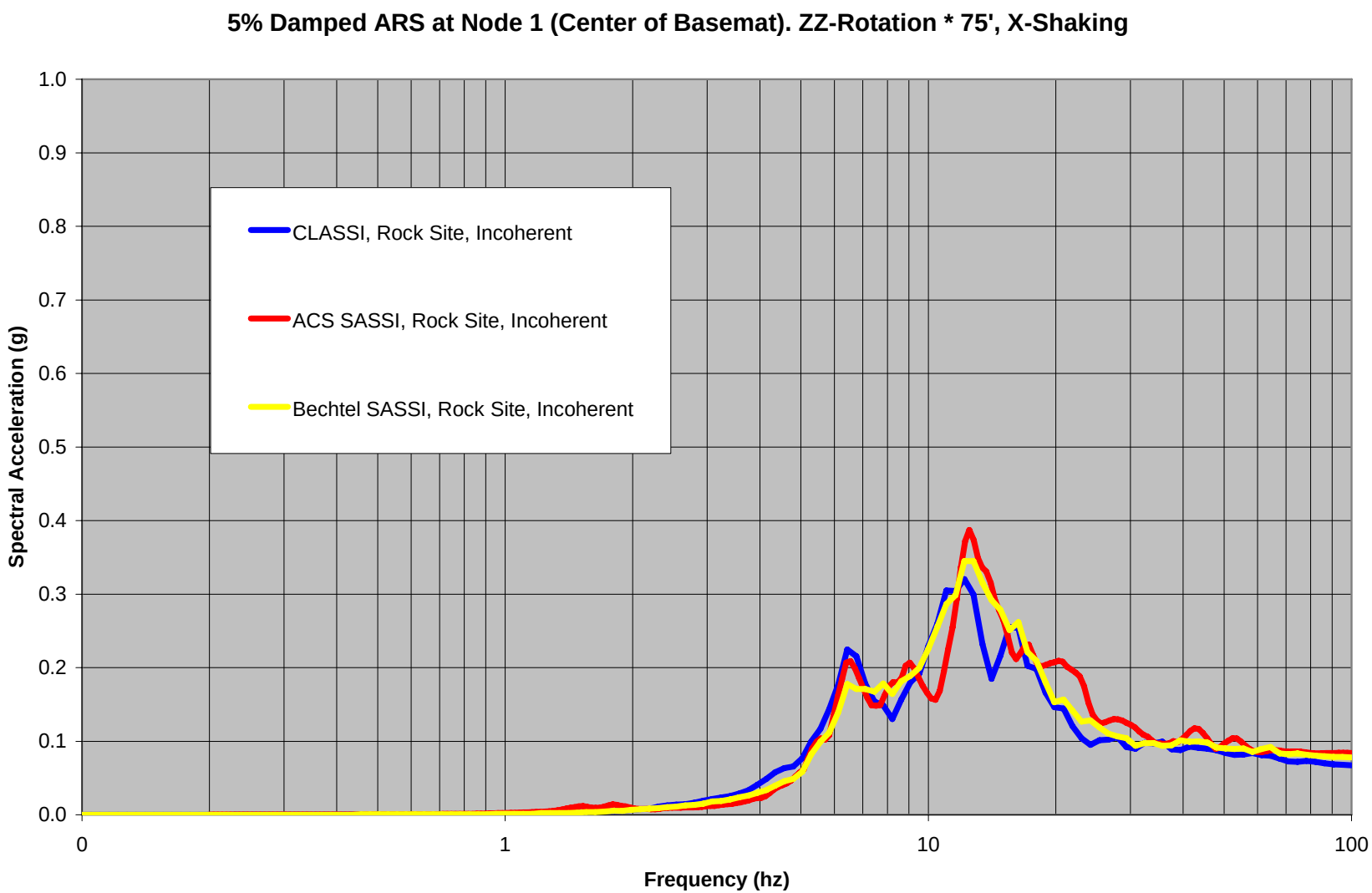
- CLASSI, ACS SASSI (x & y input only to date), & Bechtel SASSI have computed response spectra and transfer functions
- There is very close agreement for coherent ground motion as would be expected.
- All programs agree closely for incoherent response spectra & transfer functions at the foundation
- There is generally good agreement at the top of stick outriggers, but there are some exceptions requiring more investigation
- Overall, good agreement between CLASSI and either version of SASSI is demonstrated

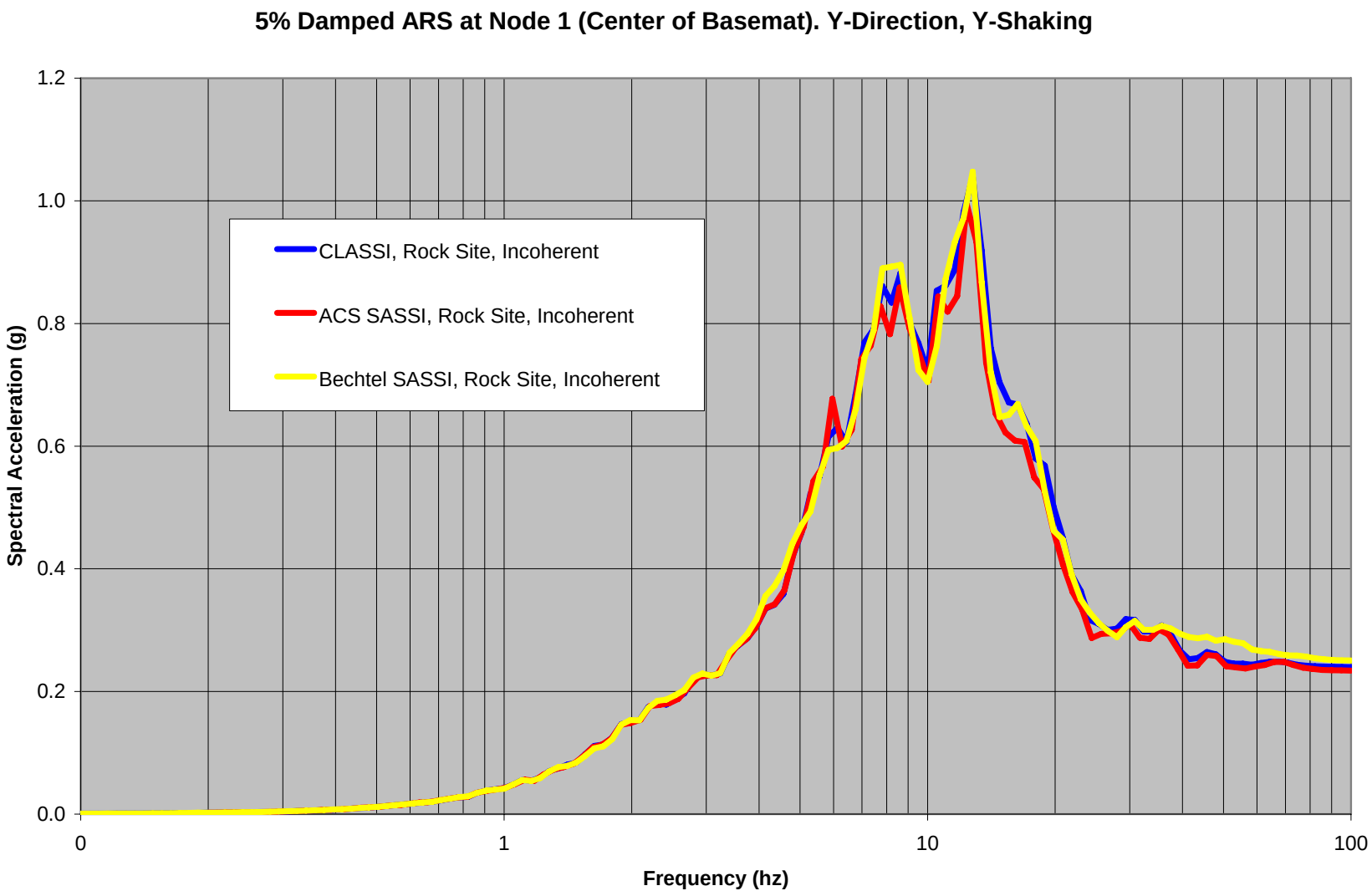
Current Activities & Next Steps

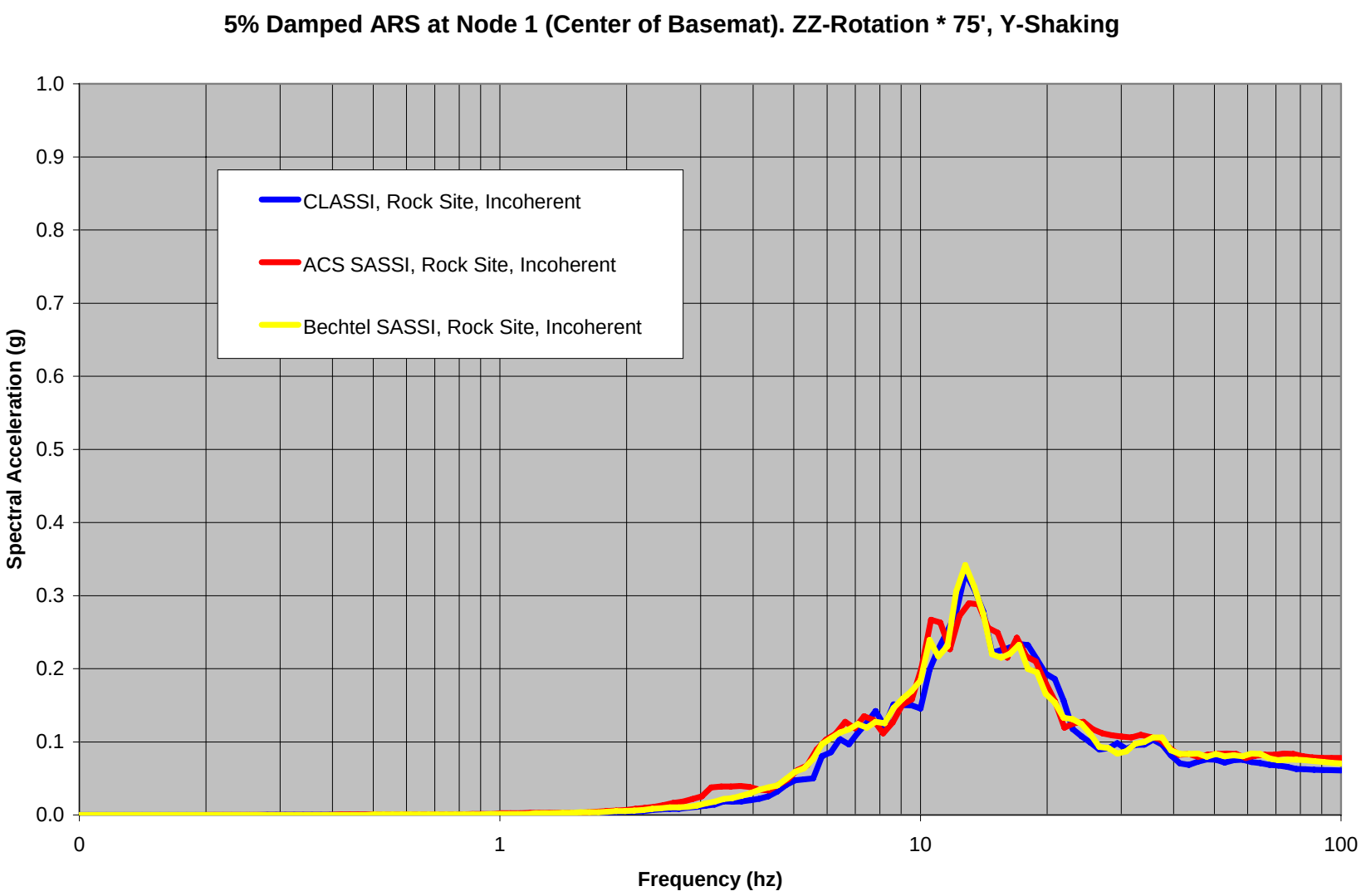
- Finalizing comparison studies
  - ACS SASSI runs for Z input
  - Investigation of CIS Outrigger Z response to Z input
- Generating user guidance document for use and validation of SASSI
- Industry & NRC technical meeting to discuss SASSI validation and revised coherency function

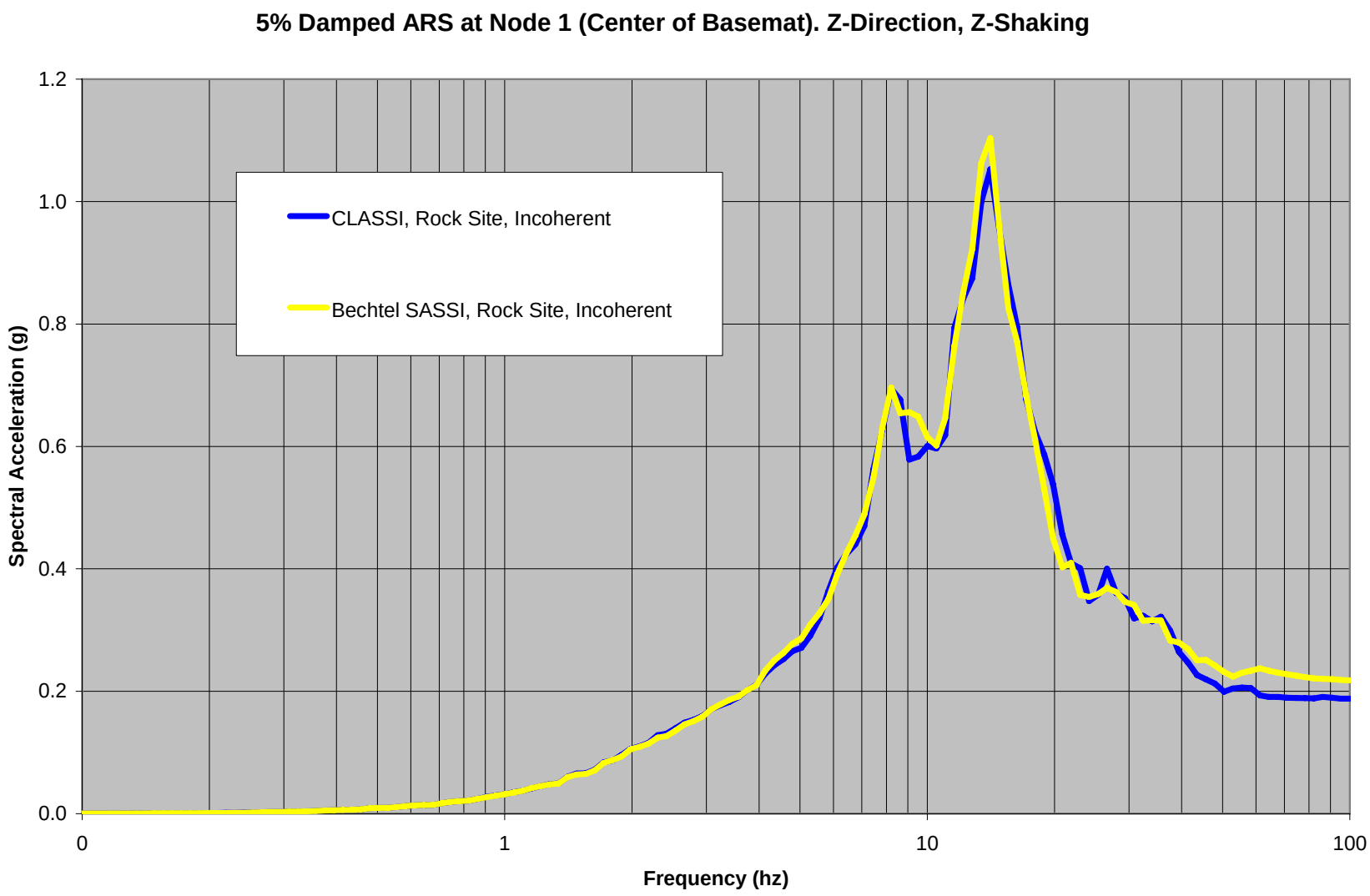
Foundation Response Spectra Comparisons

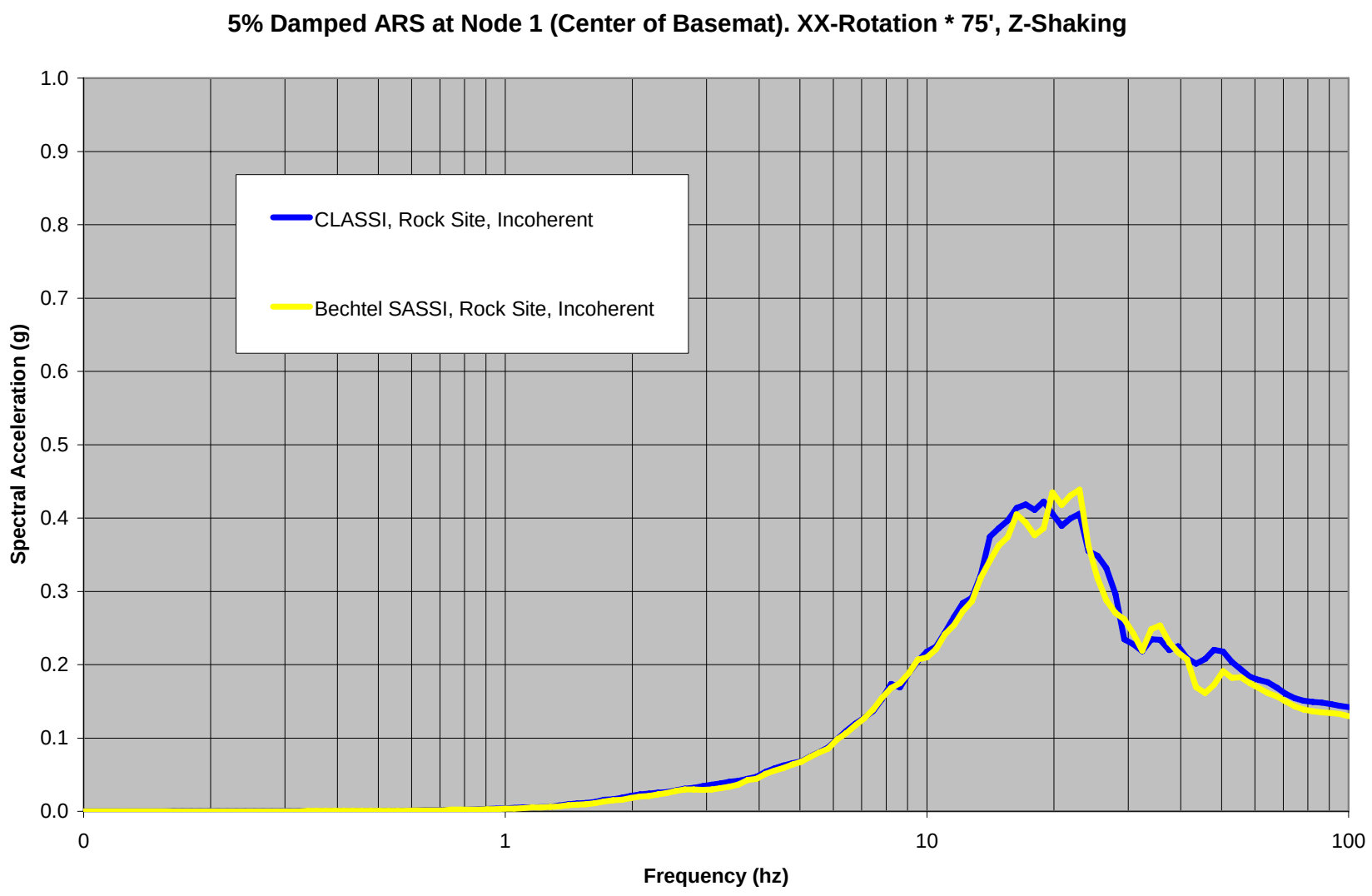

5% Damped ARS at Node 1 (Center of Basemat). X-Direction, X-Shaking
CLASSI, Rock Site, Incoherent
ACS SASSI, Rock Site, Incoherent
Bechtel SASSI, Rock Site, Incoherent
Spectral Acceleration (g)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
1
10
100
Frequency (hz)

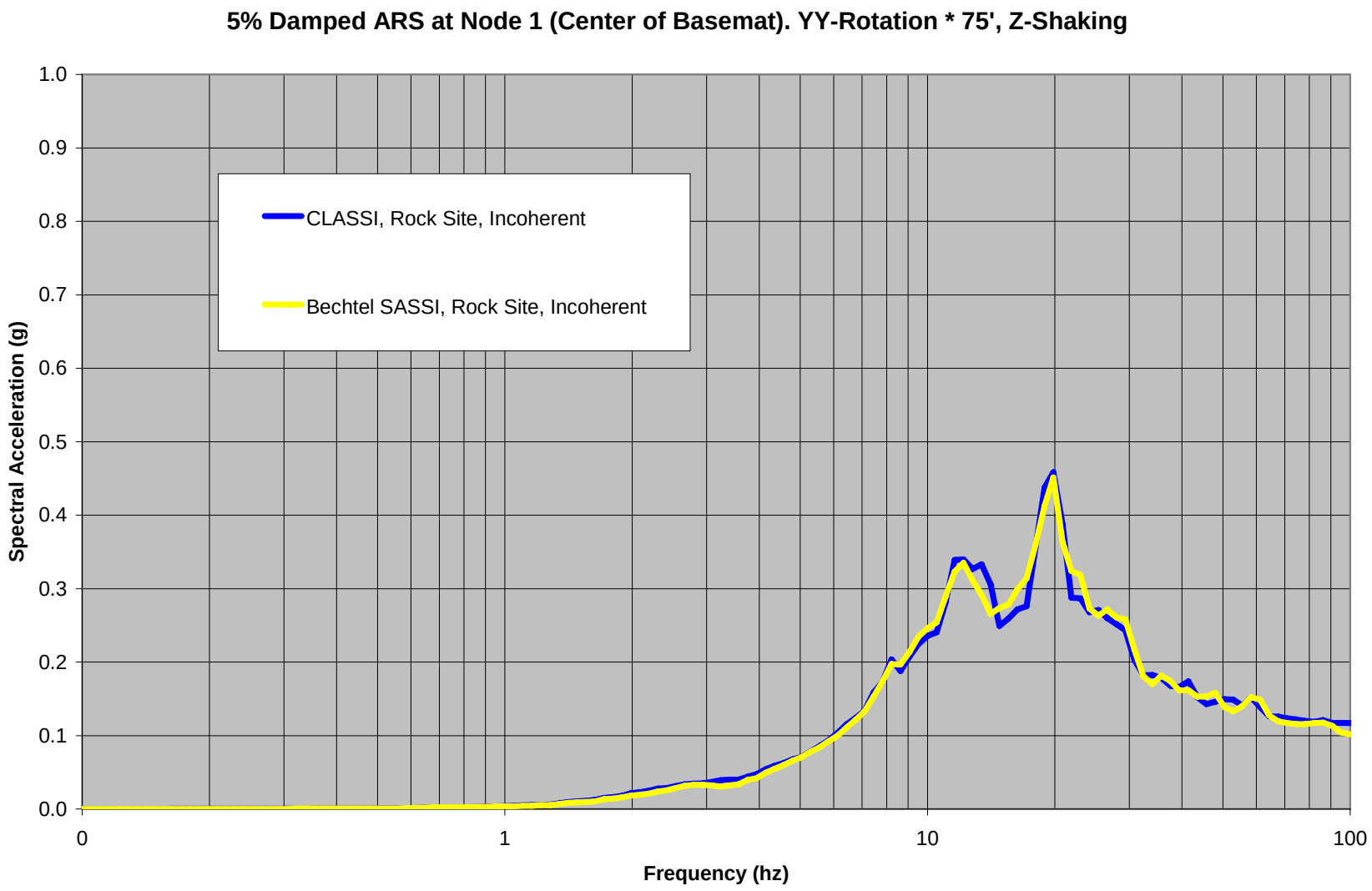

5% Damped ARS at Node 1 (Center of Basemat). ZZ-Rotation * 75', X-Shaking
CLASSI, Rock Site, Incoherent
ACS SASSI, Rock Site, Incoherent
Bechtel SASSI, Rock Site, Incoherent
Spectral Acceleration (g)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
1
10
100
Frequency (hz)


5% Damped ARS at Node 1 (Center of Basemat). Y-Direction, Y-Shaking
CLASSI, Rock Site, Incoherent
ACS SASSI, Rock Site, Incoherent
Bechtel SASSI, Rock Site, Incoherent
Spectral Acceleration (g)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
1
10
100
Frequency (hz)

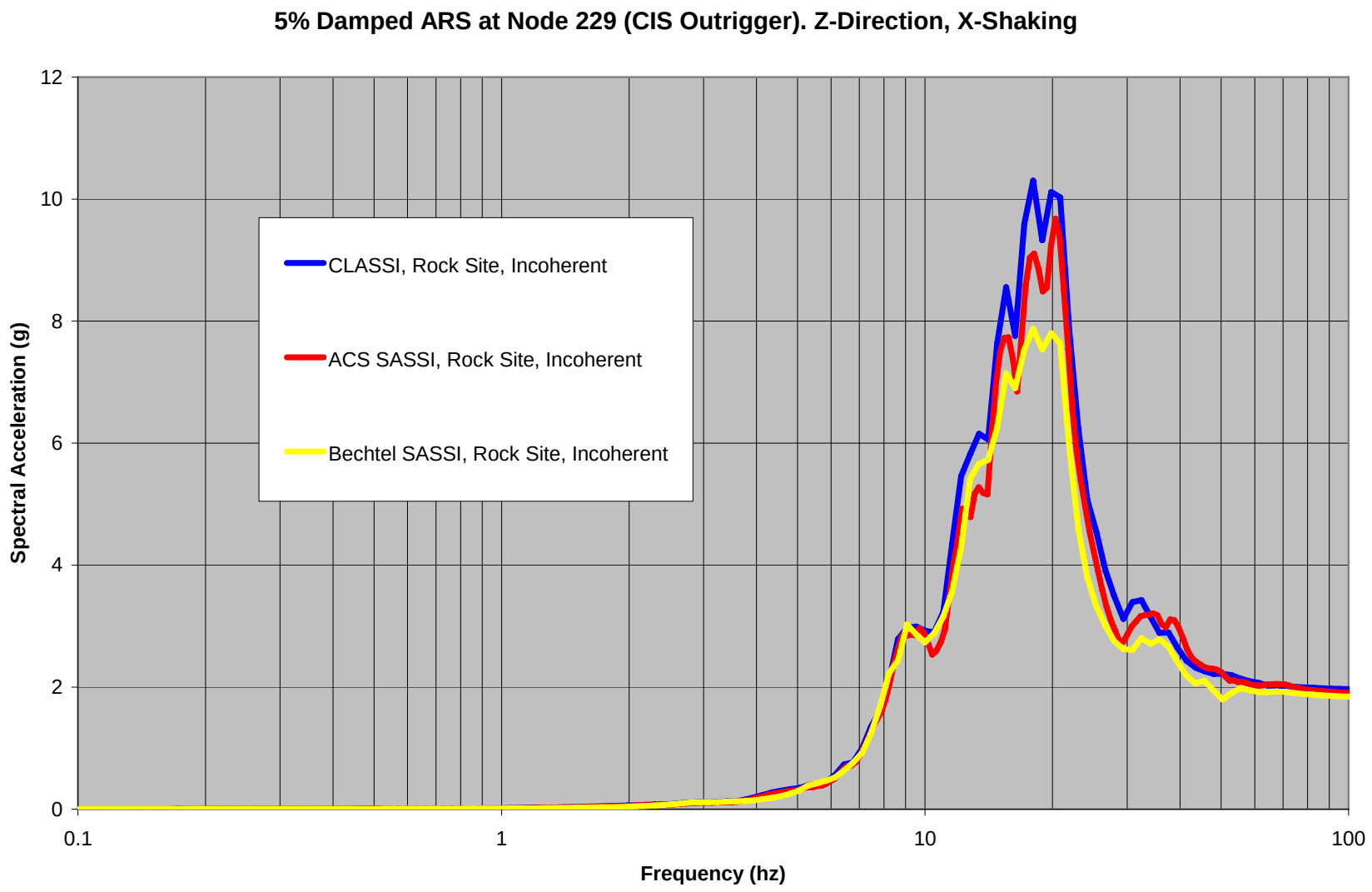

5% Damped ARS at Node 1 (Center of Basemat). ZZ-Rotation * 75', Y-Shaking
CLASSI, Rock Site, Incoherent
ACS SASSI, Rock Site, Incoherent
Bechtel SASSI, Rock Site, Incoherent
Spectral Acceleration (g)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
1
10
100
Frequency (hz)

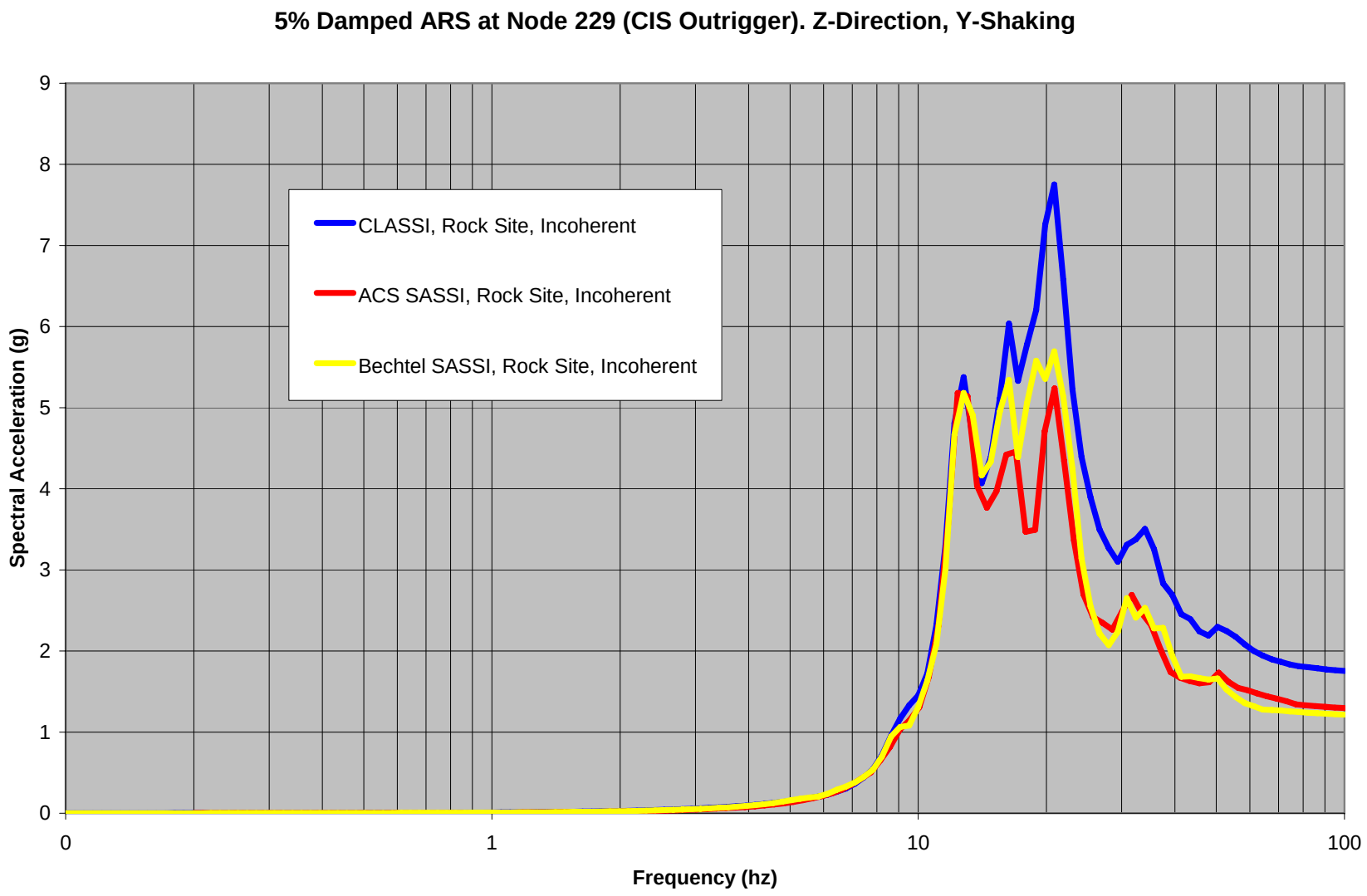

5% Damped ARS at Node 1 (Center of Basemat). Z-Direction, Z-Shaking
CLASSI, Rock Site, Incoherent
Bechtel SASSI, Rock Site, Incoherent
Spectral Acceleration (g)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
1
10
100
Frequency (hz)

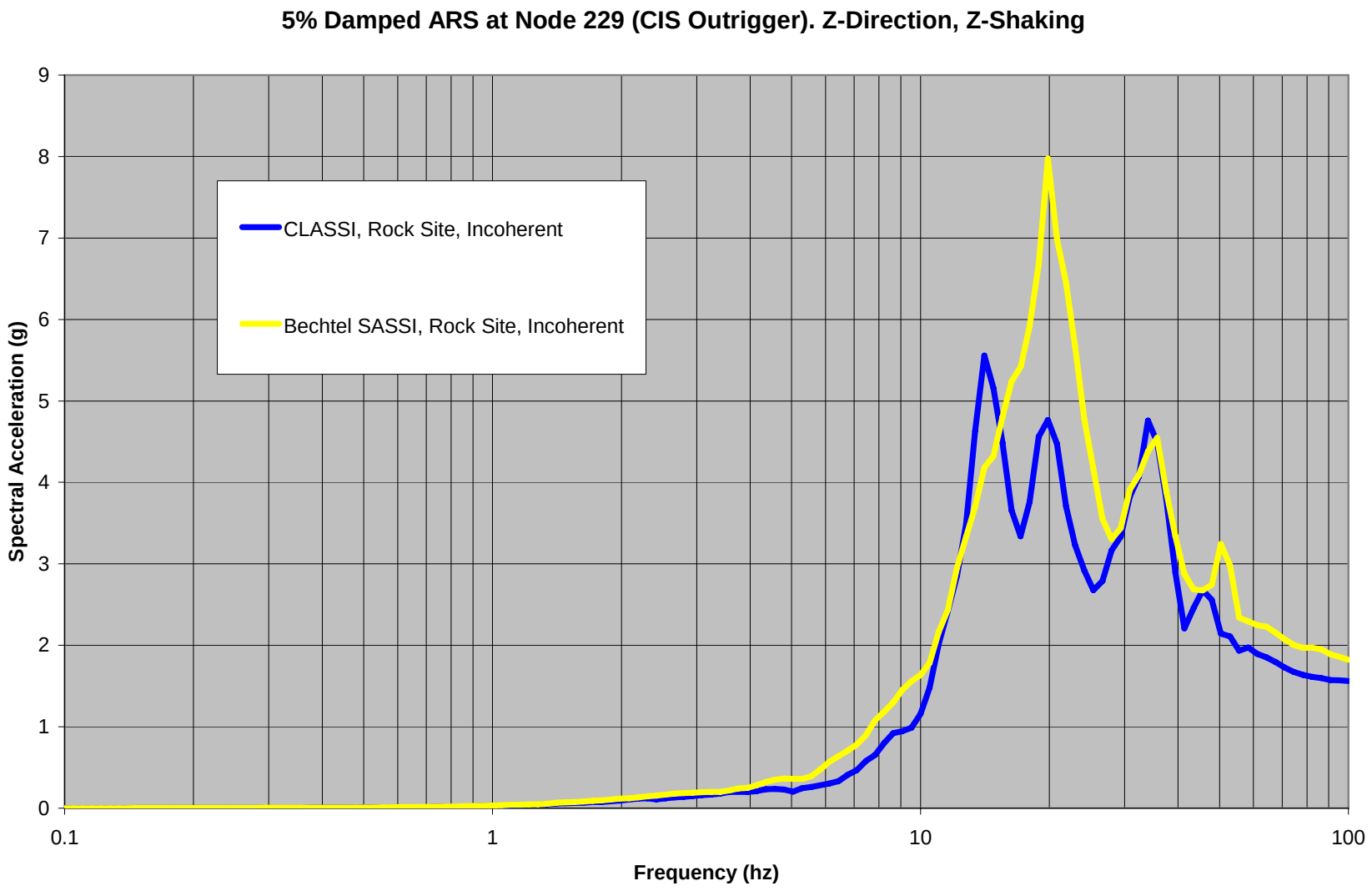

5% Damped ARS at Node 1 (Center of Basemat). XX-Rotation * 75', Z-Shaking
CLASSI, Rock Site, Incoherent
Bechtel SASSI, Rock Site, Incoherent
Spectral Acceleration (g)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
1
10
100
Frequency (hz)

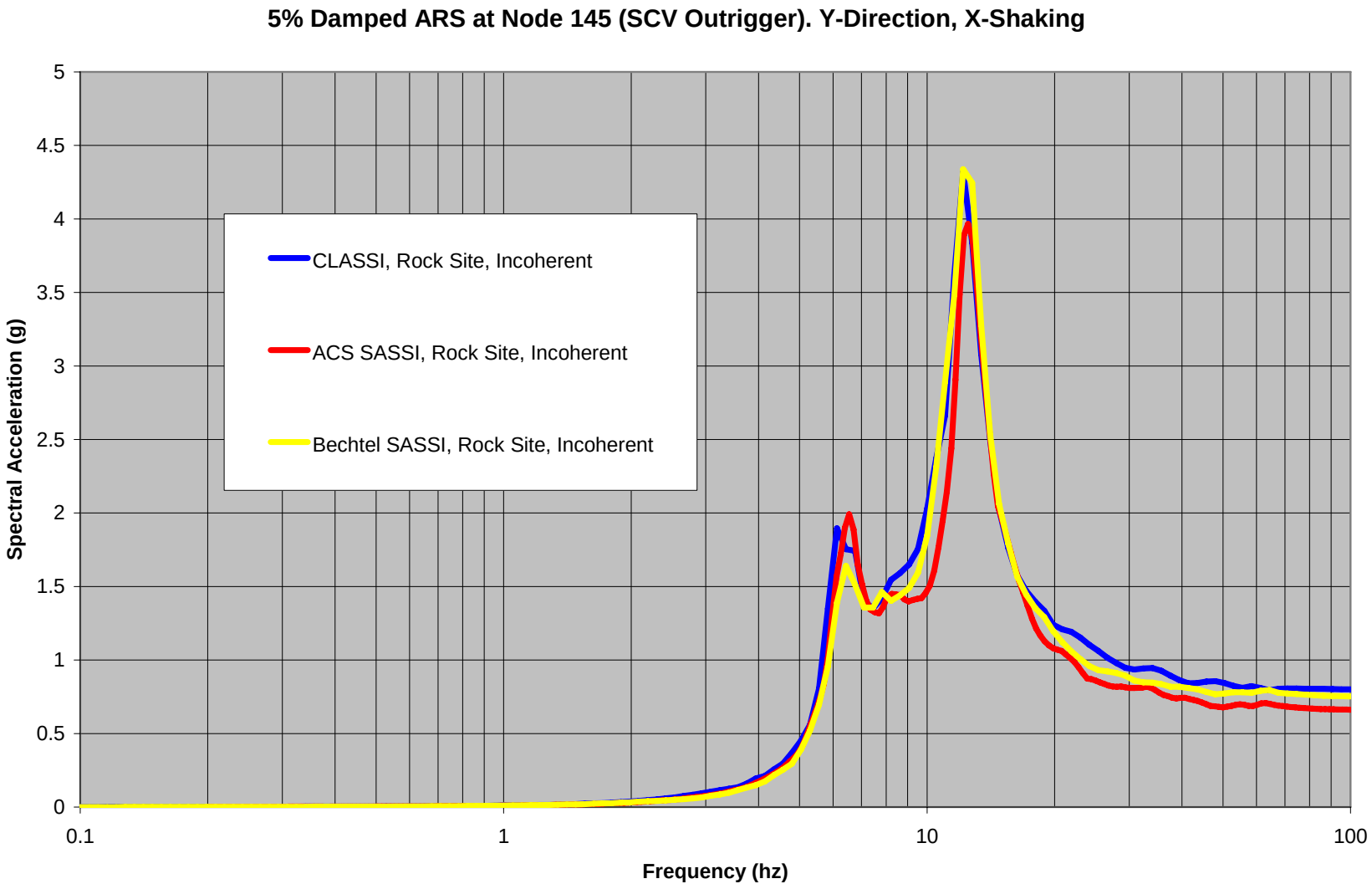

5% Damped ARS at Node 1 (Center of Basemat). YY-Rotation * 75', Z-Shaking
CLASSI, Rock Site, Incoherent
Bechtel SASSI, Rock Site, Incoherent
Spectral Acceleration (g)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
1
10
100
Frequency (hz)

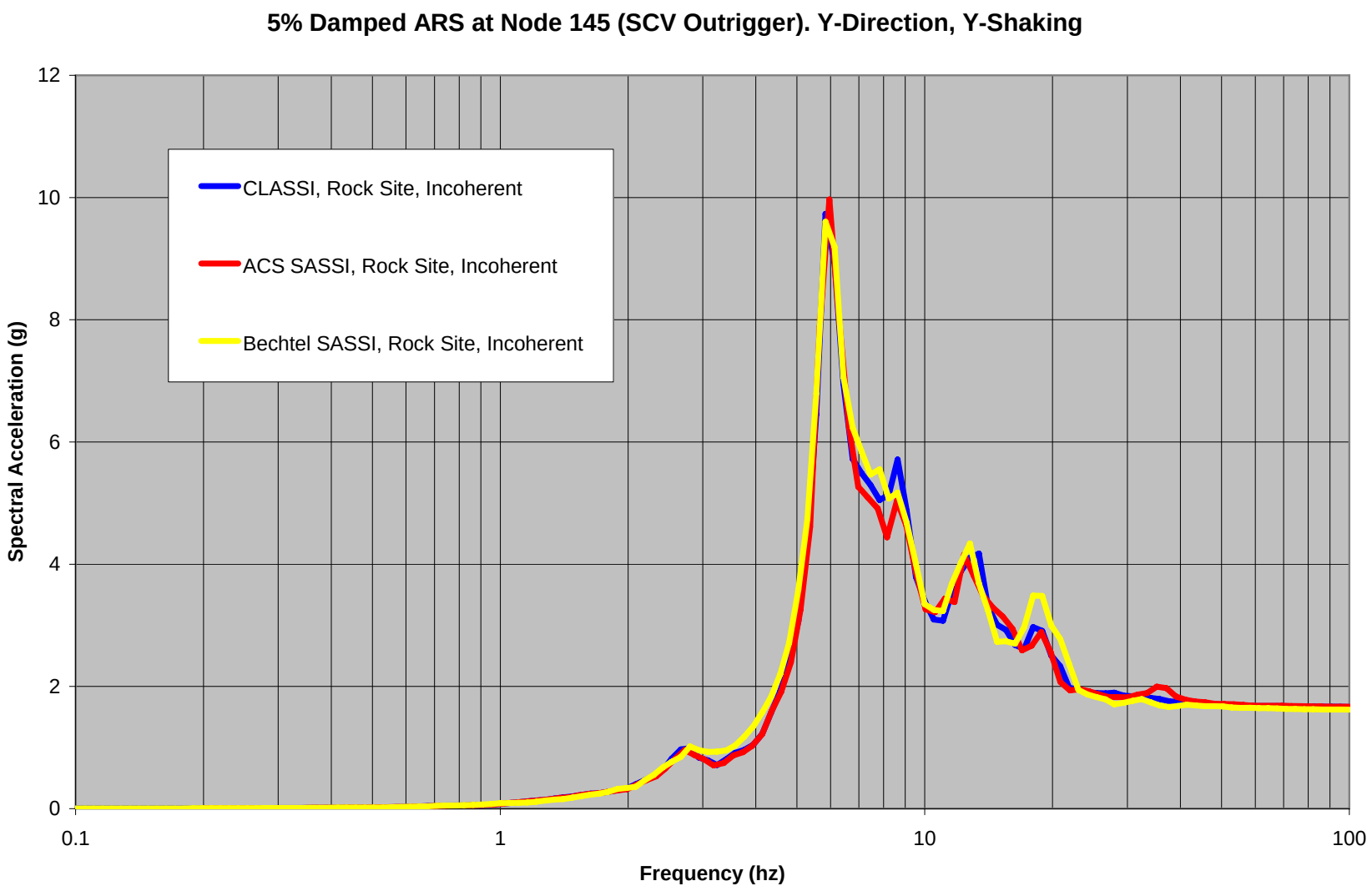
Top of Stick Outrigger Response Spectra Comparisons

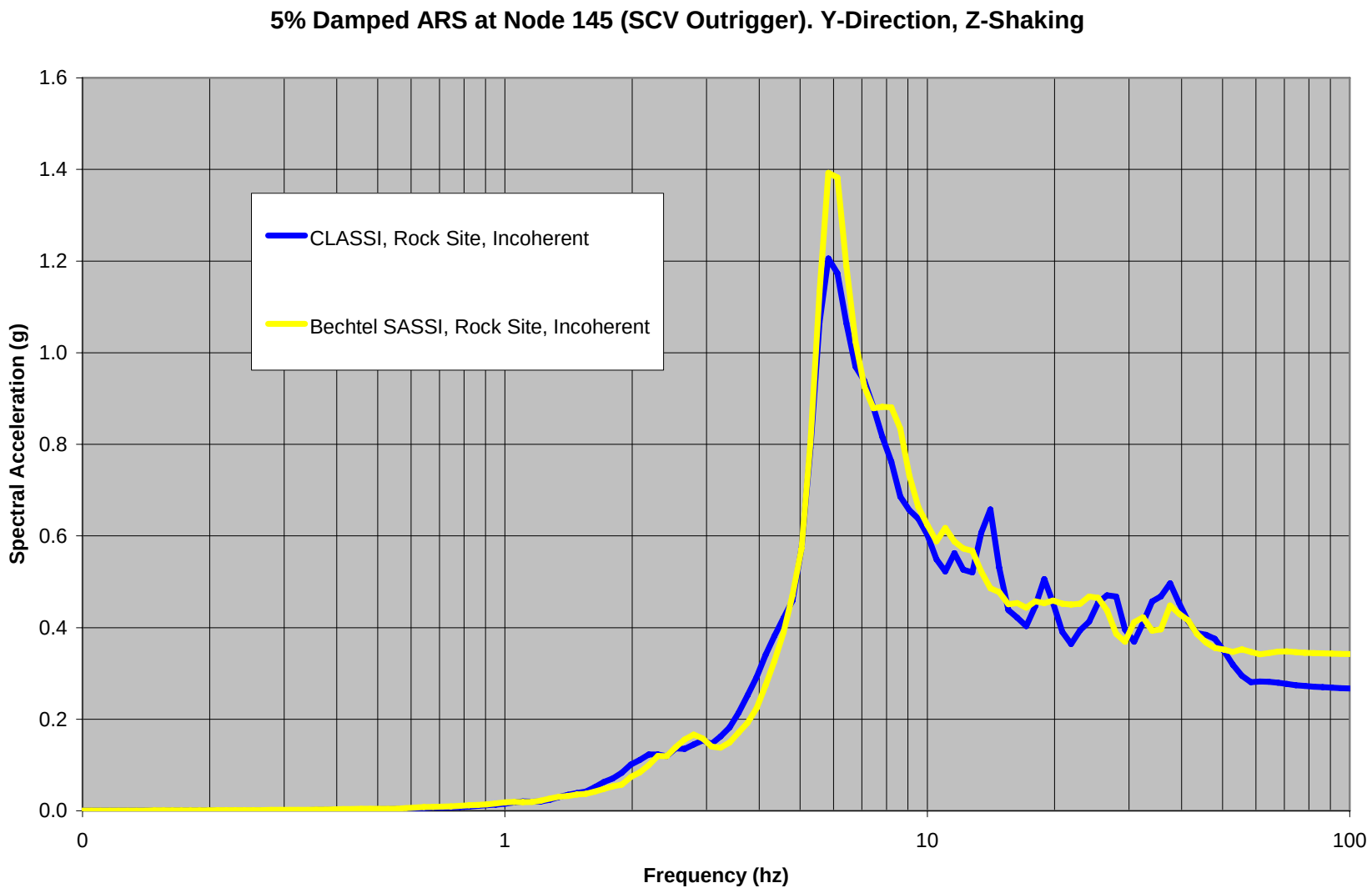

5% Damped ARS at Node 229 (CIS Outrigger). Z-Direction, X-Shaking
Spectral Acceleration (g)
Frequency (hz)
CLASSI, Rock Site, Incoherent
ACS SASSI, Rock Site, Incoherent
Bechtel SASSI, Rock Site, Incoherent
0
2
4
6
8
10
12
0.1
1
10
100

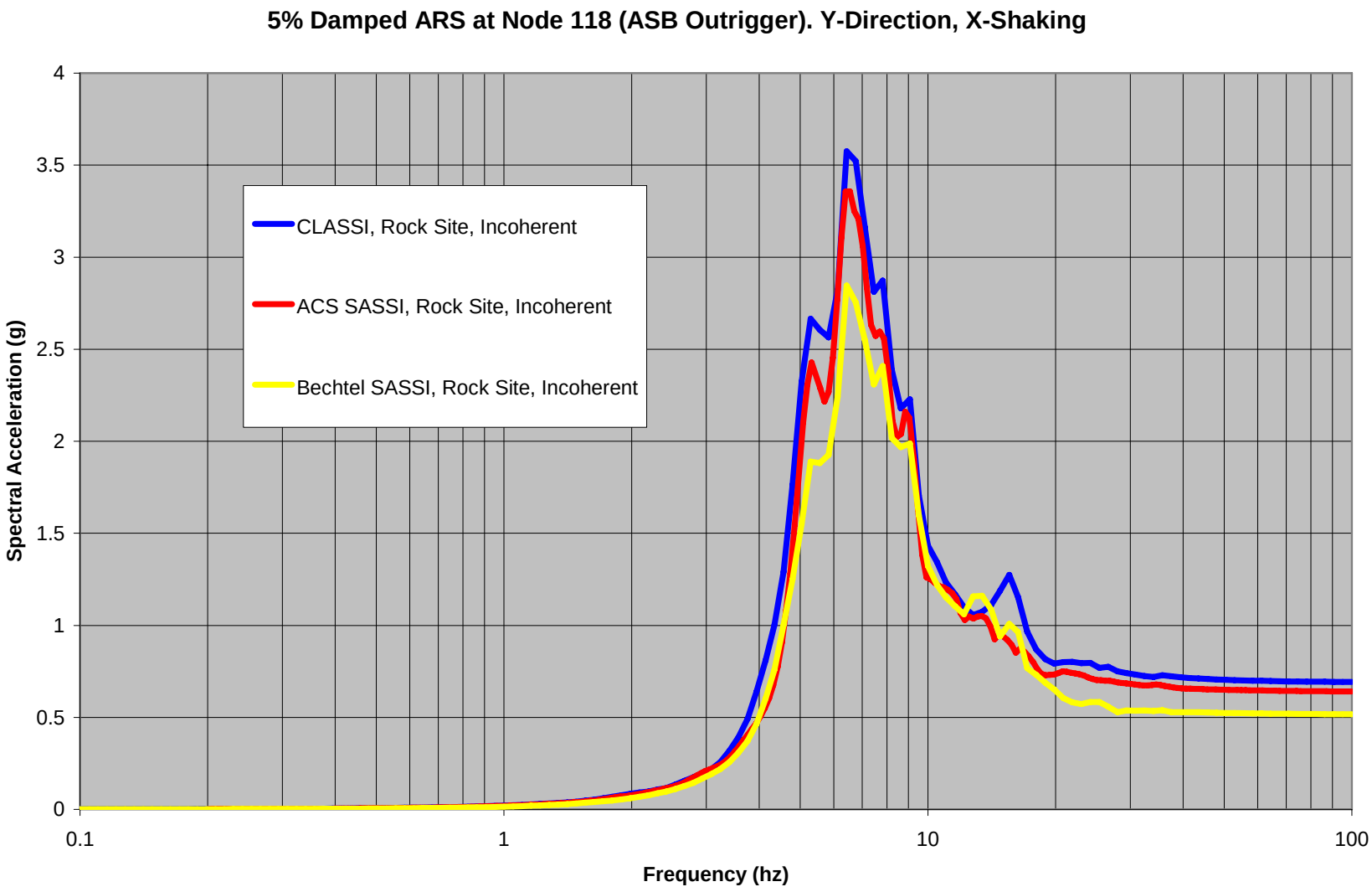

5% Damped ARS at Node 229 (CIS Outrigger). Z-Direction, Y-Shaking
CLASSI, Rock Site, Incoherent
ACS SASSI, Rock Site, Incoherent
Bechtel SASSI, Rock Site, Incoherent
Spectral Acceleration (g)
Frequency (hz)
0
1
2
3
4
5
6
7
8
9
0
1
10
100

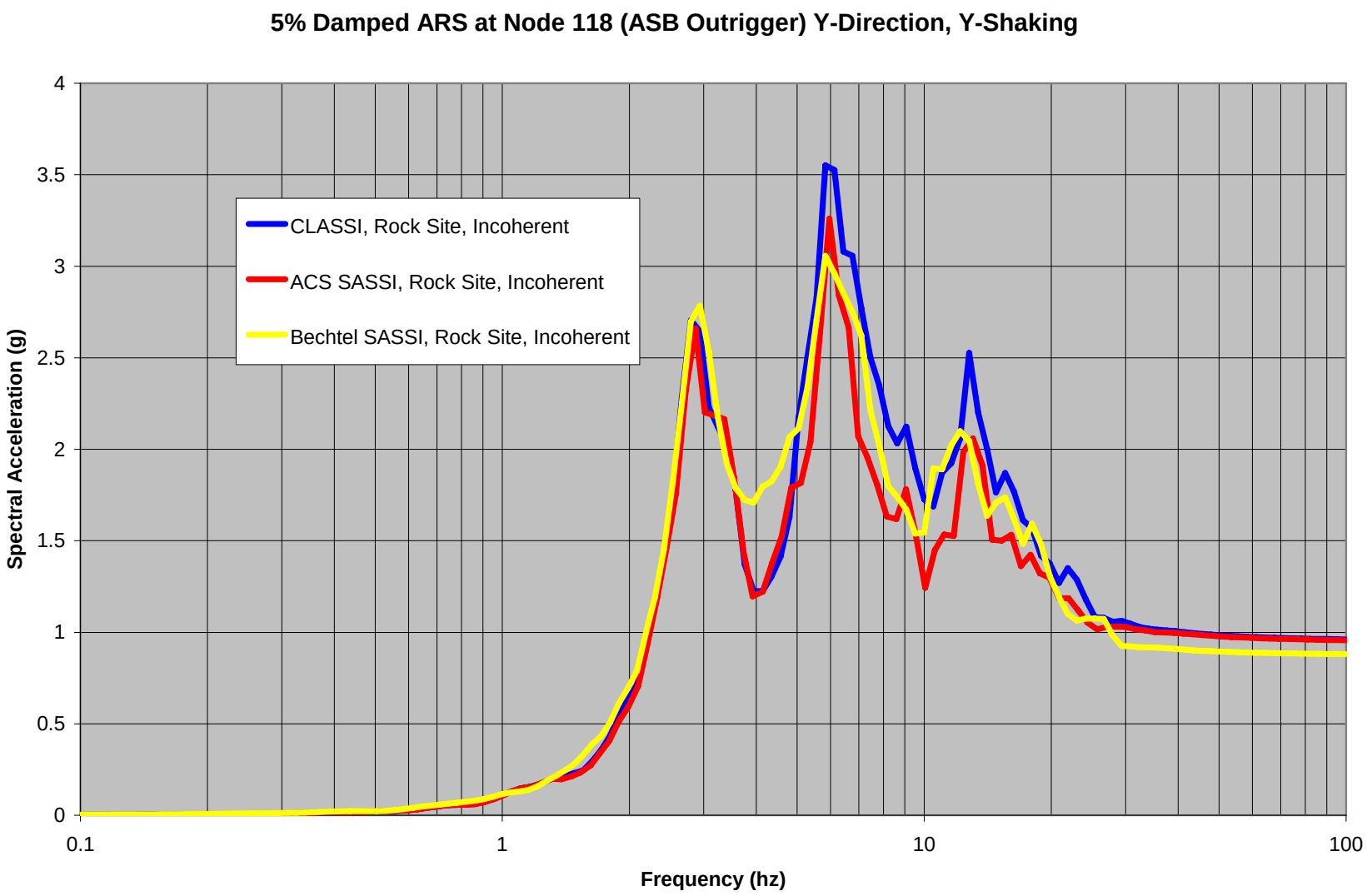

5% Damped ARS at Node 229 (CIS Outrigger). Z-Direction, Z-Shaking
CLASSI, Rock Site, Incoherent
Bechtel SASSI, Rock Site, Incoherent
Spectral Acceleration (g)
Frequency (hz)
0
1
2
3
4
5
6
7
8
9
0.1
1
10
100

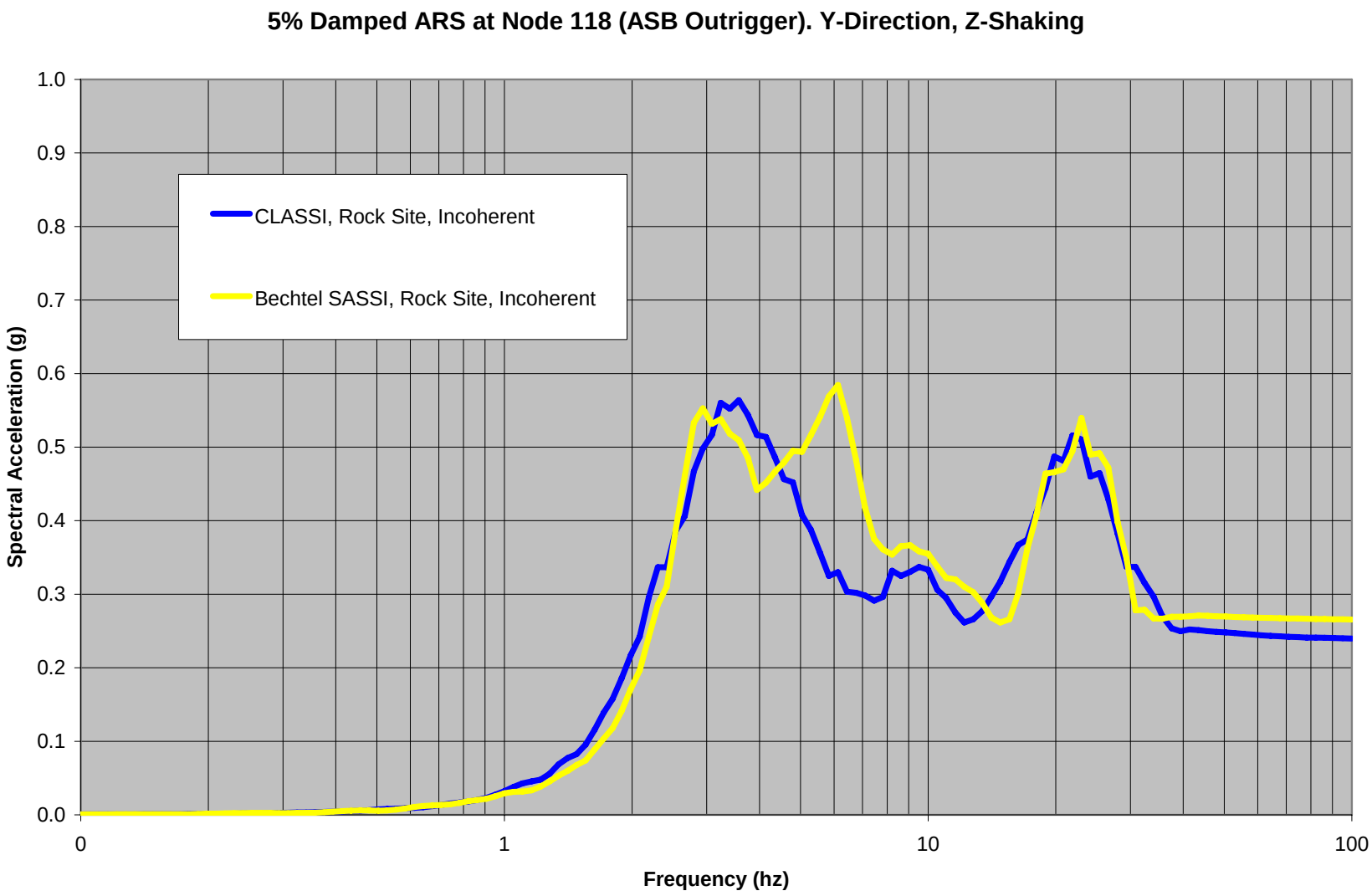

5% Damped ARS at Node 145 (SCV Outrigger). Y-Direction, X-Shaking
Spectral Acceleration (g)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0.1
1
10
100
Frequency (hz)
CLASSI, Rock Site, Incoherent
ACS SASSI, Rock Site, Incoherent
Bechtel SASSI, Rock Site, Incoherent


5% Damped ARS at Node 145 (SCV Outrigger). Y-Direction, Y-Shaking
CLASSI, Rock Site, Incoherent
ACS SASSI, Rock Site, Incoherent
Bechtel SASSI, Rock Site, Incoherent
Spectral Acceleration (g)
0
2
4
6
8
10
12
0.1
1
10
100
Frequency (hz)

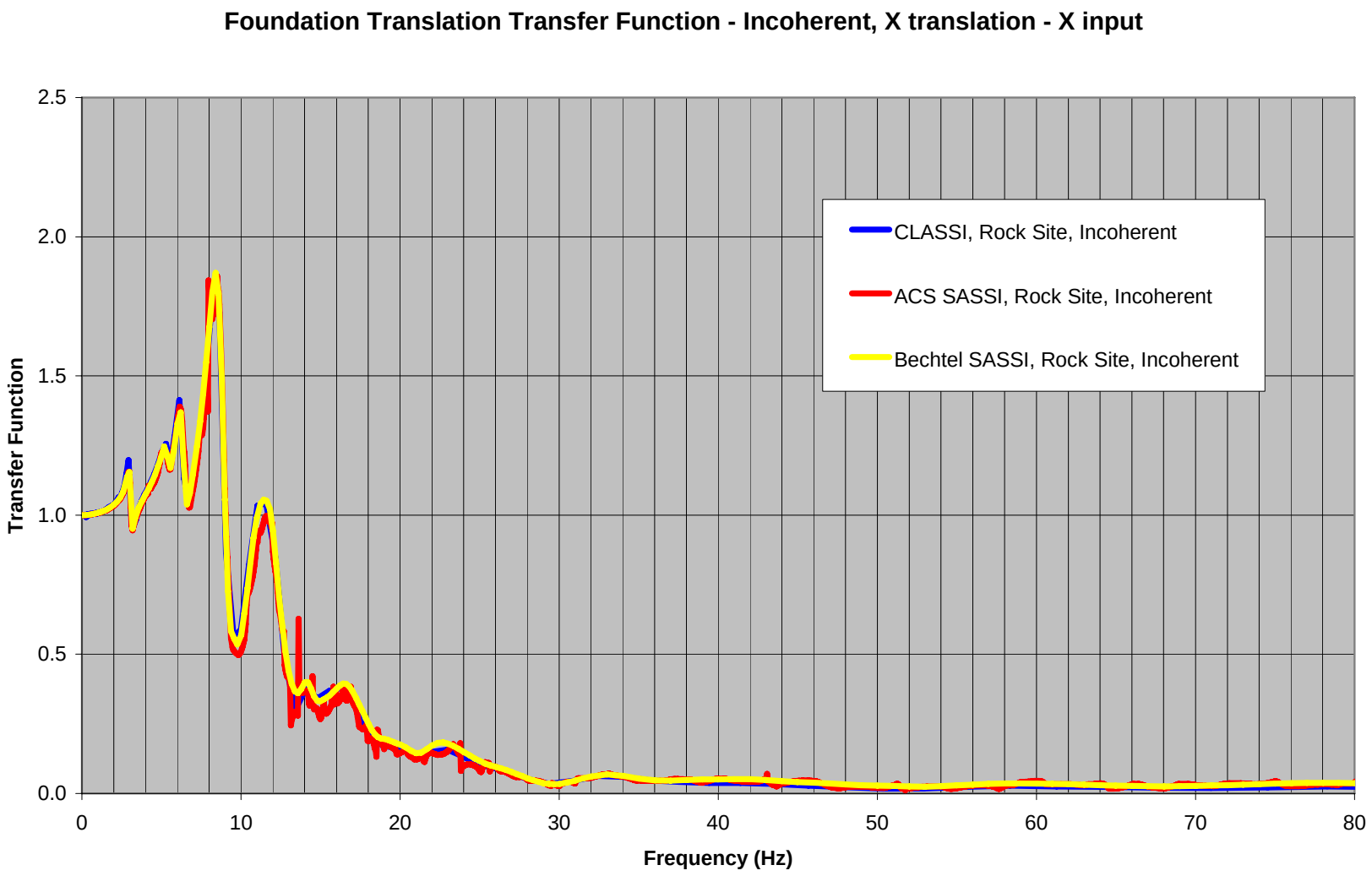

5% Damped ARS at Node 145 (SCV Outrigger). Y-Direction, Z-Shaking
CLASSI, Rock Site, Incoherent
Bechtel SASSI, Rock Site, Incoherent
Spectral Acceleration (g)
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
1
10
100
Frequency (hz)

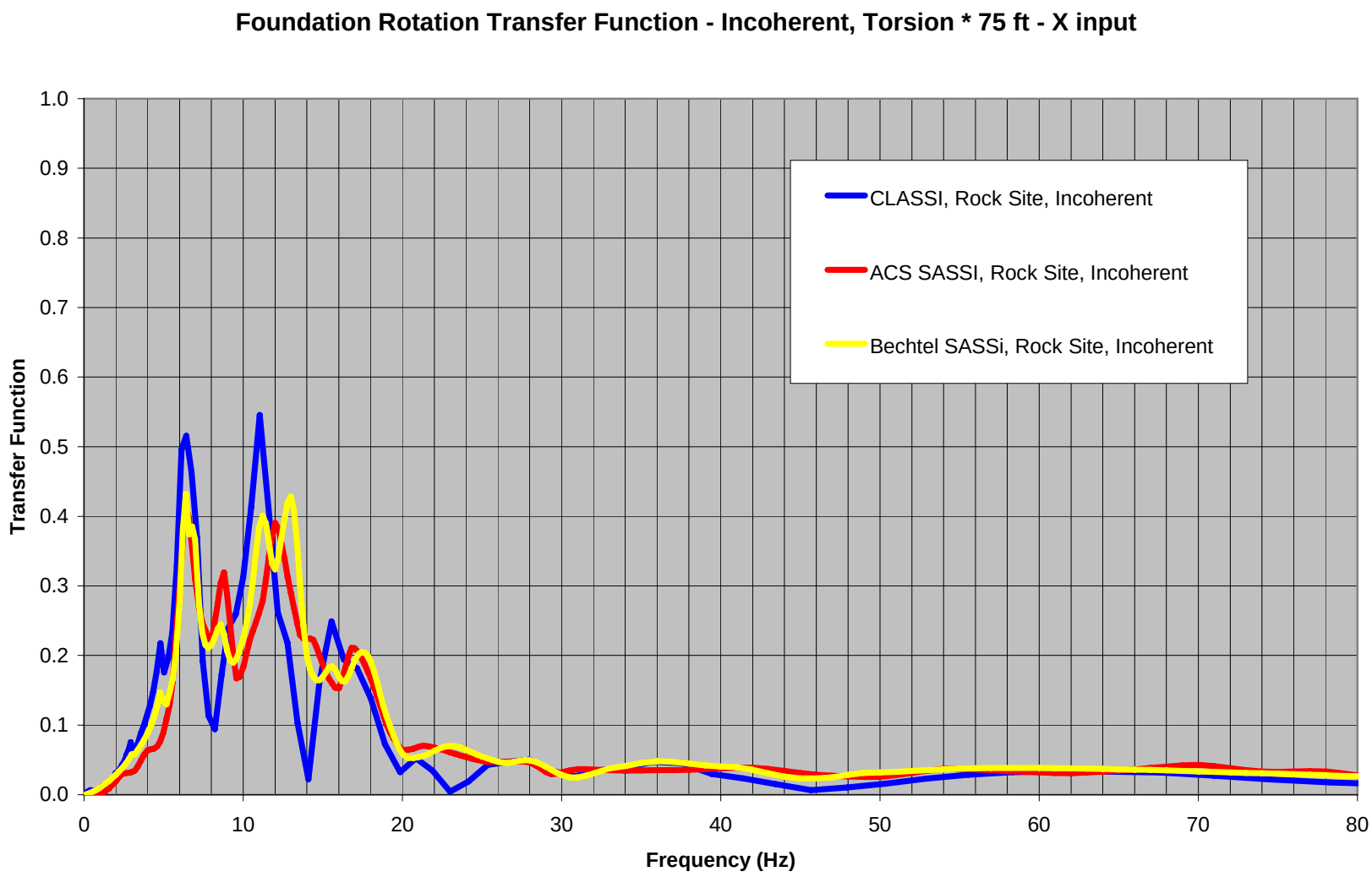

5% Damped ARS at Node 118 (ASB Outrigger). Y-Direction, X-Shaking
CLASSI, Rock Site, Incoherent
ACS SASSI, Rock Site, Incoherent
Bechtel SASSI, Rock Site, Incoherent
Spectral Acceleration (g)
Frequency (hz)
4
3.5
3
2.5
2
1.5
1
0.5
0
0.1
1
10
100

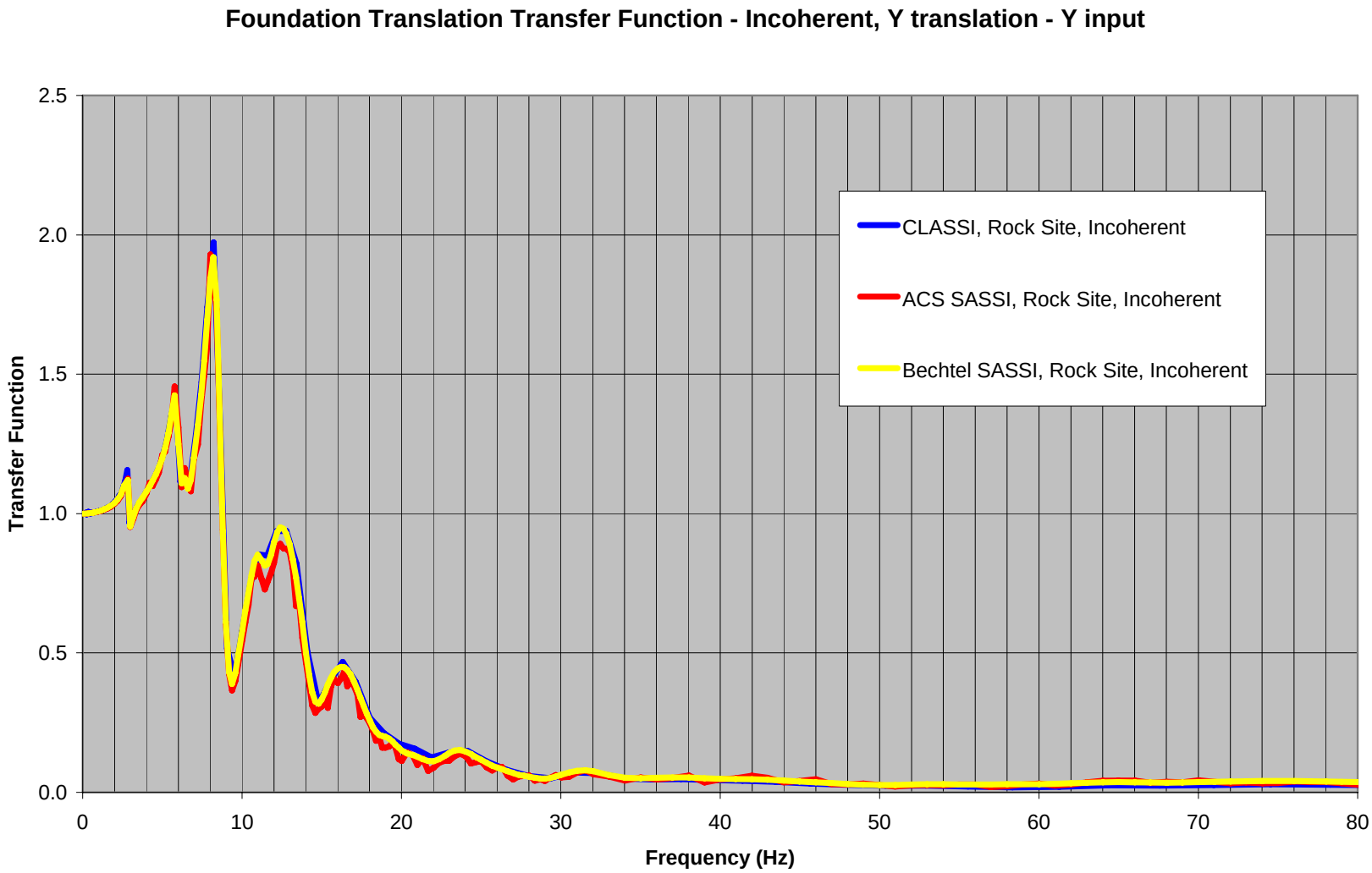

5% Damped ARS at Node 118 (ASB Outrigger) Y-Direction, Y-Shaking
CLASSI, Rock Site, Incoherent
ACS SASSI, Rock Site, Incoherent
Bechtel SASSI, Rock Site, Incoherent
Spectral Acceleration (g)
Frequency (hz)
4
3.5
3
2.5
2
1.5
1
0.5
0
0.1
1
10
100

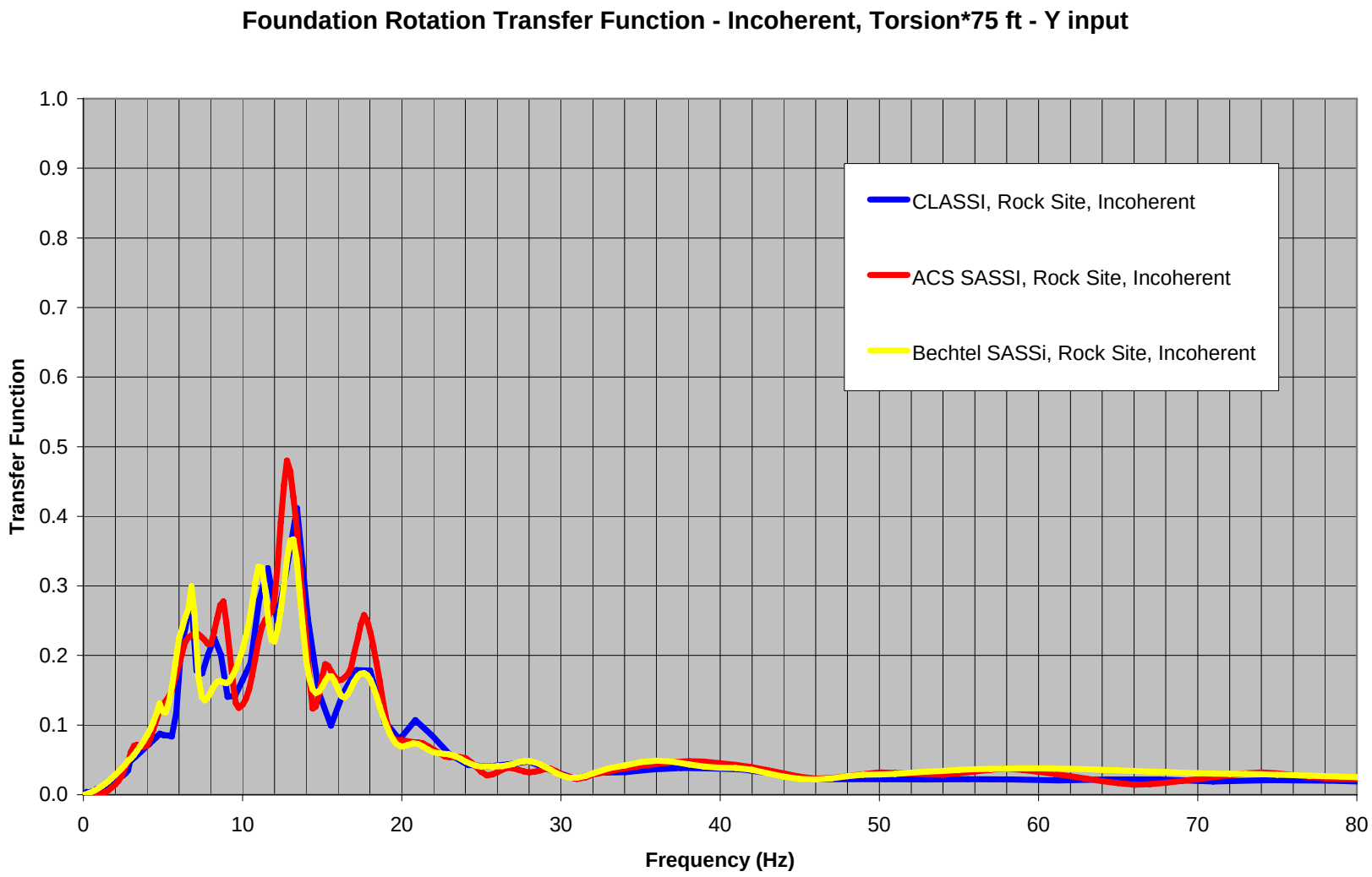

5% Damped ARS at Node 118 (ASB Outrigger). Y-Direction, Z-Shaking
CLASSI, Rock Site, Incoherent
Bechtel SASSI, Rock Site, Incoherent
Spectral Acceleration (g)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
1
10
100
Frequency (hz)

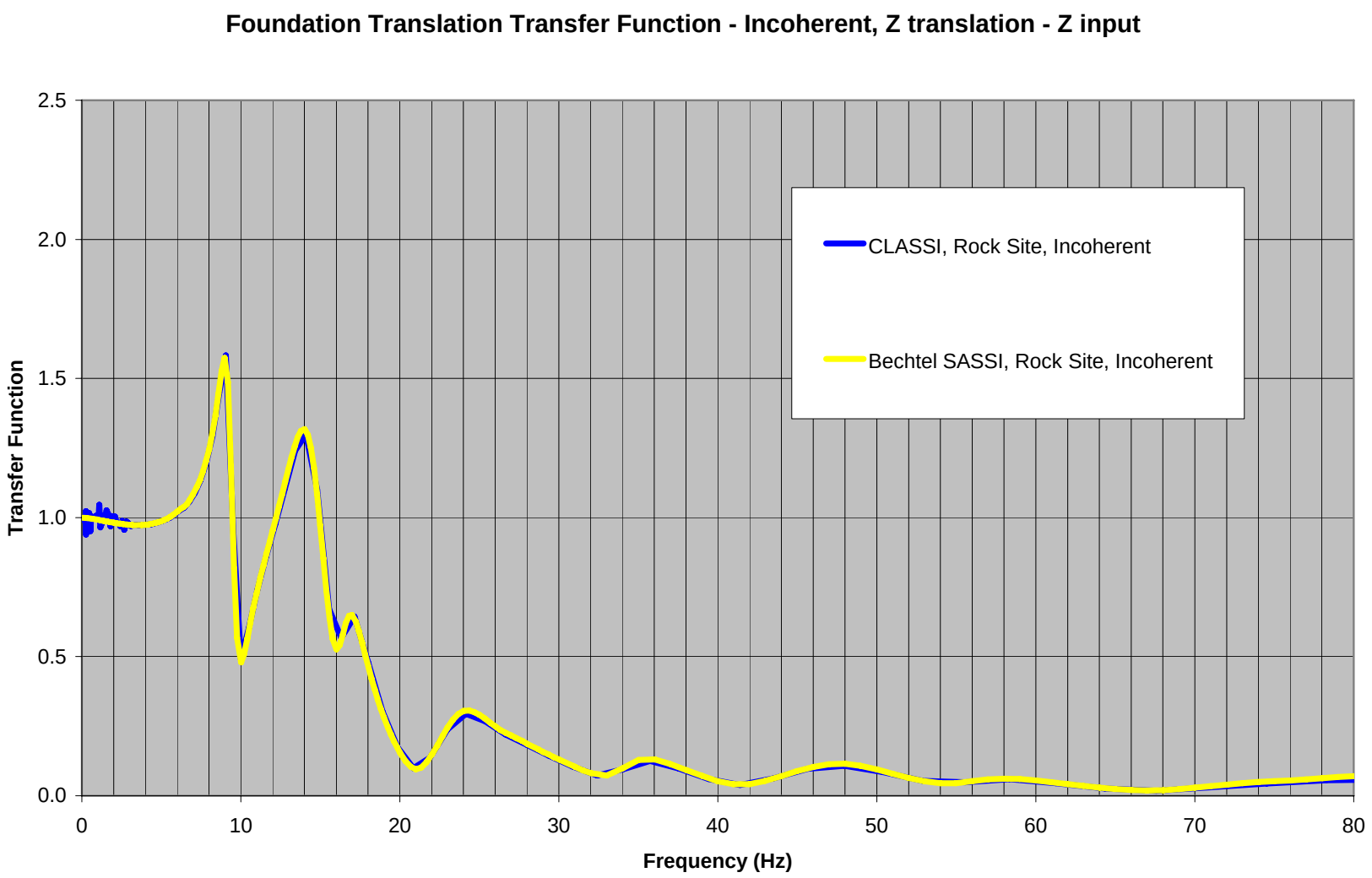
Transfer Function Comparisons

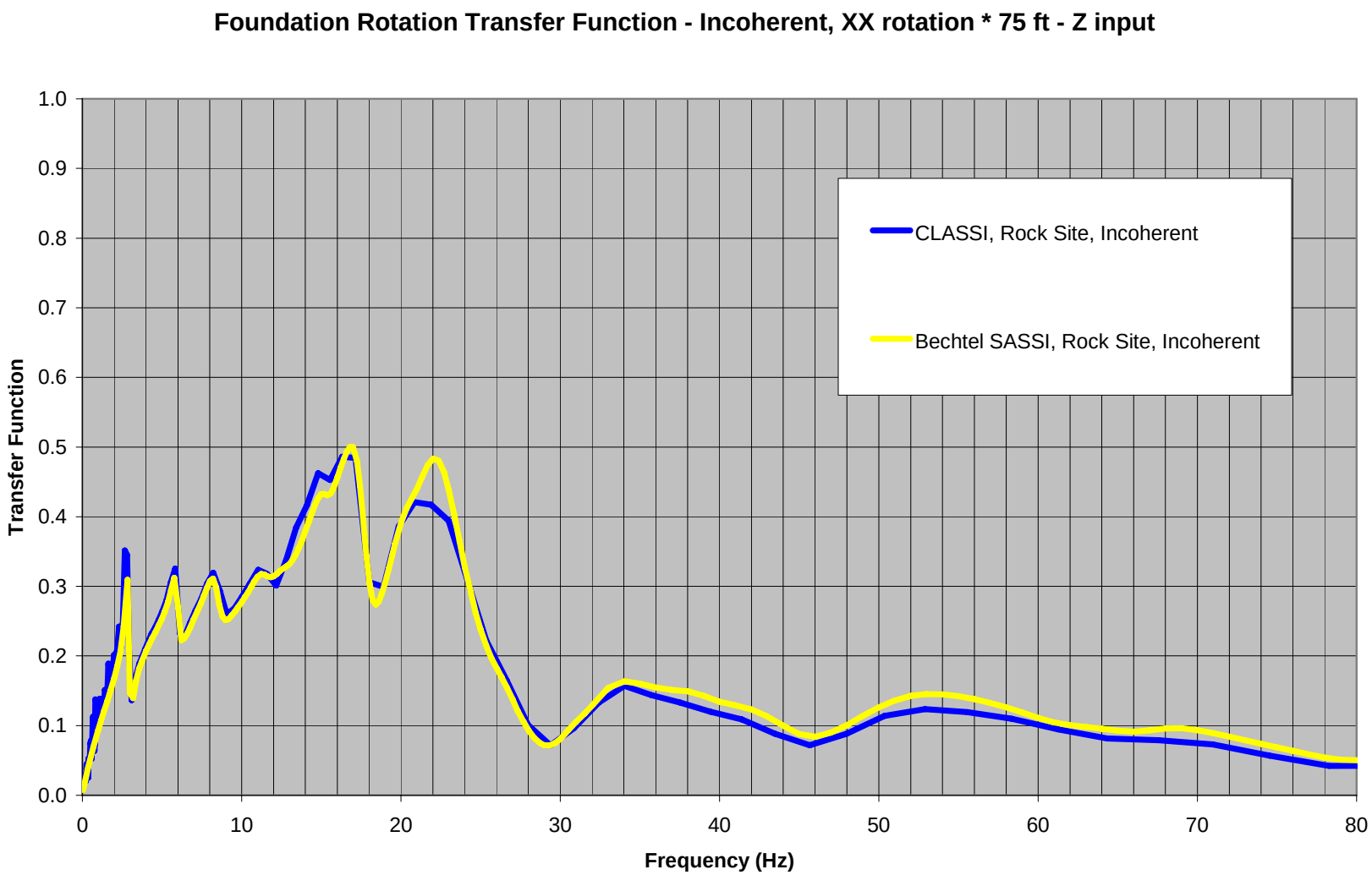

Foundation Translation Transfer Function - Incoherent, X translation - X input
Transfer Function
2.5
2.0
1.5
1.0
0.5
0.0
0
10
20
30
40
50
60
70
80
Frequency (Hz)
CLASSI, Rock Site, Incoherent
ACS SASSI, Rock Site, Incoherent
Bechtel SASSI, Rock Site, Incoherent

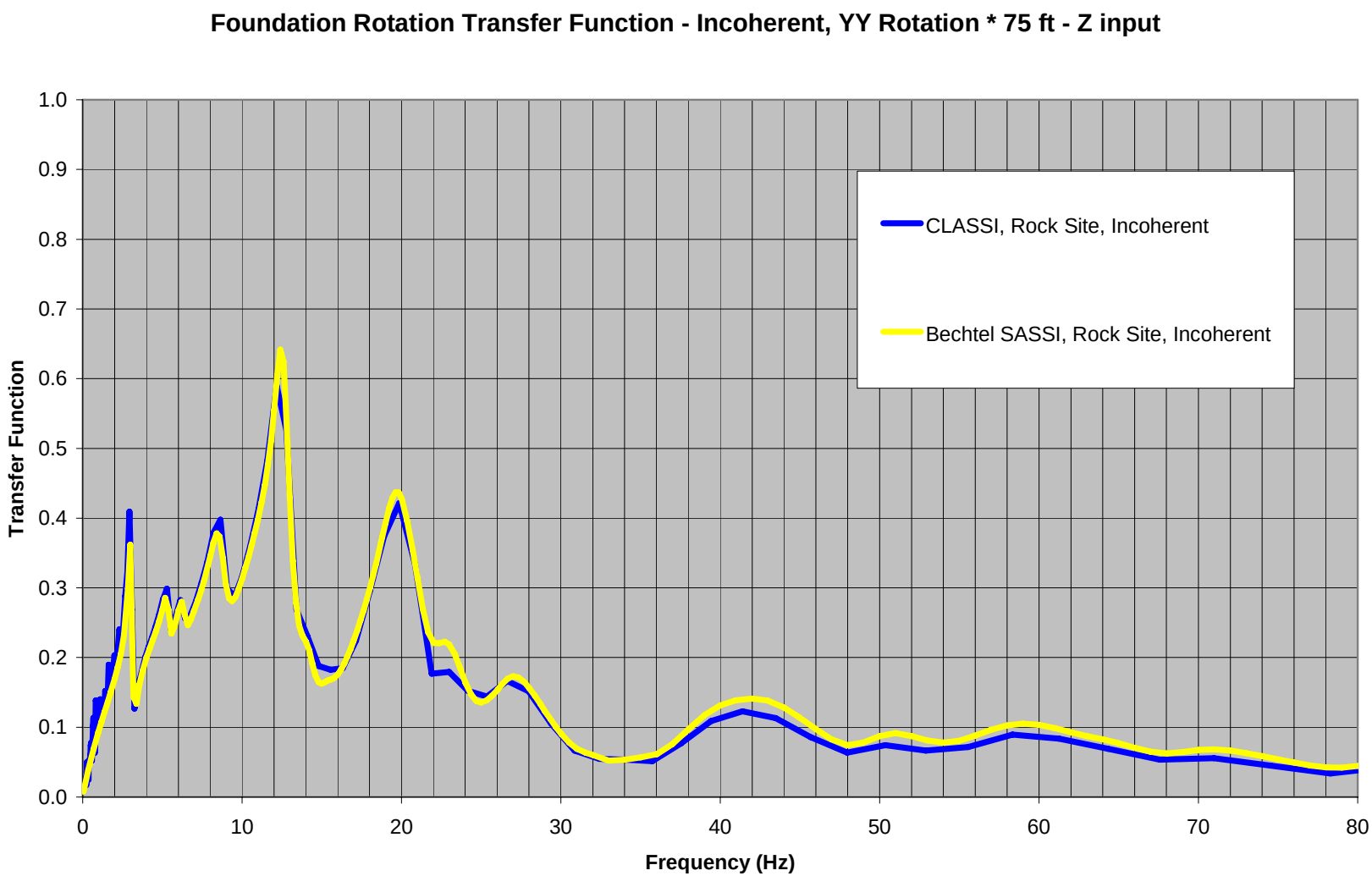

Foundation Rotation Transfer Function - Incoherent, Torsion * 75 ft - X input
Transfer Function
Frequency (Hz)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
10
20
30
40
50
60
70
80
CLASSI, Rock Site, Incoherent
ACS SASSI, Rock Site, Incoherent
Bechtel SASSi, Rock Site, Incoherent


Foundation Translation Transfer Function - Incoherent, Y translation - Y input
Transfer Function
Frequency (Hz)
2.5
2.0
1.5
1.0
0.5
0.0
0
10
20
30
40
50
60
70
80
CLASSI, Rock Site, Incoherent
ACS SASSI, Rock Site, Incoherent
Bechtel SASSI, Rock Site, Incoherent


Foundation Rotation Transfer Function - Incoherent, Torsion*75 ft - Y input
Transfer Function
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
10
20
30
40
50
60
70
80
Frequency (Hz)
CLASSI, Rock Site, Incoherent
ACS SASSI, Rock Site, Incoherent
Bechtel SASSi, Rock Site, Incoherent


Foundation Translation Transfer Function - Incoherent, Z translation - Z input
Transfer Function
2.5
2.0
1.5
1.0
0.5
0.0
0
10
20
30
40
50
60
70
80
Frequency (Hz)
CLASSI, Rock Site, Incoherent
Bechtel SASSI, Rock Site, Incoherent


Foundation Rotation Transfer Function - Incoherent, XX rotation * 75 ft - Z input
Transfer Function
Frequency (Hz)
CLASSI, Rock Site, Incoherent
Bechtel SASSI, Rock Site, Incoherent
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
10
20
30
40
50
60
70
80


Foundation Rotation Transfer Function - Incoherent, YY Rotation * 75 ft - Z input
Transfer Function
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
10
20
30
40
50
60
70
80
Frequency (Hz)
CLASSI, Rock Site, Incoherent
Bechtel SASSI, Rock Site, Incoherent