STRUCTURE-SOIL-STRUCTURE INTERACTION AT SRS

Structural Mechanics – SRS

October 25, 2011

Objective

Determination of Structure Soil Structure Interaction (SSSI) effects, if any between large and more massive Process Building (PB) and Exhaust Fan Building (EFB).

Results of the SSSI analysis were compared with those from Soil Structure Interaction (SSI) analysis of the individual buildings, for the following parameters:

- In-structure floor response spectra (ISRS)
- Transfer functions
- Relative displacements for EFB and PB
- In-plane- shear from SASSI at EFB wall

Building Description

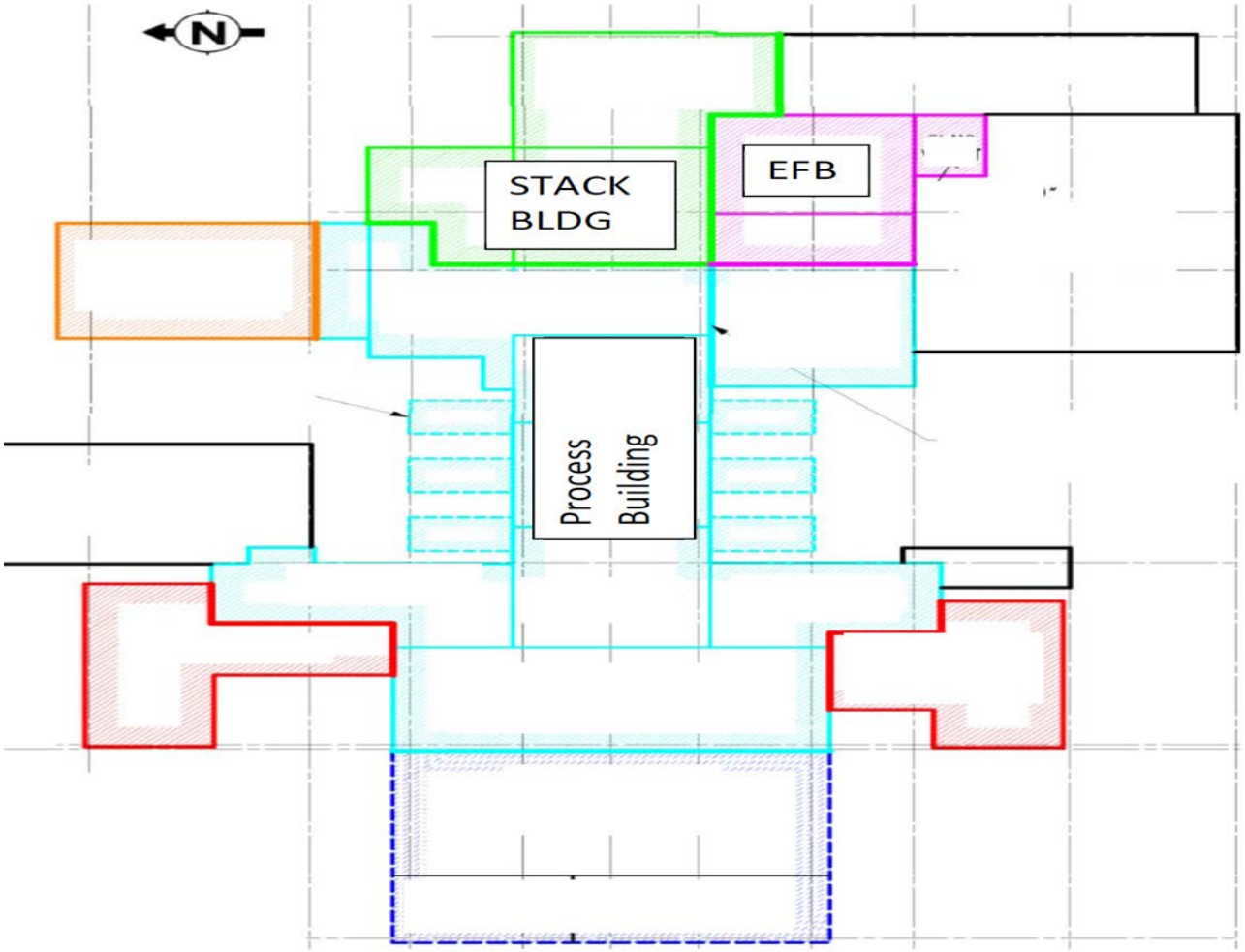
The Process Building is a massive reinforced concrete structure supported approximately 40 feet below the finished grade.

The PB approximate foundation dimensions are approximately 250.0 feet along the east-west direction and 200.0 feet along the north-south direction.

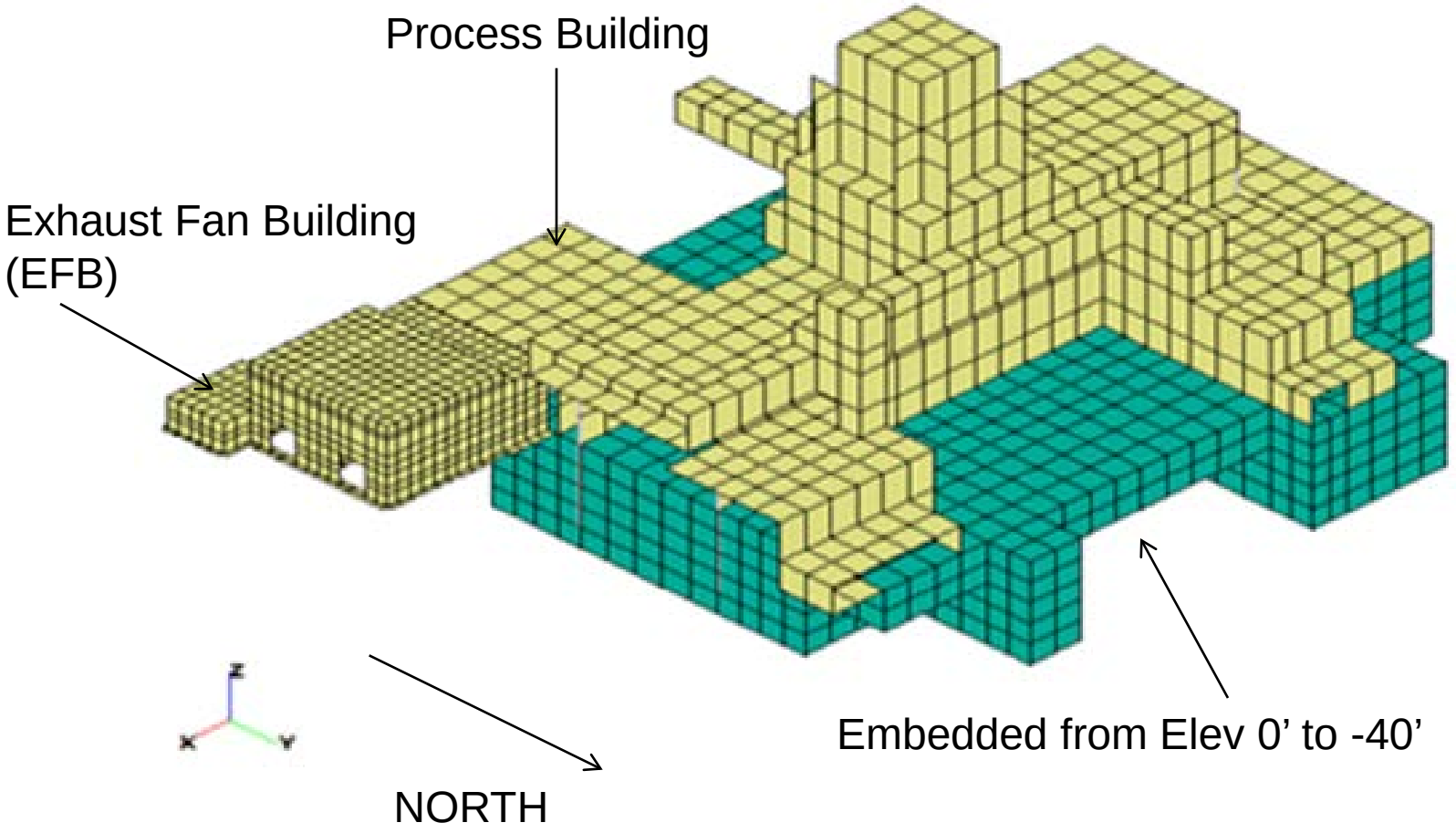
A portion of the Process Building rises approximately 150 feet above the finished grade level.

The EFB is approximately 75’x75’ in plan and extends 40’ above ground level. The EFB is located at the southeast corner of the Process Building and separated by an expansion joint.

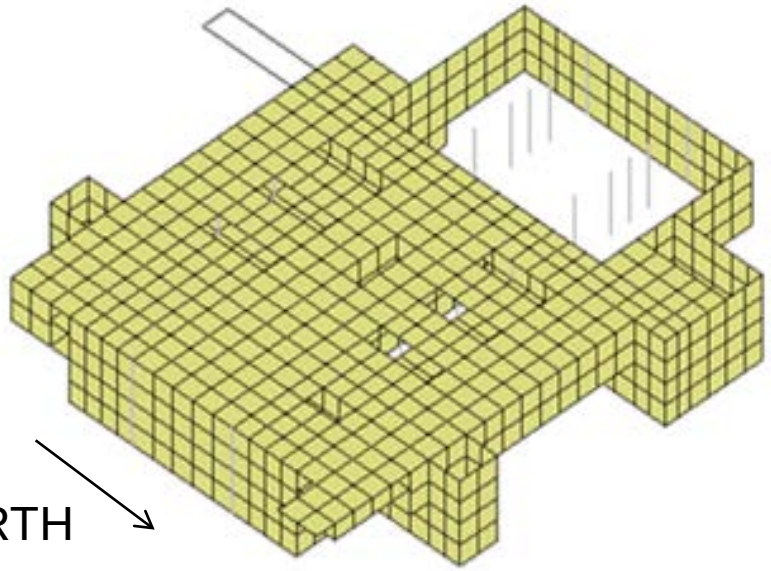
Process and Exhaust Fan Building - Plan view



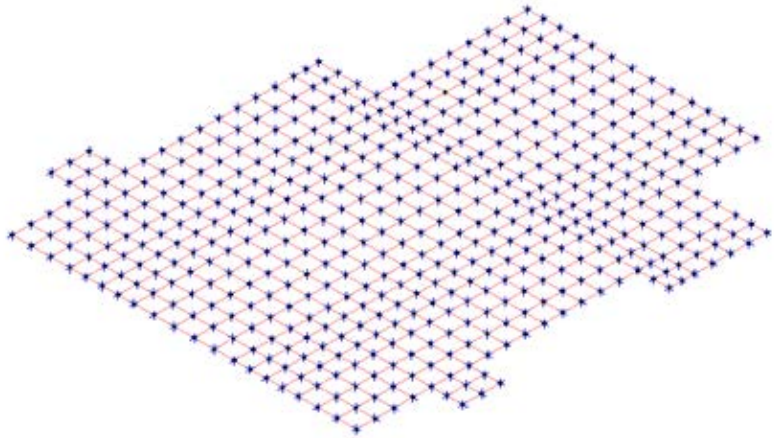
Process and Exhaust Fan Building FEM



Process Building Embedded EL 0 to -40 ft

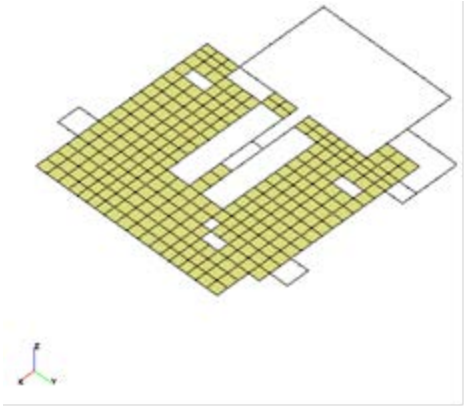


Process Building EL 0’ to -40’

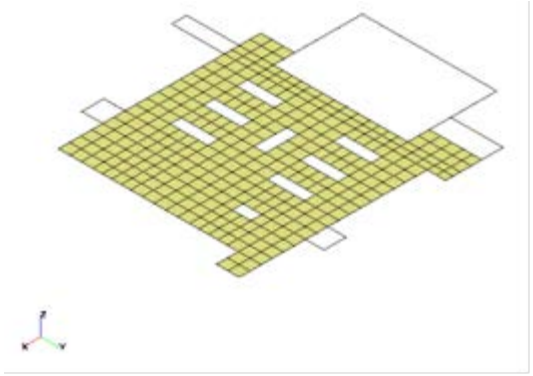


Process Building Interaction Nodes at Grade EL 0’

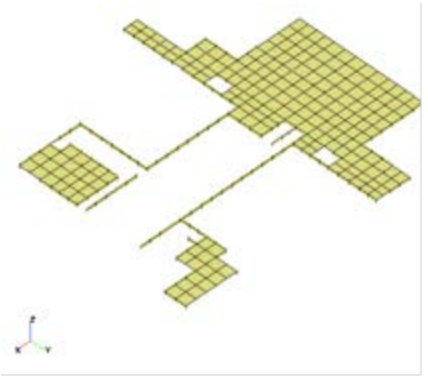
Process Building Embedded EL -20’ to -148’



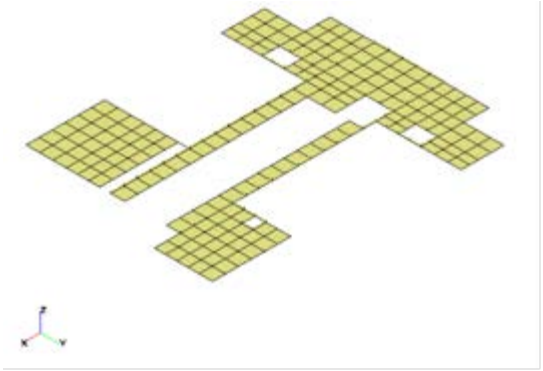
Process Building EL -20’



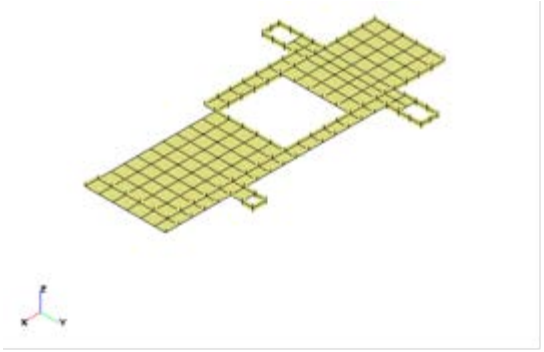
Process Building EL 0’



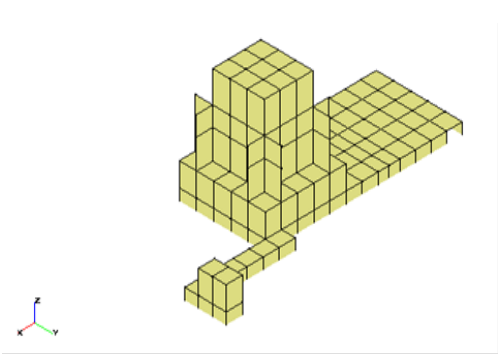
Process Building EL 15’



Process Building EL 34’

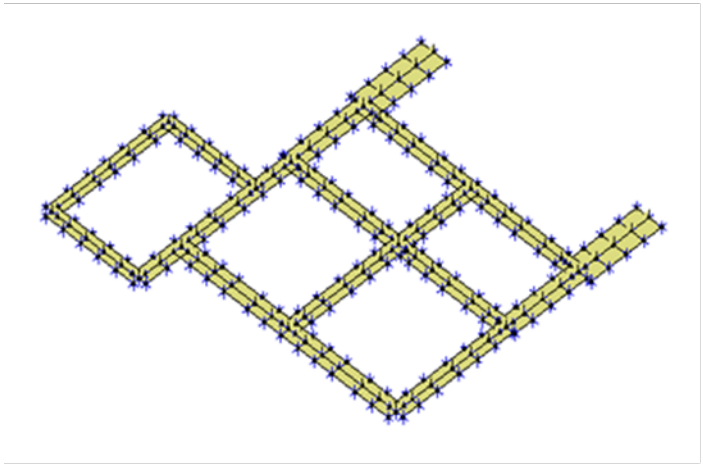


Process Building EL 48’

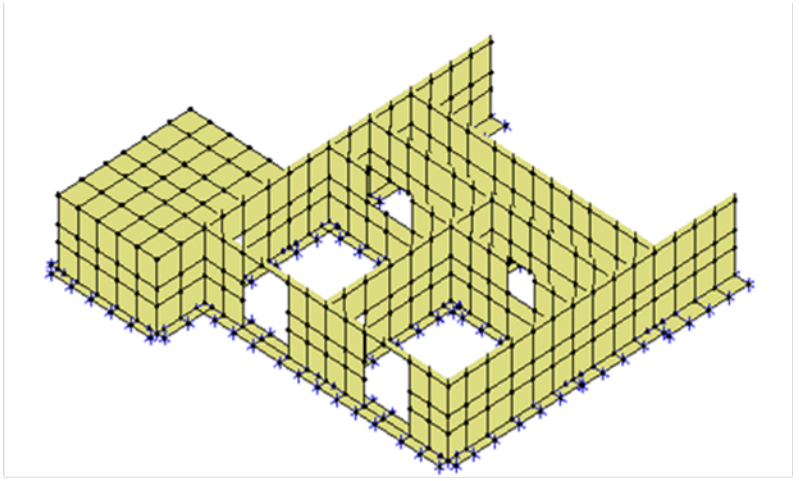


Process Building EL 72’ to 148’

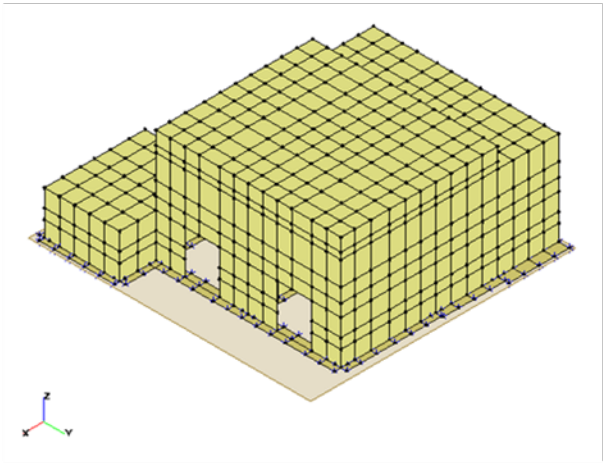
Exhaust Fan Building (Surface) EL 0’ to + 40’



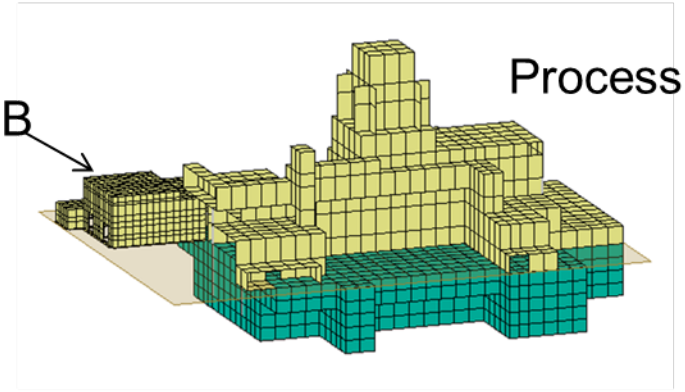
Exhaust Fan Building El 0’



Exhaust Fan Building El 0’ To +16’

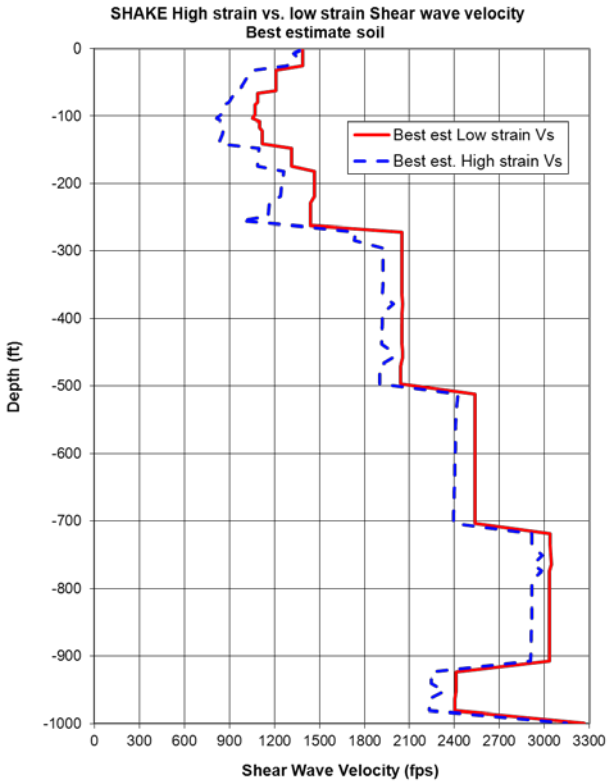


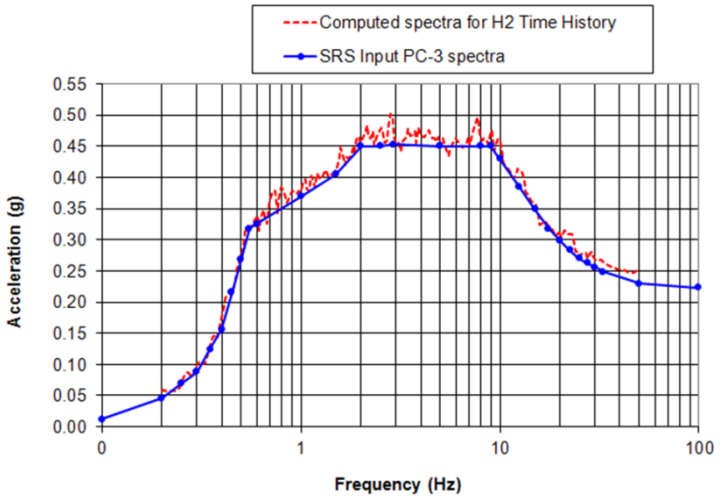
Exhaust Fan Building 0’ To +40’



Exhaust Fan Building with Process Building’

Soil Profile at SRS Site





SRS PC-3 Input spectra vs. Time history

SRS Site 1000’ best estimate soil
High strain vs. low strain shear wave velocity (fps)

Model Statistics

Mesh Size:

Maximum element size in the horizontal direction (PB) = 12.8 feet
Maximum element size in the horizontal direction (EFB) = 8.3 feet
Vertical soil layer size for embedded portion = 10 feet

Cut-off frequency- Using the maximum element size and 1/5 λ_s criteria:

	Critical V_s.	Mesh Limiting Freq (Hz)	Soil Cut-Off Freq (Hz)
BE:	984 ft/s	15.4	19.7

Hard Rock Natural Frequencies: PB = 6.0 Hz
EFB = 15 Hz

Total number of nodes and elements for 3D FEM

Process	Total nodes	Interaction nodes	Plate elements	Beam elements
Process	5129	1446	2728	94
EFB	1127	301	1090	NA
SSSI	6256	1747	3818	94

Total seismic weight (kips) of PB and EFB

Process Building 370,000 kips EFB 6500 kips

RESULTS: SSI vs. SSSI E-W Transfer Functions, Elev 0’

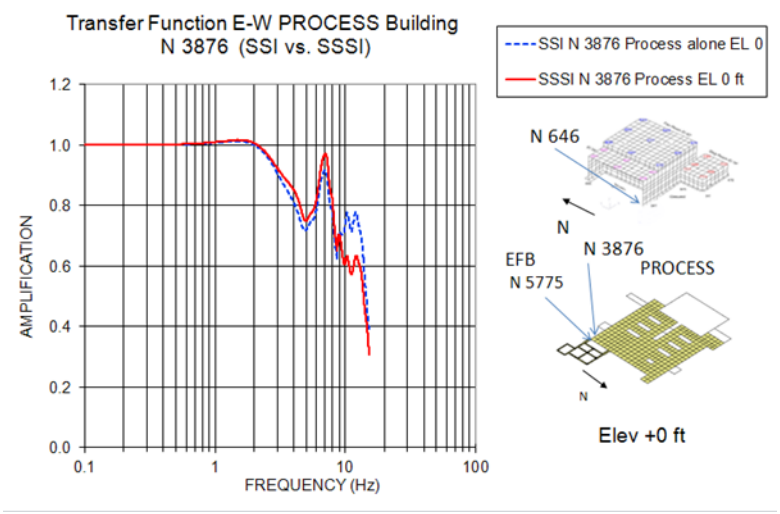


Figure 1. Grade EL 0’ Transfer Function for PB E-W SSI vs. SSSI

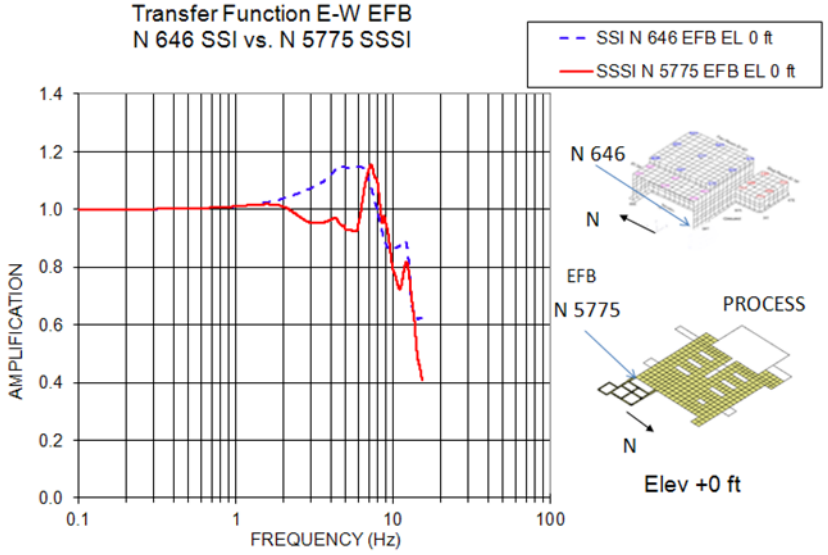


Figure 1A. Grade EL 0’ Transfer Function for EFB E-W SSI vs. SSSI

RESULTS: SSI vs. SSSI E-W ISRS, Elev 0’

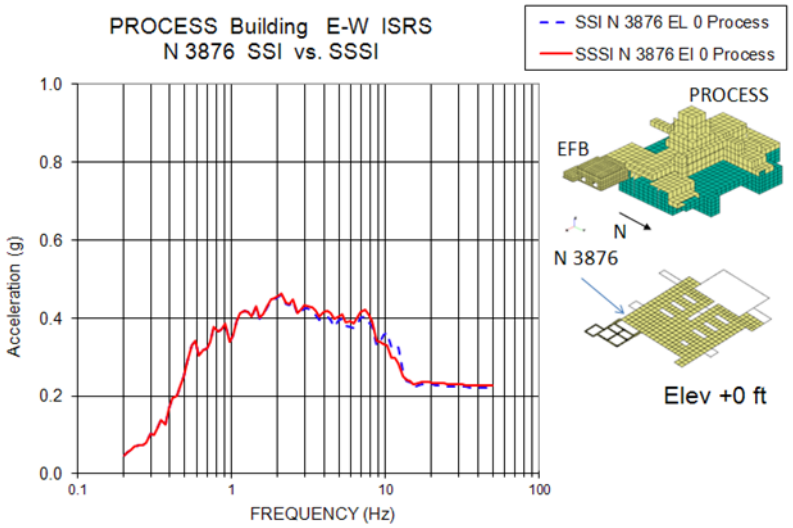


Figure 1B. Grade EL 0’ ISRS for **Process** – E-W SSI vs. SSSI (5% damping).

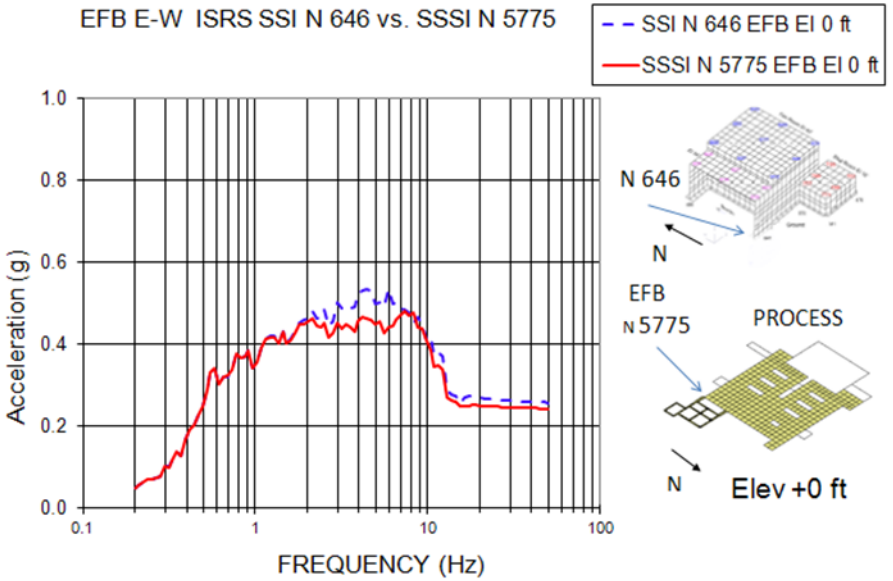


Figure 1C. Grade EL 0’ ISRS for **EFB** – E-W SSI vs. SSSI (5% damping).

RESULTS: SSI vs. SSSI E-W ISRS, Elev +34’

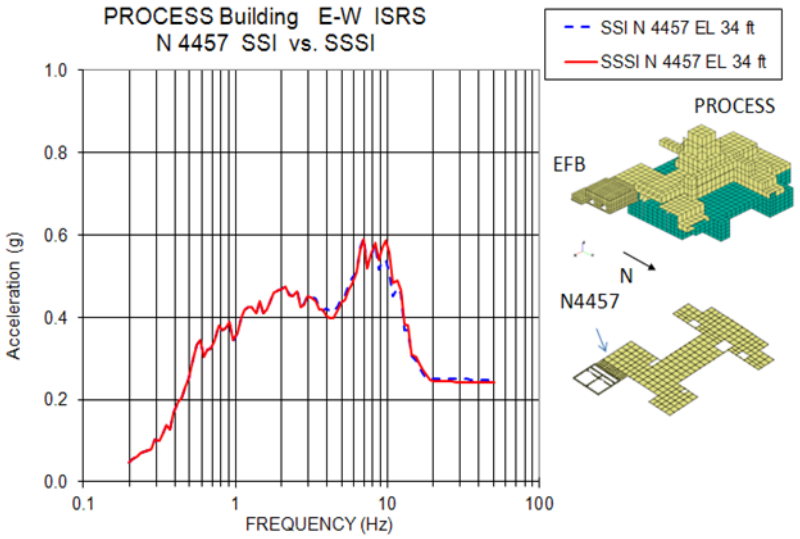


Figure 2. EL 34’ ISRS for **Process**
E-W SSI vs. SSSI (5% damping).

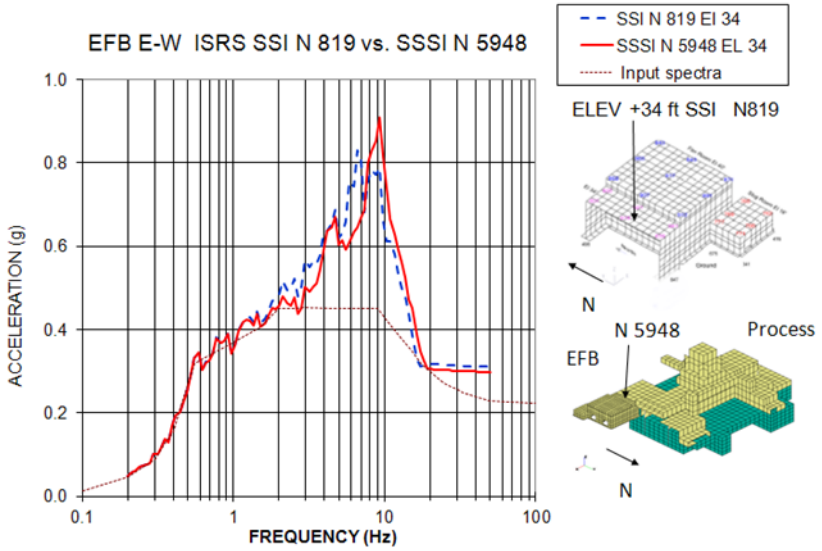


Figure 2A. EL 34’ ISRS for **EFB**
E-W SSI vs. SSSI (5% damping).

RESULTS: SSI vs. SSSI E-W ISRS, Elev +40’

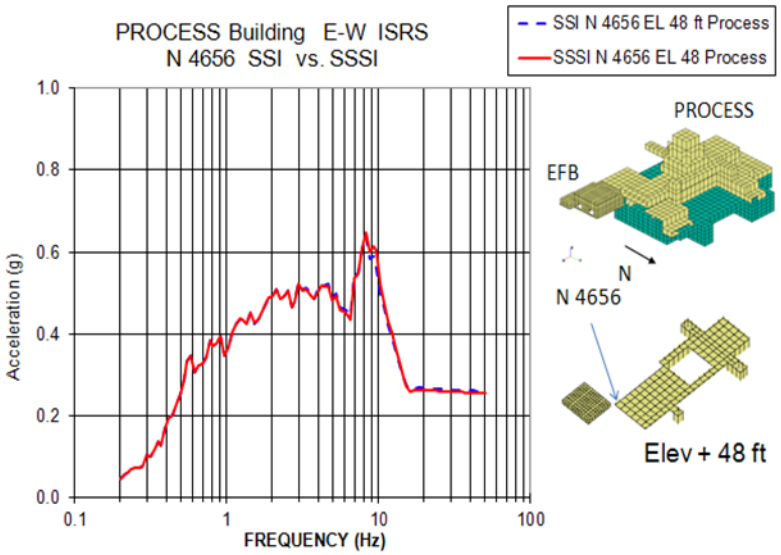


Figure 3. EL 48’ ISRS for **Process**
E-W SSI vs. SSSI (5% damping).

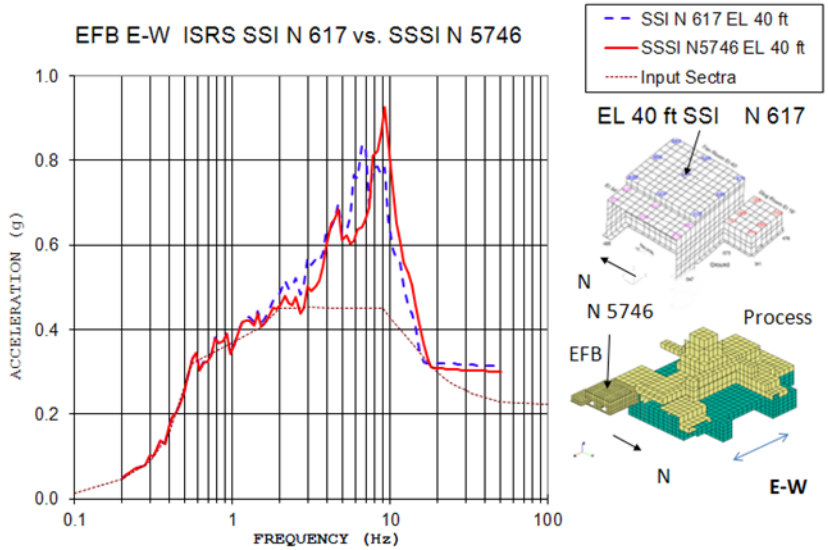
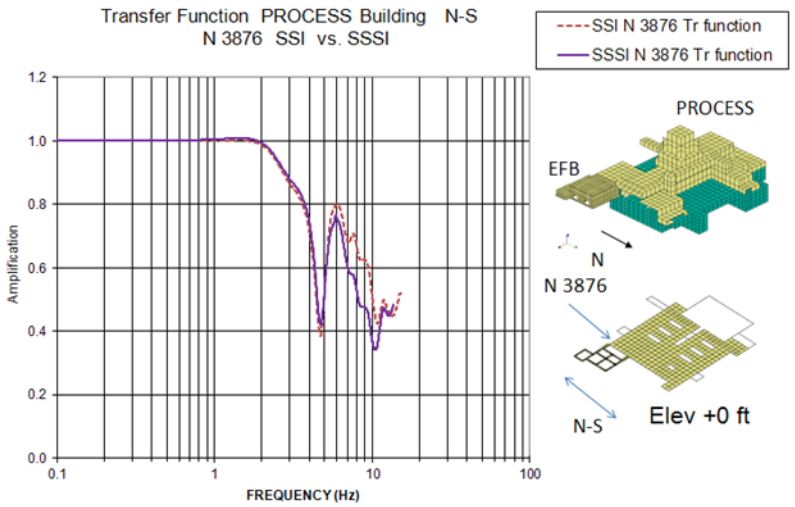


Figure 3A. EL 40’ ISRS for **EFB**
E-W SSI vs. SSSI (5% damping).

RESULTS: SSI vs. SSSI N-S Transfer Function, Elev 0’

EFB node # 646 is 1 inch from PB



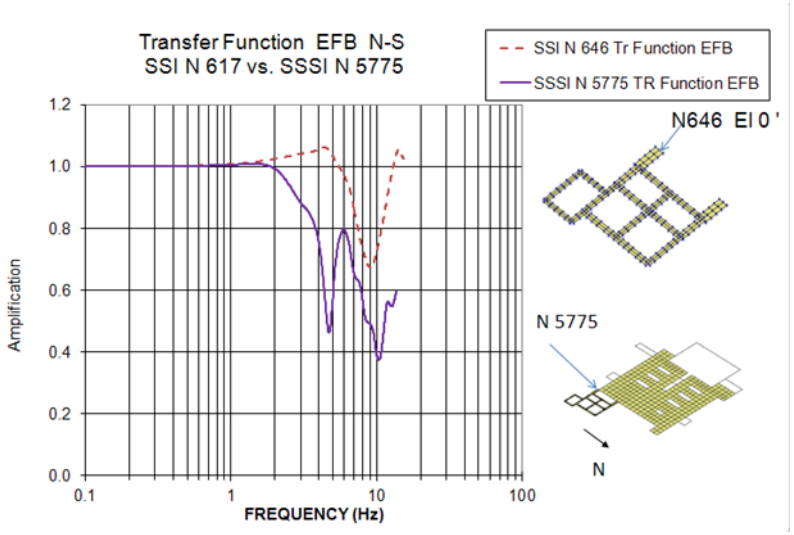


Figure 4. Grade EL 0’ Transfer function for **Process** – N-S SSI vs. SSSI

Figure 4A. Grade EL 0’ Transfer function for **EFB** – N-S SSI vs. SSSI **Node 646 is 1 inch from PB**

RESULTS: SSI vs. SSSI N-S ISRS, Elev 0’

EFB node 1 inch from PB

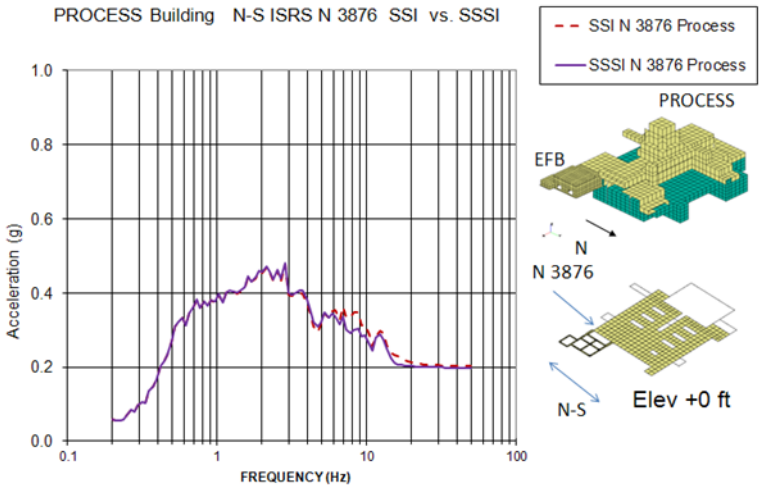


Figure 4B. Grade EL 0’ ISRS for **Process** SSI vs. SSSI (5% damping).

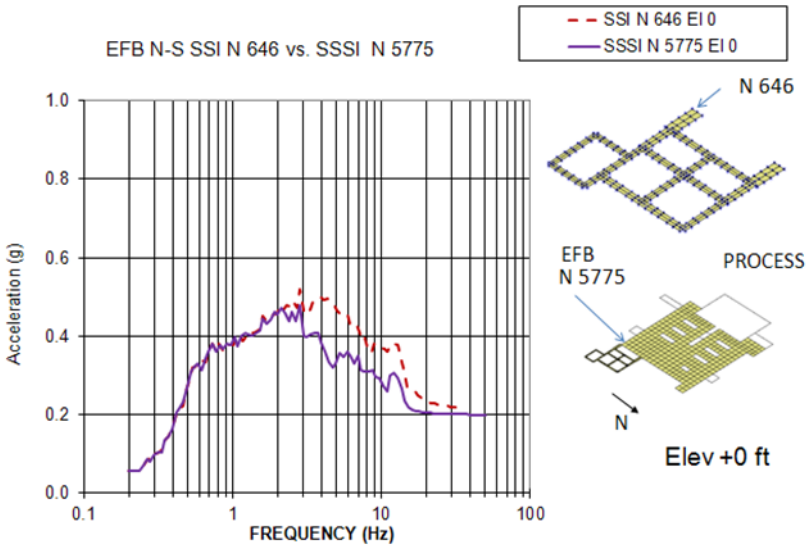


Figure 4C. Grade EL 0’ ISRS for **EFB** N-S SSI vs. SSSI (5% damping).

RESULTS: SSI vs. SSSI N-S ISRS, Elev 0’

EFB node # 1115 is 20 feet from PB

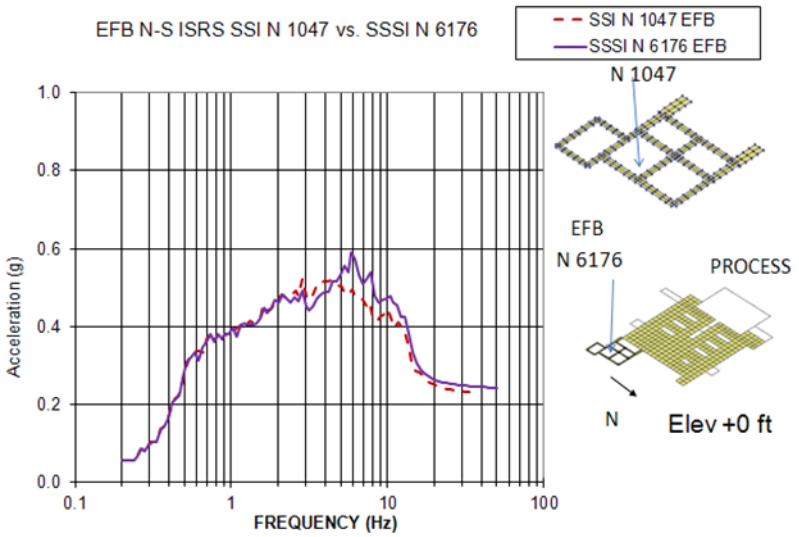


Figure 5. Grade EL 0’ ISRS for **EFB**
N-S SSI vs. SSSI (5% damping).

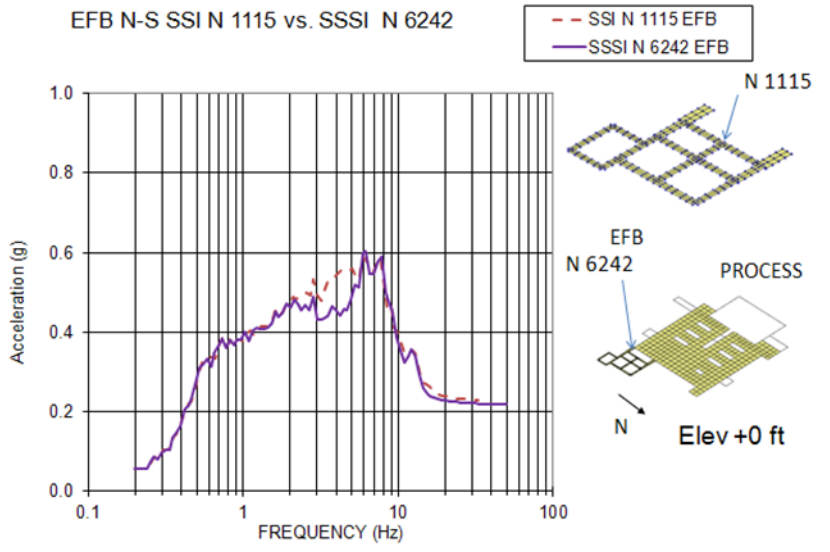


Figure 5A. Grade EL 0’ ISRS for **EFB**
N-S SSI vs. SSSI (5% damping).
Node 1115 is 20 feet from PB

RESULTS: Enveloped N-S ISRS, Elev 0’

EFB – four nodes

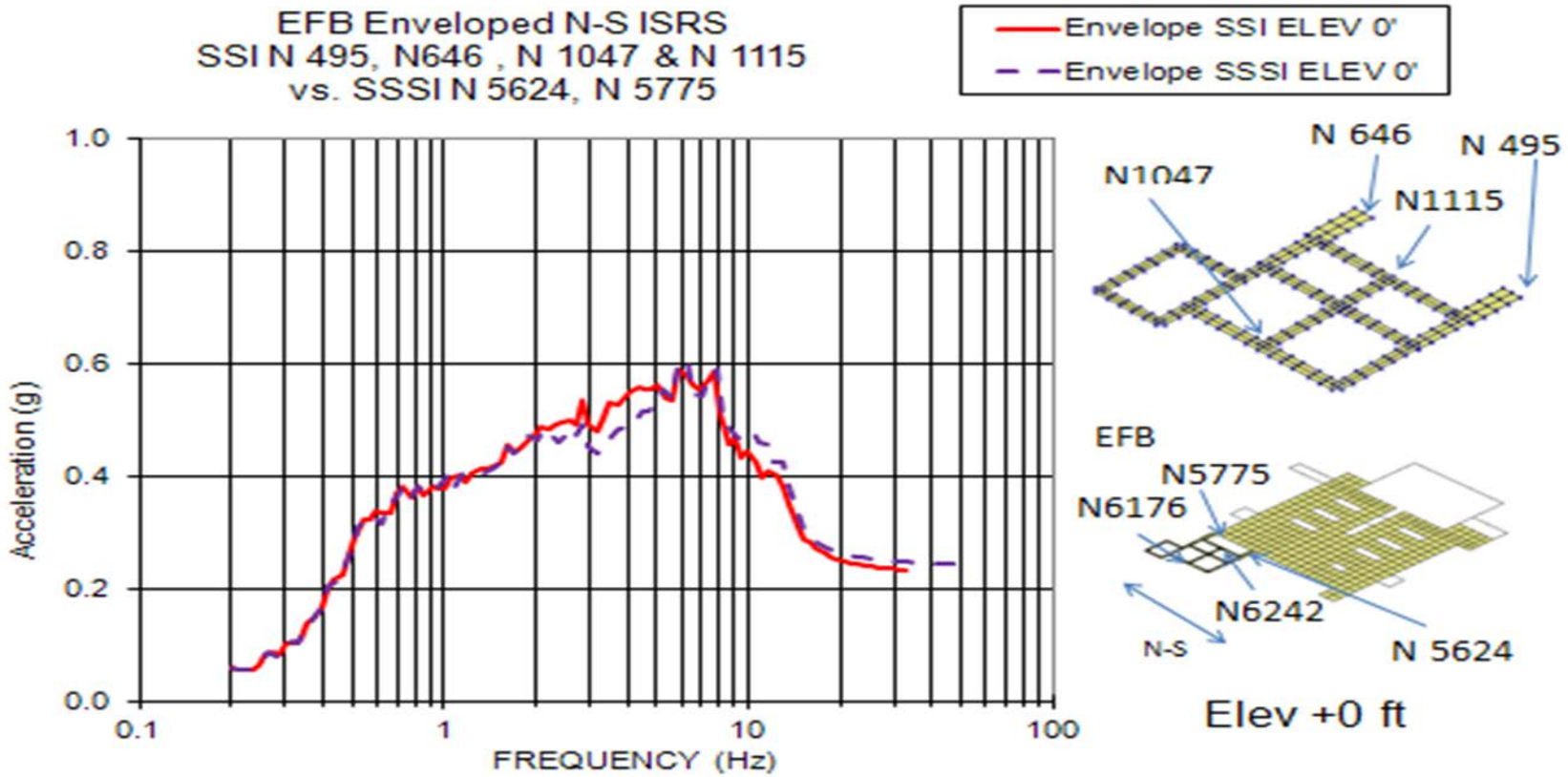
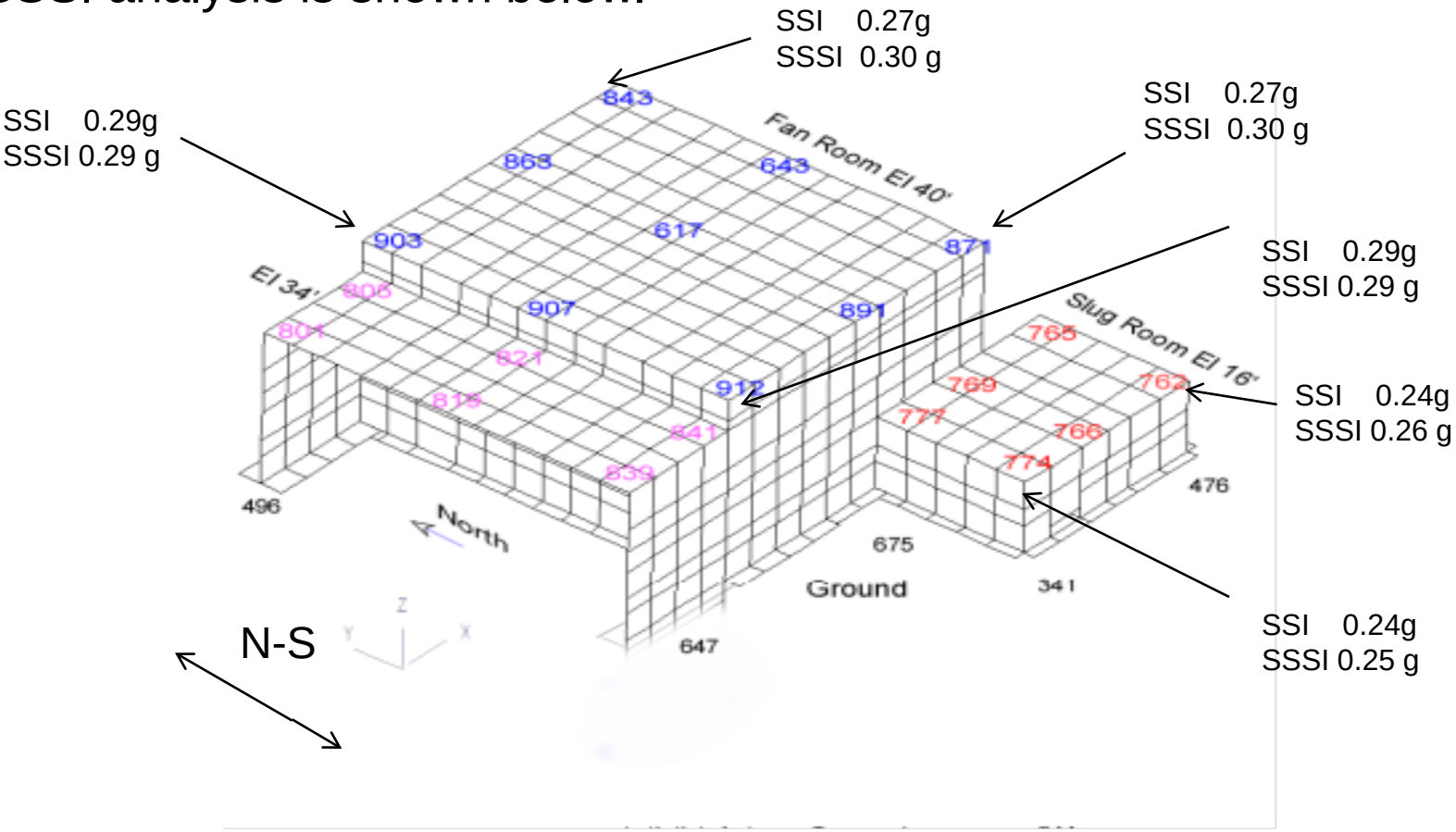


Figure 6. Grade EL 0’ Enveloped ISRS for **EFB**
N-S SSI vs. SSSI (5% damping).

RESULTS: Acceleration (ZPA) N-S SSI vs. SSSI - EFB

- The Zero Period Acceleration (ZPA) for EFB at selected nodes for SSI vs. SSSI analysis is shown below.

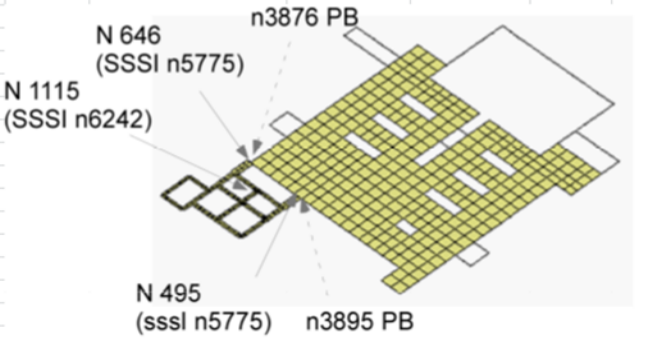


Relative Displacements- SSI vs. SSSI

- The effect of the Process Building on EFB is also evaluated by comparing relative displacement at selected nodes for EFB with SSI and SSSI results

SASSI Relative Displacement (inches) Relative to Contorl Motion

Node # ELEV 40 ft	SSSI node #	Elevation	Building	SSI N-S (Y) Displacement	SSSI N-S (Y) Displacement	% Increase SSSI	SSI E-W (X) Displacement	SSSI E-W (X) Displacement	% Increase SSSI
495	5624	0 ft	EFB Spread Footing	0.014	0.032	125%	0.020	0.034	65%
646	5775	0 ft	EFB Spread Footing	0.014	0.030	108%	0.020	0.029	41%
1115	6242	0 ft	EFB Spread Footing	0.029	0.031	8%	0.022	0.026	22%
3876	6036	0 ft	Process Building	0.029	0.031	8%	0.032	0.035	7%
3895	5746	0 ft	Process Building	0.030	0.032	8%	0.038	0.036	-6%
617	5746	40ft	EFB EL 40 ft roof	0.052	0.048	-7%	0.053	0.049	-7%



SSSI PROCESS AND EFB EL 0 FT

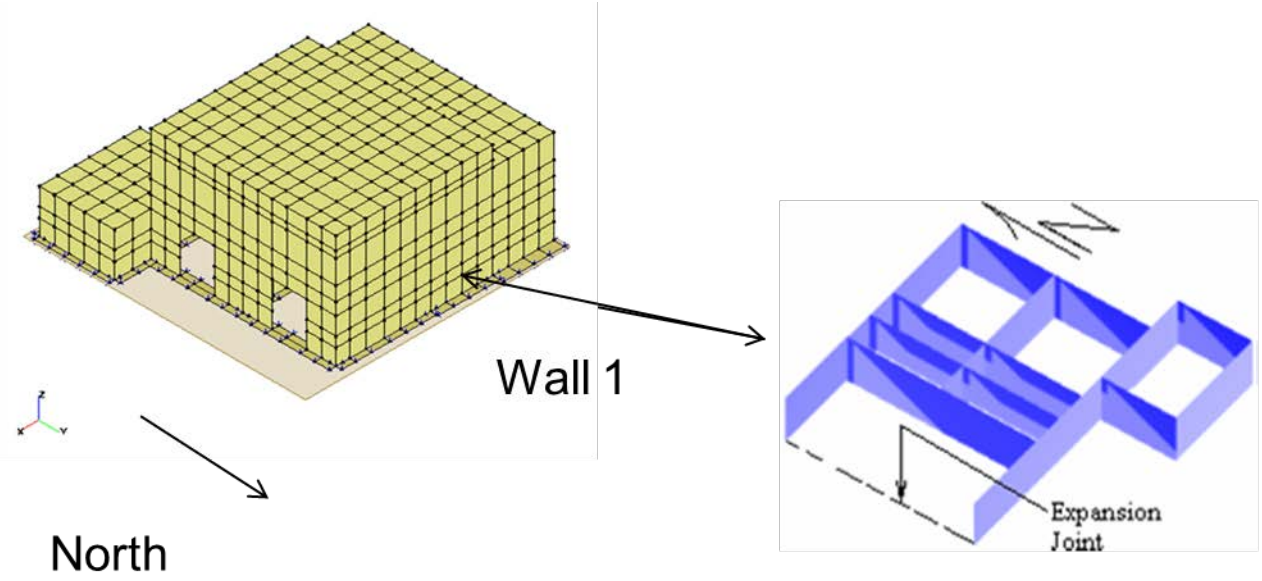
In-Plane Shear - SSI vs. SSSI

- In-Plane shear from SASSI (STRESS module) is obtained for Wall 1 from EFB model (SSI) and EFB + Process model (SSSI).

SSI: 734 kips

SSSI: 638 kips.

- From equivalent static analysis SSI In-Plane shear =750 kips



RESULTS: Vertical SSI vs. SSSI Transfer Function & ISRS, Elev 0'

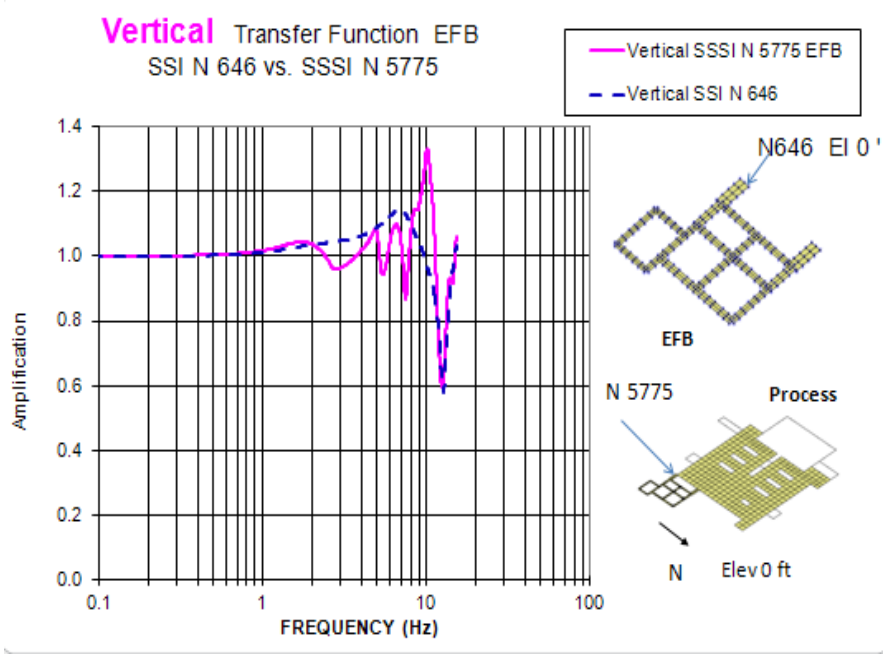


Figure 7A. Grade EL 0' Transfer function for **EFB** –VERTICAL SSI vs. SSSI

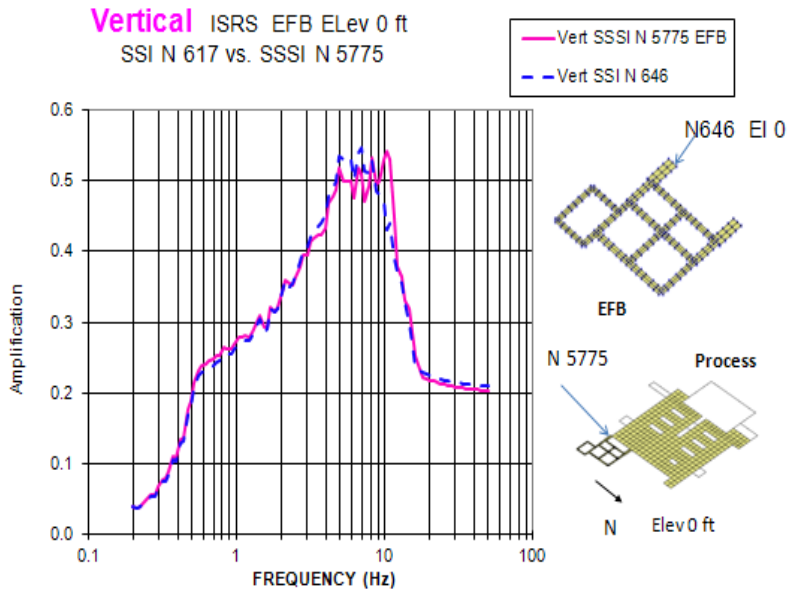


Figure 7B. Grade EL 0'' ISRS for **EFB** – Vertical SSI vs. SSSI

RESULTS: SSI vs. SSSI Vertical Transfer Function & ISRS, Elev 34'

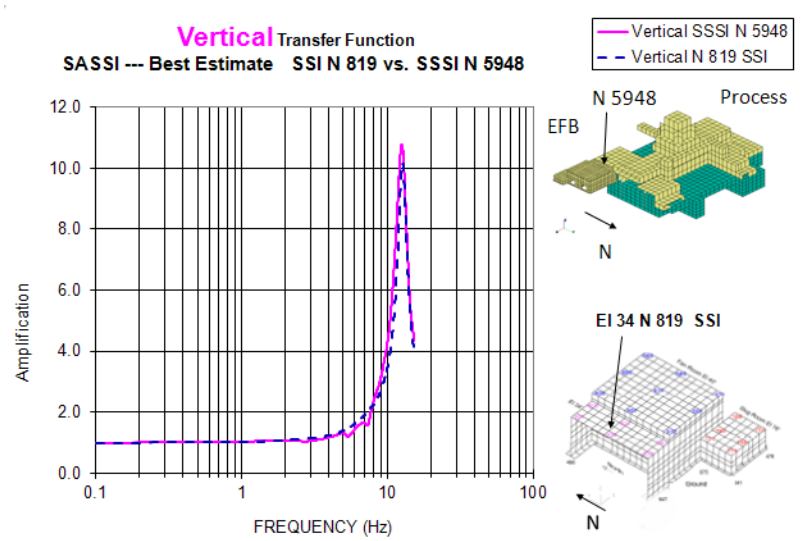


Figure 8A. EL 34' Transfer function for **EFB** –VERTICAL SSI vs. SSSI

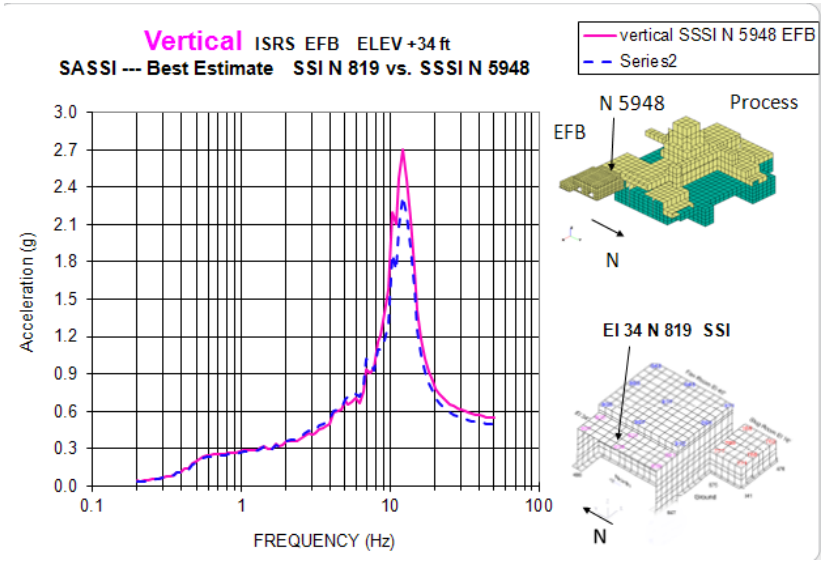


Figure 8B. EL 34' ISRS for **EFB** – Vertical SSI vs. SSSI

RESULTS: SSI vs. SSSI Vertical ISRS, EL 16’ and 40‘

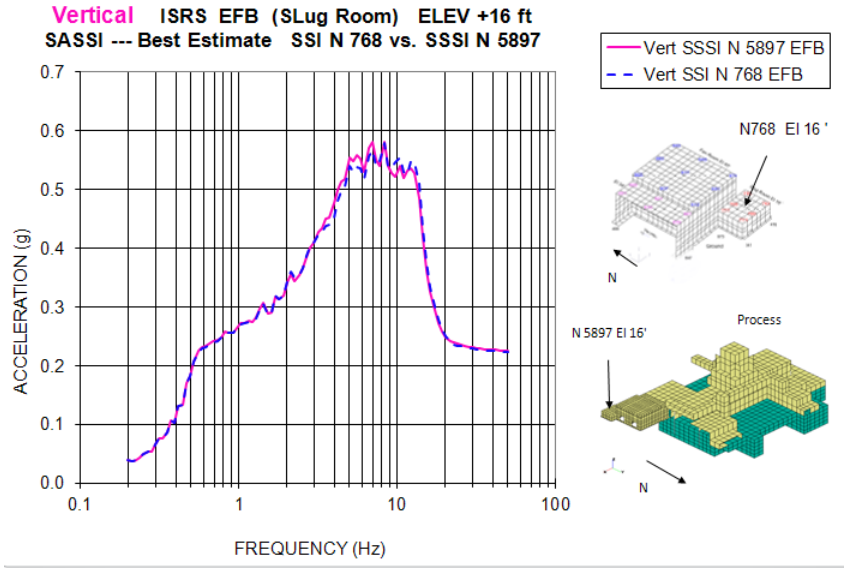


Figure 9A. EL 40’ Transfer function
for **EFB** –VERTICAL SSI vs. SSSI

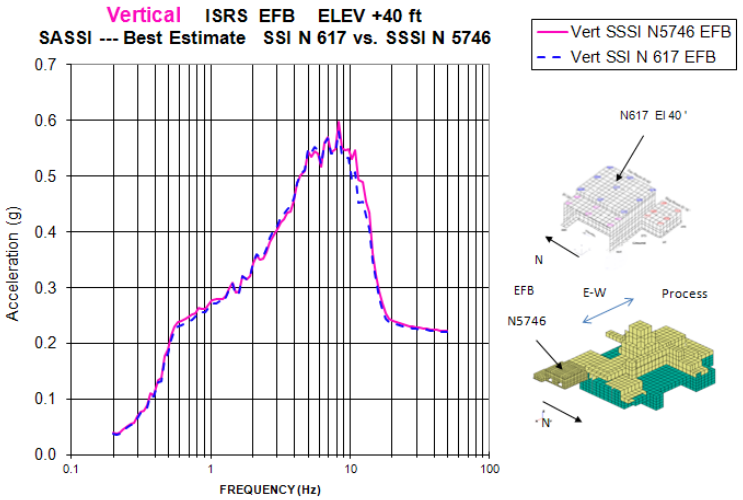


Figure 9B. EL 40’ ISRS
for **EFB** – Vertical SSI vs. SSSI

Conclusions

Response at EFB nodes immediately adjacent to PB is de-amplified – (matches lower response of PB)

Response at EFB nodes further (20 feet) away at EFB grade level SSSI spectra is higher (effect of PB is reduced).

Conclusions

No effect of EFB on massive Process Building for SSI vs. SSSI

- Transfer functions and ISRS are identical.

Minor effect on ISRS of EFB due to massive Process building

- SSSI EFB Transfer function similar to PB
- Small effect on ISRS
- Minor effect on acceleration, displacement, and in-plane shear

Future Work

Include other adjacent structures (e.g Stack Building) in SSSI analysis

Compare 3D FEM SSSI results to stick model SSSI results

QUESTIONS?