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
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 Building Embedded  EL 0 to -40 ft

NORTH

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’
Soil Profile at SRS Site

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

SRS PC-3 Input spectra vs. Time history
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 $1/5 \lambda_s$ criteria:

<table>
<thead>
<tr>
<th></th>
<th>Critical $V_s$</th>
<th>Mesh Limiting Freq (Hz)</th>
<th>Soil Cut-Off Freq (Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BE</td>
<td>984 ft/s</td>
<td>15.4</td>
<td>19.7</td>
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</tbody>
</table>

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

Total number of nodes and elements for 3D FEM

<table>
<thead>
<tr>
<th>Process</th>
<th>Total nodes</th>
<th>Interaction nodes</th>
<th>Plate elements</th>
<th>Beam elements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process</td>
<td>5129</td>
<td>1446</td>
<td>2728</td>
<td>94</td>
</tr>
<tr>
<td>EFB</td>
<td>1127</td>
<td>301</td>
<td>1090</td>
<td>NA</td>
</tr>
<tr>
<td>SSSI</td>
<td>6256</td>
<td>1747</td>
<td>3818</td>
<td>94</td>
</tr>
</tbody>
</table>

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.
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?