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Firewater Service Complex Structural Design Report

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This is a public version of WG3-U63-ERD-S-0003, Rev 2, from which the security-related information has been removed. Portions of the document that have been removed are indicated by white space within single brackets as shown here { }. The footer of each page where security-related information is withheld carries the notation "{{{Security-Related Information - Withheld Under 10 CFR 2.390}}}."

REVISION CHART (CONT)

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RECORD OF REVISION

Rev #	Description
0	Initial issue
1	Incorporate comments and effects of soil separation.
2	Incorporate NRC comments on Rev.1

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1. SCOPE

The objective of this report is to document the North Anna Unit 3 (NA3) site-specific structural design evaluation of the Economic Simplified Boiling Water Reactor (ESBWR) Firewater Service Complex (FWSC) for the site-specific seismic load demands that exceed the seismic loads used for the standard design of the FWSC structure in Reference 2.1.2-i. The scope of the evaluation is the analysis and stress checks of the FWSC structures for site-specific seismic loads in combination with other design loads in critical seismic load combinations. The analysis is performed using the same NASTRAN model used for the standard design of the FWSC structures in Reference 2.1.2-i. The design loads applied to the model are the same as those considered in the standard design except for the site-specific Safe Shutdown Earthquake (SSE) loads that are obtained from Reference 2.1.2-l. The NA3 site-specific SSE loads are combined with non-seismic standard plant loads following the same standard design analysis methodology and acceptance criteria.

2. APPLICABLE DOCUMENTS

2.1 Supporting and Supplemental Documents

The following documents form a part of this document:

2.1.1 Supporting Documents

Supporting documents are those documents that complete the requirements of this document and are referred to herein.

	Designation
a. Firewater Service Complex Concrete Drawing, 105E4502, Revision 3	U63-2020

2.1.2 Supplemental Documents

Supplemental documents are those documents that are to be used in conjunction with this document.

	Designation
a. Standard Review Plans and Regulatory Guides Design Specification, SR3-1-A11-TRD-5201	A11-5201
b. Industry Codes and Standards Design Specification, SR3-1-A11-TRD-5202	A11-5202
c. Composite Design Specification, 26A6007, Revision 6	A11-5299
d. Seismic Analysis of Firewater Service Complex, 26A7419, Revision 1	U63-5030
e. General Civil Design Criteria, 26A6558, Revision 4	A40-4010
f. Firewater Service Complex General Arrangement Drawings, 105E4483, Revision 1	U63-2010

g. Design Specification for Firewater Service Complex, 26A7391, Revision 0
U63-4010

h. Stability Analysis of Firewater Service Complex, 26A7421, Revision 1
U63-5020

i. Firewater Service Complex Structural Design Report, 26A7420, Revision 2
U63-5010

j. North Anna 3 Firewater Service Complex Stability Analysis Report, WG3-U63-ERD-S-0002, Revision 1

k. North Anna 3 Firewater Service Complex Seismic Analysis Report, WG3-U63-ERD-S-0001, Revision 4

l. North Anna 3 Bounding Seismic Demands for CB and FWSC Site-Specific Evaluations, SER-DMN-032, Revision 3

m. North Anna 3 Control Building and Firewater Service Complex Seismic Structure-Soil-Structure Interaction Analyses Report, WG3-U73-ERD-S-0002, Revision 6

n. North Anna 3 Evaluation of FWSC Concrete Fill and Effects of Separation between Concrete Fill and Surrounding Soil, SER-DMN-034, Revision 2

o. North Anna 3 Reactor Building Structural Design Report, WG3-U71-ERD-S-0004, Revision 2

2.2 Industry Codes and Standards

The following industry codes and standards shall form a part of this document to the extent specified herein. Unless otherwise specified, the applicable revision of the industry codes and standards as indicated in the Industry Codes and Standards Design Specification (Reference 2.1.2-b) shall be used.

a. ACI 349-01: "Code Requirements for Nuclear Safety-Related Concrete Structures (ACI 349-01) and Commentary (ACI 349R-01)"

b. ASCE 7-02: "Minimum Design Loads for Buildings and Other Structures", 2002

c. ASCE 4-98: "Seismic Analysis of Safety Related Nuclear Structures", 2002

d. ACI 350.3-01: "Seismic Design of Liquid-Containing Concrete Structures (ACI 350.3-01) and Commentary (ACI 350.3R-01)"

e. ASME-2004: Boiler and Pressure Vessel Code, Section III, Rules for Construction of Nuclear Power Plant Components, Division 2, Subsection CC, "Code for Concrete Reactor Vessels and Containments"

2.3 Regulation and Regulatory Requirements

The following regulations and regulatory requirements shall form a part of this document to the extent specified herein. Unless otherwise specified, the applicable revision of the Standard Review Plans (SRP) and Regulatory Guides (RG) as indicated in the Standard Review Plans and Regulatory Guides Design Specification (Reference 2.1.2-a) shall be used.

a. NUREG-0800, "USNRC Standard Review Plan for Review of Safety Analysis Reports for Nuclear Power Plants - LWR Edition".

2.4 References

a. TM 5-855-1: "Foundations of Protective Design for Conventional Weapons", Department of the Army Technical Manual, Nov. 1986

b. Topical Report, Design of Structures for Missile Impact, Bechtel Power Corp., BC-TOP-9A Revision 2, September 1974.

3. STRUCTURAL DESCRIPTION AND GEOMETRY

3.1 Structural Geometry and Dimensions

The FWSC consists of two Firewater Storage Tanks (FWS) and one Fire Pump Enclosure (FPE) which are categorized as Seismic Category I (C-I) structures. The FWSC has a 52.0m x 20.0m x 2.5m basemat with shear keys, where the FWS and the FPE sit symmetrically. There are three shear keys under basemat: two are installed in the EW direction and one is installed in the NS direction. They are located at FP1, FP5 and FPB grid lines, whose layout is further described in Section 3.3. The size of shear keys at FP1 and FP5 grid lines is 20m x 2m x 3.6m. The size of shear key at FPB grid line is 52m x 2m x 3.6m.

The FWS are cylindrical structures with 17.50m outside diameters and are 15.05m high above the basemat. Each FWS has a water storage capacity of 550,000 gallons.

The FPE is a 13.3m x 12.5m box structure that is 3.6m high above the basemat. It includes the Electric Pump, RPV Makeup Water Pump, Diesel Pump, Tank Recirculation Pump, and Diesel Fuel Oil Storage Tank.

3.2 Key Structural Elements and Descriptions

Each FWS is designed with a cylindrical reinforced concrete wall and a dome-shaped reinforced concrete roof. The FPE is a reinforced concrete box type structure with shear walls and a roof slab.

3.3 Floor Layout and Elevations

Floor layouts and sections of the FWSC are shown in Figures 3.3-1 and 3.3-2.

3.4 Conditions of Vicinity and Support

The site-specific evaluation presented in this report considers supporting subgrade conditions shown in Table 3.4-1 that correspond to the generic Soft Site profile described in Reference 2.1.2-d. The FWSC is founded on concrete fill. The applied site properties are identical to those used for the standard design. The Soft Site conditions are conservative for NA3 rock site because softer soils lead to larger structural deformations and stress demands on the FWSC basemat and structures. Therefore, the Soft Site is acceptable for all site configurations.

Ground temperature is considered to be 15.5°C.

3.5 Special Structural Features

None

4. STRUCTURAL MATERIAL REQUIREMENTS

4.1 Concrete

Concrete for the FWSC structures has the following specified compressive strength, f'_c:

- f'_c = 27.6 MPa = 4000 psi: basemat
- f'_c = 34.5 MPa = 5000 psi: other FWSC structures

4.2 Reinforcement

Reinforcement is Grade 60 deformed billet steel that conforms to ASTM A615, "Specification for Deformed and Plain Billet-Steel Bar for Concrete Reinforcement Steel". Minimum yield strength, f_y is 414 MPa = 60000 psi.

5. STRUCTURAL LOADS

5.1 Dead Loads

The following types of dead load are considered in the structural evaluation and are identical to those used for the standard design of the FWSC structures in Reference 2.1.2-i.

5.1.1 Structural Weight

The weights of modeled structural members, i.e. concrete slabs and walls, are included in the model by specifying the unit weight for each member, so that they are automatically accounted for in the analysis calculation.

The following unit weights are used for modeled members.

- Reinforced concrete: 23.5 kN/m^3
- Steel: 77.0 kN/m^3

5.1.2 Other Weight

The following weights are considered in the analysis and shown in Table 5.1-1.

1. Deck and steel beam.. 3.00 kN/m^2
2. Finishing weight

– Man-walking roof (cover concrete, waterproofing).................... 1.77 kN/m^2

– Floor slab (Mat)... 0.98 kN/m^2

– Outer wall above grade (architectural finishing concrete)............. 1.18 kN/m^2

3. Parapet weight

– Parapet on FPE roof... 9.0 kN/m

4. Reinforced Concrete (RC)-made partition wall

– Weight of RC-made partition walls is calculated using the unit weight of 23.5 kN/m^3.

5. Piping load (Miscellaneous commodities and their supports)

– On the ceiling of the FPE... 2.40 kN/m^2

6. Liner

– Weight of Liner applied to the floor area inside FWS.................. 1.60 kN/m^2

– Weight of Liner applied to the wall area inside FWS.................. 1.00 kN/m^2

5.1.3 Equipment Weight

The site-specific structural evaluation also considers equivalent dead load, which includes the weight of piping, cables and cable trays, ducts and their supports. It also includes the weight of the fluid contained within the piping and some minor equipment under operating conditions. Floors are designed for the actual equipment loads. For permanently attached small equipment, piping, conduits and cable trays on the roof of the FPE, a minimum of 2.4 kN/m^2 (50 psf) is applied as shown in Table 5.1-1. These equipment weight loads, considered for the site-specific evaluation of the FWSC structures, are identical to the loads used for the standard design in Reference 2.1.2-i.

Table 5.1-2 presents the weight of major equipment located in the FWSC. Consistent with the standard design, a design margin of 20% is added to the equipment weight in accordance with the Design Specification for Firewater Service Complex (Reference 2.1.2-g).

5.1.4 Static Water Pressure

The unit weight of water used in the calculations of static water pressure is 9.81 kN/m^3. The height of water in the tanks is assumed to be 11.1m.

The hydrostatic pressure applied on the FWS wall is increased with the depth measured from the free surface of water. The hydrostatic pressure is uniformly distributed on the FWS tank bottom. The static water pressures used for the site-specific structural evaluation are identical to those used for the standard design of the FWSC structures in Reference 2.1.2-i.

5.2 Live Loads

The site-specific structural evaluation considers live loads that are the same as those used for the standard design of the FWSC structures in Reference 2.1.2-i. The following three types of live loads are considered as described below:

5.2.1 Floor Live Loads

The floor live loads are considered as shown in Table 5.2-1. The floor live loads are reduced to 1/4 of their values when used in the evaluation of site-specific seismic loads.

5.2.2 Static Soil Pressure

Consistent with the standard design in Reference 2.1.2-i, the site-specific evaluation does not consider the static lateral soil pressure on the side face of basemat since the effect of lateral soil pressure on the design stress for the basemat design is negligible.

5.2.3 Snow/Rain Loads

A snow load of 2.4 kN/m^2 (50 psf) is considered in accordance with Standard Design (Reference 2.1.2-i, 5.2.3, SH NO.12). One hundred percent of the snow load is used in the evaluation of seismic loads. The NA3 site-specific snow loads (1.2 kN/m^2 (25psf)) are bounded by the above standard design loads.

A roof drainage system consisting of roof scuppers and drains is considered independently in accordance with Standard Design (Reference 2.1.2-i, 5.2.3, SH NO.12).

5.3 Thermal Loads

Figure 5.3-1 provides the temperatures during normal plant operation for both summer and winter seasons. These temperatures are identical to those used for the standard design of the FWSC structures in Reference 2.1.2-i.

These FWSC thermal loads are obtained from the results of a heat transfer analysis. Figure 5.3-2 shows the equations used for the heat transfer analysis. The winter and summer thermal conditions considered in the analysis are provided in Tables 5.3-1 and 5.3-2 for normal operation condition (To). The average temperature (Td) and temperature difference (Tg) of walls and slabs are determined by the equations shown in Figure 5.3-2.

5.4 Wind Loads

Design conditions for calculating the basic wind load are as follows:

Basic wind speed (50 year recurrence interval), m/s (mph)	62.6 (140)
Importance factor (safety-related structures)	1.15
Exposure category	Exposure D

Wind load values at each elevation level are shown in Table 5.4-1. Design coefficients are shown in Table 5.4-2. The evaluation of these design wind loads, which are identical to those used for the standard design of the FWSC structures, is described in Appendix A of Reference 2.1.2-i. The NA3 site-specific wind loads (Basic wind speed is 40.2m/s (90 mph)) are bounded by the above standard design loads.

5.5 Tornado Loads

Design conditions as specified in the Composite Design Specification (Reference 2.1.2-c) for calculating the tornado wind load are as follows:

Maximum tornado wind speed, m/s (mph)	147.5 (330)
Maximum rotational speed, m/s (mph)	116.2 (260)

Maximum translational speed, m/s (mph)	31.3 (70)
Radius, m (ft)	45.7 (150)
Maximum pressure drop, kPa (psi)	16.6 (2.4)
Maximum rate of pressure drop, kPa/s (psi/s)	11.7 (1.7)

The magnitude of the tornado loads on the FWS and the FPE are provided in Table 5.5-1. The evaluation of these design tornado loads, which are identical to those used for the standard design of the FWSC structures, is described in Appendix A in Reference 2.1.2-i. The NA3 site-specific tornado loads (for example, Maximum Tornado wind speed is 134.1 m/s (300 mph)) are bounded by the above standard design loads.

5.6 Site-Specific Seismic Loads

The design seismic loads are determined from the results of the site-specific Soil-Structure Interaction (SSI) analyses of the FWSC standalone model and the Structure-Soil-Structure Interaction (SSSI) analyses of the FWSC-CB combined model described in References 2.1.2-k and 2.1.2-m, respectively. The design seismic loads are also determined considering the effects of soil separation on the seismic response of the FWSC structures, as described in Reference 2.1.2-n. Reference 2.1.2-l provides the site-specific seismic loads used for the evaluation presented in this report. These loads bound the effects of structural stiffness variations, SSSI of the Control Building (CB) on the seismic response of the FWSC structures, and separation between the concrete fill underneath the FWSC foundation and surrounding soil, as described in References 2.1.2-k, 2.1.2-m, and 2.1.2-n, respectively.

Four components (two horizontal, one vertical and one torsional) of the seismic loads on the FWS and the FPE structures are considered following the methodology used for the standard design in Reference 2.1.2-i. Overturning moment loads applied at each floor elevation are also considered to account for the effects of floor rocking on the wall axial forces.

The site-specific seismic design loads applied to the FWSC structures are shown in the following tables and figures.

- Horizontal seismic loads, moments, and torsion: Table 5.6-1
  Figures 5.6-2 and 5.6-3
- Vertical accelerations: Table 5.6-3
- Lateral resistance forces at Shear Key: Table 5.6-4

The node numbers in the above tables are described in Figure 5.6-1.

5.6.1 Seismic Hydrodynamic Load from Water in FWS Tank

Site-specific hydrodynamic pressure load due to seismic is applied on the FWS structure. The site-specific hydrodynamic load is developed following the methodology used for the standard design in Reference 2.1.2-i, which is in accordance with the provisions of ACI 350.3-01 (Reference 2.2-d). The two components of hydrodynamic pressure are considered: impulsive pressure (P_{iy}) and convective pressure (P_{cy}), which are listed in Table 5.6-2. The

distribution of the vertical hydrodynamic pressure is shown in Figure 5.6-4. The horizontal distribution of the hydrodynamic pressure applied on the tank surface at each major elevation is shown in Figure 5.6-5.

Following the methodology used for the standard design of the FWSC structures in Reference 2.1.2-i, the axisymmetric lateral hydrodynamic pressure associated with vertical seismic response, P_{hy}, acting on the FWS wall is considered as a vertical seismic load. P_{hy} load components are dependent on the direction of a vertical earthquake, and vertically upward seismic load produces a load component that causes tension on the inside of the tank wall and vice versa.

The hydrodynamic pressure is calculated by the following ACI 350.3-01 equation:

$$P_{hy} = \ddot{u}_v \times q_{hy}$$

where,

P_{hy} : Lateral hydrodynamic pressure component associated with vertical excitation of liquid

$\ddot{u}_v$: Effective spectral acceleration from an elastic vertical response spectrum as shown in Figure 5.6-6 (g)

q_{hy} : Unit hydrostatic pressure (lb/ft^2)

5.6.2 Seismic Load on Shear Keys

The site-specific structural evaluation considers the site-specific lateral resistance pressure loads applied along the FWSC shear keys normal to the direction of seismic motion. Table 5.6-4 presents the magnitudes of the site-specific lateral loads on shear keys, which are obtained from Reference 2.1.2-l based on the FWSC site-specific sliding stability evaluation presented in Section 5.1 of Reference 2.1.2-j and Section 6.3 of Reference 2.1.2-n. The pressure is distributed along the shear key height in a triangular shape and the direction is opposite to the direction of the seismic motion as shown in Figure 5-1 of Reference 2.1.2-j. As shown in Section B.4.1 of Appendix B of Reference 2.1.2-k, the seismic response analyses of the models representing full (uncracked concrete) stiffness properties of the FWSC reinforced concrete structure provide seismic load demands that bound the effects of concrete cracking on the site-specific seismic load demands on the FWSC shear keys.

6. STRUCTURAL ANALYSIS AND DESIGN

6.1 General Description

The structural analysis and design of the FWSC are performed consistently with the procedure used for the standard design in Reference 2.1.2-i, as follows:

1. Perform stress analyses for the site-specific seismic loads described in Section 5.6, using the same Finite Element (FE) model as the one used for the standard design to calculate section forces due to SSE. More detail is described in Section 6.2.2.

2. Combine the SSE section forces with the section forces due to non-seismic design loads, calculated in Reference 2.1.2-i, according to the site-specific seismic design load combination described in Section 6.3.

3. Perform structural design calculations using the section forces from the site-specific seismic design load combinations and compare them with the corresponding results for the non-seismic load combinations selected in Reference 2.1.2-i.

The design of reinforced concrete members in the FWSC is performed according to the ACI 349-01 (Reference 2.2-a).

6.2 Stress Analysis

6.2.1 Analysis Program

The computer program used for the stress analysis calculation is the MSC/NASTRAN version 2013. It is a general-purpose stress analysis program which is technically based on the FE method. Analysis calculations are executed on Red Hat Enterprise Linux Server release 5.7 OS.

6.2.2 Analysis Model

6.2.2.1 Outline of the Analysis Model

The stress analysis model is a three-dimensional FE model. Figure 6.2-1 illustrates the stress analysis model, which is the same as the model used for the standard design in Reference 2.1.2-i and includes 3.0 m deep shear keys. See additional model details in the following subsections. The effect of the shear key height change from 3.0m to 3.6m is evaluated in Appendix D.

6.2.2.2 Modeling Principles

The global FE model was developed for the standard design analyses according to the following modeling principles.

1. Primary structure members, including basemat, walls, and roof slab are modeled so that their design section forces can be adequately evaluated.

2. The global coordinate system of the analysis model is determined as follows:

   - Origin: The origin is at EL 0.0m at the center of the basemat.
     (EL 0.0m is 3.4m below the center of the basemat in height.)
   - X-axis: Positive X is the southward direction from the origin.
   - Y-axis: Positive Y is the eastward direction from the origin.
   - Z-axis: Positive Z is the vertically upward direction.

3. Local coordinate system (for application of element forces) of vertical shell elements for the FPE outer walls is determined as follows:

   - For East and West walls:
     - Z-axis: Positive Z is the westward direction.
     - X-axis: Positive X is same as the global X-axis.
     - Y-axis: Positive Y is the vertically upward direction.
   - For North and South walls:
     - Z-axis: Positive Z is the southward direction.
     - X-axis: Positive X is same as the global Y-axis.
     - Y-axis: Positive Y is the vertically upward direction.

4. Local coordinate system of horizontal shell elements, such as the basemat and roof slab, is determined as follows:

   - Z-axis: Positive Z is the vertically upward direction.
   - X-axis: Positive X is same as the global X-axis.
   - Y-axis: Positive Y is same as the global Y-axis.

5. Local coordinate system of cylindrical wall elements for the FWS is determined as follows.

   - Z-axis: Positive Z is the outward direction.
   - X-axis: Positive X is counterclockwise direction (looking down).
   - Y-axis: Positive Y is the vertically upward direction.

6.2.2.3 Modeling of the Basemat and Ground

6.2.2.3.1 Basemat and Shear Keys

The basemat is modeled with thick shell elements that have equal thickness of 2.5m. The elements are placed horizontally at the center of basemat, EL 3.4m.

Figure 6.2-2 shows the FE model of the basemat.

The FWSC shear keys include one shear key in the N-S direction and two shear keys in the E-W direction. They are represented by shell elements located at the center of shear keys starting from the bottom elevation of the FWSC basemat. The FWSC shear keys shell elements are connected with the FWSC basemat by rigid links. The horizontal mesh of the shear keys corresponds to the basemat mesh. The FE model of the FWSC shear keys is shown in Figure 6.2-3. The lateral resistance force provided by the shear keys is calculated in Section 5.1 of Reference 2.1.2-j and Section 6.3 of Reference 2.1.2-n.

6.2.2.3.2 Ground

The subgrade is modeled with spring elements. Three independent spring elements, one vertical and two horizontals, are attached to each of the basemat grid points.

Spring constants are calculated using the generic soil properties described in Section 3.4. Table 6.2-1 shows the vertical and horizontal spring constants per the unit area. These values are multiplied by the tributary area of each grid point to estimate the spring constants of spring elements.

The constants are calculated based on soil spring constants of the Sway-Rocking model used for the standard plant SSI analyses in Reference 2.1.2-d. Resistances of the shear keys are represented by the application of reaction loads.

6.2.2.4 Modeling of Shear Walls

All of the seismic walls considered in the seismic analysis model are included in the stress analysis model.

The walls are modeled from the top elevation of basemat using shell elements located at the wall centerlines and are connected to basemat elements by rigid links. The horizontal mesh of the walls is consistent with the basemat mesh. FE models of the FWSC walls are shown in Figures 6.2-4 through 6.2-7.

6.2.2.5 Modeling of Roof Slabs

Roof slabs are modeled with shell elements. Elements are positioned at the center of the roof slab thickness.

FE models of the roof slabs are shown in Figures 6.2-8 and 6.2-9.

6.2.2.6 Units and Material Constants

Stress analyses are executed with the following SI units.

- length: m
- force: MN
- moment: MN m
- pressure: MPa
- temperature: °C

Material constants shown in Table 6.2-2 are used for the stress analysis calculations.

Young's modulus used for concrete in the thermal load analysis is reduced, depending on the average temperature of each element as shown in Table 6.2-2.

6.2.3 Method of Applying Loads

Table 6.2-3 shows a list of the design basic load cases. A total of 21 load cases were considered in Reference 2.1.2-i for the standard design of the RC shell elements, which include basemat, walls and slabs. Table 6.2-4 shows the list of analysis load cases considered

for the standard design. In order to obtain the member stresses for site-specific seismic loads, the global FE model analyses are performed for the site-specific seismic analysis load cases.

A total of five site-specific seismic load cases are analyzed for the site-specific evaluation presented in this report.

6.2.3.1 Dead Loads

6.2.3.1.1 Structural Weight (GRAV)

The weights of reinforced concrete members included in the analysis model were evaluated in Reference 2.1.2-i using a GRAV feature that NASTRAN provides. It applies a downward gravity force to each element mass, which is calculated from the unit weight and the volume of the element.

Evaluation of the structural weights using the GRAV feature has one drawback, which is double counting of weights at such regions as wall-to-wall and wall-to-slab corners. However, this double counting can be ignored in the analysis since duplicated weights of corners are negligibly small compared with the total weight of the analysis model.

6.2.3.1.2 Other Dead Loads (DL)

Dead weights, other than those included in the analysis model by using the GRAV feature, were evaluated in Reference 2.1.2-i as specified in Section 5.1.2 and applied to the analysis model as follows:

a. Decks and Steel Beams

   The weights of decks and steel beams are applied to slabs as distributed surface loads.

b. Finishing

   The weights of finishing for roof slabs, floor slabs, and outer walls are applied as distributed loads.

c. Partition Walls

   The weights of RC-made partition walls, which are not included in the FE model, are applied as grid forces to the specific grid.

d. Parapet

   The uniform loads due to parapet weight are applied as concentrated forces at the intersection grids of parapets and roof slab. The applied force to each grid is calculated according to its tributary area.

e. Piping Loads

   The weights of miscellaneous structures, piping and commodities are applied as distributed surface loads to the floor slab elements.

f. Liner

Liner weight is applied as a distributed load to slabs and walls as described in Subsection 5.1.2.

6.2.3.1.3 Equipment Loads (EL)

The loads due to equipment weight were calculated in Reference 2.1.2-i as specified in Section 5.1.3. They were applied to the slab elements as a uniformly distributed surface load.

6.2.3.1.4 Hydrostatic Loads (WP)

The vertical and lateral pressures of water in the FWS are treated as hydrostatic loads (WP) against the wall and floor of the FWS. These loads are identical to the hydrostatic loads used for the standard design of the FWS tank in Reference 2.1.2-i.

6.2.3.2 Live Loads (LL)

Floor live loads are applied to slab elements as uniformly distributed surface loads. The snow loads are applied to the roof slab and part of basemat. Floor live loads are reduced to 1/4 of their values when used in the evaluation of seismic loads.

6.2.3.3 Thermal Loads (TLS0, TLW0)

The average temperature, Td, and the surface temperature difference, Tg, are obtained by heat transfer analyses as described in Section 5.3 and are applied to the corresponding shell elements.

6.2.3.4 Wind Loads (WON, WOS, WOE, WOW)

For the standard design analyses in Reference 2.1.2-i, the wind pressure loads acting on the walls and roof slab were applied to shell elements as uniform pressure loads. The average pressure for each element is calculated and applied to the element as a uniformly distributed pressure load.

The description for the design wind loads (WON, WOS, WOE and WOW) are as follows. WON is a wind load from North to South. WOS is a wind load from South to North. WOE is a wind load from East to West. WOW is a wind load from West to East.

6.2.3.5 Tornado Loads (WTN, WTS, WTE, WTW, WTD)

Analyses for the tornado wind loads were performed in Reference 2.1.2-i using the same method as the one used for the design wind load.

A maximum pressure of 0.0165 MPa is applied to roof slabs and outer walls above grade as the tornado differential load.

The description for the design tornado wind loads (WTN, WTS, WTE and WTW) and tornado differential load (WTD) is as follows. WTN is a tornado wind load from North to South. WTS is a tornado wind load from South to North. WTE is a tornado wind load from East to West. WTW is a tornado wind load from West to East.

6.2.3.6 Site-Specific Seismic Loads

The site-specific seismic loads applied to the model for the site-specific stress analyses are determined from the design seismic loads presented in Section 5.6. Four components – two horizontal, one vertical, and one torsional – of the seismic loads are evaluated.

The methods of applying the site-specific seismic forces on the FWSC FE model are described below.

Two different combinations of the directions of seismic force acting on each of the two FWS tanks are considered in which:

- Both FWS tanks are subjected to seismic load in the same direction (XS1, YS1, VAS1, TMS1)
- The two FWS tanks are subjected to seismic force with opposite direction (XS2, YS2, VAS2, TMS2).

The details about the direction of the applied site-specific seismic loads are presented in Table 6.2-4.

6.2.3.6.1 Shear Forces & Overturning Moment (XS1, XS2, YS1, YS2)

Calculation methods for the shear forces and the overturning moments are given in Figure 6.2-10. The horizontal force applied to each node is calculated by subtracting the total design shear force above its nodal elevation from shear force on its own elevation. The overturning moment applied to each nodal elevation is determined in such a way that the sum of the applied moment and the one due to shear forces applied to the node above is equal to or larger than the design moment of the node. The moment is adjusted considering the difference between the height where the design seismic loads are obtained and the height where the seismic forces are applied.

Tables 6.2-5 and 6.2-6 summarize the applied shear forces and overturning moments for the seismic walls for the two horizontal earthquake components. Columns labeled "m+dMq" in these tables show the values of the applied moments.

Shear Forces

Shear forces are applied as horizontal nodal forces to grid points as illustrated in Figure 6.2-11. The nodal forces are applied to grid points that are on the walls and at floor slab levels.

In addition to the design shear forces, the inertia forces of the basemat due to the earthquake are applied to the basemat grid points. Inertia forces are applied as horizontal nodal forces. The nodal force applied to each grid point is calculated as the tributary weight of the node multiplied by the specified acceleration.

The distribution of hydrodynamic pressures, including impulsive pressure and convective pressure, is described in Section 5.6.1. Considering the effect of water impact on FWS walls,

shear forces are applied to each node by multiplying the hydrodynamic pressure (p_{cy}, p_{iy}) by the half heights of its upper and lower elements.

Overturning Moments

Overturning moments are applied as vertical nodal forces to nodes as illustrated in Figure 6.2-12. The magnitude of the vertical force is assumed to be proportional to the distance from the center of the building in each direction. The nodal force applied to each node is then calculated by multiplying it by the tributary wall area of the node. The nodal forces are applied to the nodes at the intersections of the walls and slab of the FPE and to the nodes of each elevation of the FWS.

In addition to the design overturning moments mentioned above, an additional moment is applied to the basemat in order to adjust the total overturning moment imposed on the soil by the total shear force. The basemat is modeled at the center of its thickness, and the soil spring elements are directly attached to the basemat nodes. However, since the actual ground is underneath the basemat, an overturning moment needs to be added. ΔM is calculated by the following equation. Table 6.2-7 shows the calculated additional overturning moments applied to the basemat.

$$\Delta M = (Q + W_{mat} \cdot A)h$$

where,

Q: Shear force at EL 4.65m

W_{mat}: Weight of Basemat

A: Horizontal Acceleration of Basemat

h: Half of Basemat thickness (1.25m)

The additional overturning moment is applied to the basemat nodes as vertical nodal forces. The magnitude of the vertical force per unit area is assumed to be proportional to the distance from the center of the basemat. The nodal force applied to each node is calculated by multiplying the uniform load and its tributary area.

6.2.3.6.2 Vertical Acceleration (VAS1, VAS2)

The site-specific seismic vertical accelerations calculated for the lumped mass locations of the dynamic models used for the site-specific seismic response analyses are applied directly to the seismic walls. On the other hand, the out-of-plane vertical load accelerations applied to the roof slabs are determined using the method described in Sections 6.1 and B.4 of Reference 2.1.2-k.

The average accelerations, ${}_{S}A_{ave}$, provided in Table 6.2-8, are obtained from Reference 2.1.2-l and represent the out-of-plane site-specific loads on the FWS and FPE roofs. These loads bound effects of concrete cracking as described in References 2.1.2-k and the effects of SSSI of the CB on the seismic response of the FWSC as described in Reference 2.1.2-m. The accelerations are uniformly applied to all roof slab grid points.

The vertical seismic forces are applied to all grid points as vertical nodal forces. Each nodal force is calculated by multiplying the tributary weight of the node by the vertical acceleration determined for the region containing the node. For the seismic walls, a design acceleration obtained at a given elevation is applied to a region that is limited by the centerlines of that elevation and the upper and lower elevations. The tributary weight of the node is obtained using the load combination for the vertical seismic loads, which consists of the dead load and a quarter of the floor live load.

6.2.3.6.3 Torsion Moment (TMS1, TMS2)

The torsional moment applied to each FWS and FPE elevation is calculated by subtracting the design torsional moment for the story above from the design torsional moment for that story. The magnitudes of the site-specific torsional loads are summarized in Table 6.2-9. The torsional moments are applied to the seismic walls as in-plane shear forces following the methodology used for the standard design in Reference 2.1.2-i. The method of calculating the shear force on the FPE walls is described in Figure 6.2-13 and the results are summarized in Table 6.2-10. The magnitude of the total shear force (q) applied to the FWS tank wall at each node elevation is equal to the applied torsional moment divided by the radius of the FWS tank. The total shear force (q) at each nodal elevation is uniformly distributed to each node located at that elevation. Torsional moments in the counterclockwise direction are considered to be positive. The method of calculating the shear force is also described in Figure 6.2-13.

The shear forces due to the torsional moments are applied as horizontal nodal forces to the grid points on floor slab levels. Their magnitudes are determined according to the tributary lengths of the nodes.

6.2.4 Analysis Results

Section deformations obtained from NASTRAN analyses for all the analysis cases are shown in Figures 6.2-14 through 6.2-38. Tables 6.2-11 through 6.2-15 tabulate section forces for the typical elements selected in Figures 6.2-2 through 6.2-8. The results presented in the tables for the non-seismic load cases are obtained from Reference 2.1.2-i.

The shell element forces and moments are defined with respect to the element local coordinate system shown in Figure 6.2-39.

6.3 Load Combinations

6.3.1 Code Requirements

Table 6.3-1 presents a summary of the load combinations, associated load factors, and acceptance criteria used for site-specific evaluation of the FWSC reinforced concrete structures. These are identical to the ones used for the standard design and are in compliance with ACI 349-01 (Reference 2.2-a) and SRP 3.8.4 (Reference 2.3-a).

6.3.2 Result of Load Combinations

Table 6.3-2 shows the detailed description of the load combinations used for the site-specific evaluation of the FWSC structures, which are identical to those considered for the standard design in Reference 2.1.2-i.

Identical to the approach used for the standard design in Reference 2.1.2-i, the seismic results are combined (in Step-2 below) based on the SRSS method for the four directions of seismic loads as follows:

$$SEISMIC_{SRSS} = \sqrt{(|\,EQNS\,|)^2 + (|\,EQEW\,|)^2 + (EQZ)^2 + (EQT)^2}$$

$$E' = SEISMIC_{SRSS}\ \text{, which } E' \text{ refers to Table 6.3-1}$$

- *EQEW*: Horizontal seismic loads in the EW direction
- *EQNS*: Horizontal seismic loads in the NS direction
- *EQZ*: Vertical seismic loads
- *EQT*: Torsional seismic loads

The basic concept for SRSS is shown below.

1) Algebraic sum of static component forces (dead, live, thermal, pressure, etc): Retain sign for each force component. For example, N_x (+), N_y (-), and N_{xy} (+) for axial forces in X and Y direction and in-plane shear force, respectively.
2) Seismic component forces (SRSS results of force due to each of four directions of seismic loads): regardless of sign
3) Assign signs to total dynamic component force to be same as the above combined static component forces: refer to Step-1 example, N_x (+), N_y (-), and N_{xy} (+)
4) Total component forces (add Step-1 and Step-3): refer to Step-1 example, N_x (+), N_y (-), and N_{xy} (+)
5) The case to reverse the signs of section forces is evaluated for total dynamic components which are described in Step-3 (the signs of static component forces in Step-1 are not reversed).

Tables 6.3-3 through 6.3-6 show the combined forces and moments for the load combinations FWSC-3 (combination id 3001), FWSC-4 (combination id 4011), FWSC-6 (combination id 6041), and FWSC-7 (combination id 7021), which were selected during the standard design from the list of load combinations provided in Table 6.3-1.

Section forces due to the following loads are shown independently in the tables:

- OTHR: Loads other than thermal and seismic loads
- TEMP: Thermal loads
- SEIS: Seismic load

6.4 Section Design Principles

Structural design is performed according to ACI 349-01 (Reference 2.2-a). The design flow chart is shown in Figure 6.4-1.

Section design calculations are carried out for the following section forces and it is confirmed that the results satisfy code requirements.

- Flexure and Membrane Forces
- Membrane Compressive Forces
- Transverse Shear

All elements are examined by the evaluation method described in the following subsections:

6.4.1 Section Design for Flexure and Membrane Forces

The design calculations are carried out for flexure and axial forces, and for in-plane shear forces, separately.

Design calculations for flexure and membrane force are performed by a computer program SSDP-2D. The program has the following characteristics:

- It calculates concrete and rebar stresses under two-dimensional equilibrium conditions for six components of the section forces in a shell element – two axial forces, two bending moments, in-plane shear, and torsional moment. Transverse shear is generated in an element but is not considered in the equilibrium conditions.
- It takes concrete cracks into account in the stress calculation. Cracked concrete is assumed not to bear tensile forces.
- It considers the reduction of thermal stresses due to the decreased stiffness of a cracked concrete section.
- It assumes concrete and rebars to be perfectly elastic.

In calculations with SSDP-2D, all section forces including axial forces, bending moments and in-plane shear are considered simultaneously. In SSDP-2D, the compressive stress distribution of concrete is based on the linear distribution which is proportional to the strain distribution at the section. Moment capacity based on this condition is more conservative than the moment capacity specified in ACI 349-01 which is based on the stress block for the compressive stress distribution of concrete. As shown in Figure 6.4.1-3 of Reference 2.1.2-o, the ASME capacity with linear concrete compressive stress distribution (used in the SSDP-2D program) is more conservative than ACI 349-01 except in the high axial force (compression) region. This is addressed in Appendix C by performing additional compression check per ACI 349-01. Additionally, in-plane shear check per ACI 349-01 is performed in Appendix B.

As for the thermal effects, section forces due to thermal loads, which are evaluated by NASTRAN analyses using un-cracked concrete stiffness, are reduced considering the depth and direction of cracking in calculations with SSDP-2D. The cracked section properties are used in the calculation only for the cracked sections. Furthermore, compatibility between strain distribution in a section and internal forces, including reduced thermal stress, is examined under an assumed cracked condition in calculations with SSDP-2D. The calculations are continued until the compatibility of strain and internal forces are satisfied. During the iterative calculations, redistribution of internal forces and strains are considered

adequately. Therefore, SSDP-2D calculation satisfies the requirements of Appendix A.3.3 (a) and (b) in ACI 349-01(Reference 2.2-a).

Table 6.4-1 shows the material constants used for the stress calculation. Allowable stresses specified in CC-3420 of ASME-2004 (Reference 2.2-e) are used in the design, since they are not specifically defined in ACI 349-01. Tables 6.4-2 and 6.4-3 show the allowable stresses of concrete and rebar.

As specified in Section 6.1 of the Design Specification for Firewater Service Complex (Reference 2.1.2-g), strengths of concrete and rebar are reduced for elevated temperatures.

Reduction of concrete strength due to high temperature is determined based upon the average value of the following upper bound and lower bound equations:

- Lower bound reduction factor
  - $\phi = 1.0 - 0.0030\ (T-21.1)$ 21.1°C (70°F) ≤ T ≤ 121.1°C (250°F)
  - $\phi = 0.70 - 0.00083\ (T-121.1)$ 121.1°C (250°F) ≤ T
- Upper bound reduction factor
  - $\phi = 1.0$ T ≤ 260.0°C (500°F)
  - $\phi = 1.0 - 0.00081\ (T-260.0)$ 260.0°C (500°F) ≤ T

Reduction of reinforcing steel strength is based upon the following equation:

- Reduction Factor
  - $\phi = 1.0 - 0.000873\ (T-21.1)$ 21.1°C (70°F) ≤ T ≤ 204.4°C (400°F)

Average temperature "Td" in Section 5.3 is applied to the "T" of the above equation. Allowable stresses listed in Tables 6.4-2 and 6.4-3 are reduced using these factors in calculations for load combinations, including thermal loads.

6.4.2 Section Design for Membrane Compressive Forces

ASME-2004 (Reference 2.2-e) specifies the allowable concrete stresses for membrane forces. It is necessary to confirm that the compressive stresses of the concrete due to membrane forces do not exceed the allowable stresses specified in CC-3420 of ASME-2004 (Reference 2.2-e). Examinations for membrane compressive forces are also performed in the design in addition to examinations for flexure and membrane forces.

The principal membrane compressive stress σ_c, which is calculated by the following equation, is used for the evaluation.

$$\sigma_c = \frac{\sigma_x + \sigma_y}{2} + \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau^2_{xy}}$$

$$\sigma_x = \frac{N_x}{h}$$

$$\sigma_y = \frac{N_y}{h}$$

$$\tau_{xy} = \frac{N_{xy}}{h}$$

where,

N_x : x-direction axial force per unit length (Compression is positive.)

N_y : y-direction axial force per unit length (Compression is positive.)

N_{xy} : in-plane shear per unit length

h: element thickness

Reduction of thermal stresses is not considered in the calculation. Table 6.4-4 shows the allowable membrane compressive stress of concrete. Reductions due to elevated temperature described in Subsection 6.4.1 are applicable to these allowables.

6.4.3 Section Design for Transverse Shear

Section design calculations for transverse shear are performed according to ACI 349-01 (Reference 2.2-a), Chapter 11. It requires that the shear force at a section and section strength satisfy the following equation:

$$V_u \le \phi(V_c + V_s)$$

where,

V_u : factored shear force at section per unit length

V_c : nominal shear strength provided by concrete per unit length

V_s : nominal shear strength provided by shear reinforcement per unit length

ϕ : strength reduction factor (=0.85)

The nominal shear strength provided by concrete, V_c, is calculated according to Figure 6.4-2. The nominal shear strength provided by shear reinforcement, V_s, is calculated by the following equation:

$$V_s = \rho_w f_y d, \quad V_s \le 8\sqrt{f_c'}d \qquad \text{(lb - in)}$$

where

ρ_w : shear reinforcement ratio

f_y: specified yield strength of rebar

d: distance from extreme compression fiber to centroid of tension reinforcement

f_c': specified compressive strength of concrete

The transverse shear stress is evaluated in the direction of the maximum shear force, and the section forces for evaluation are calculated by the following equations:

$$V_u = \sqrt{Q_x^{\,2} + Q_y^{\,2}}$$

$$M_u = M_x \sin^2\theta + M_y \cos^2\theta + 2M_{xy}\sin\theta\cos\theta$$

$$N_u = N_x \sin^2\theta + N_y \cos^2\theta + 2N_{xy}\sin\theta\cos\theta$$

$$\theta = \tan^{-1}\left(Q_x / Q_y\right)$$

7. SUMMARY OF RESULTS

7.1 Provided Sections

The basemat has a uniform thickness of 2.5 m. Figure 7.1-1 shows the typical sections of the basemat. #11 bars are used for the primary reinforcement. Bottom and top rebars are arranged orthogonally in NS- and EW- directions. Standard bar pitches are 200 mm.

Figure 7.1-2 shows the typical sections of the roofs. As primary reinforcement, #9 bar is used for the FWS roof and #11 bar is used for the FPE roof. Bottom and top rebars are arranged orthogonally in NS- and EW- directions. Standard bar pitches are 200 mm.

Figures 7.1-3, 7.1-4 and 7.1-5 show the typical sections of the wall for the FWS, FPE and shear keys, respectively. #11 bars are used for the primary reinforcement. Standard bar pitch in the FPE and shear keys is 200 mm. As for the FWS, standard vertical bar pitch is 1 degree, and 150 mm for horizontal bars.

The thickness and rebar ratios of sections used in the evaluation are the same as the standard design excluding some portions as shown in Table 7.1-1.

7.2 Tabulation of Allowable Stresses versus Calculated Stresses

7.2.1 Calculations for Flexure and Membrane Forces

The calculations are performed for all elements for the load combinations described in Section 6.3, and it is confirmed that all values are less than their allowable stresses.

Tables 7.2-1 through 7.2-4 show the rebar and concrete stresses at these sections for the typical elements selected in Figures 6.2-2 through 6.2-8. Tables 7.2-5 and 7.2-6 give a summary of the maximum stress ratios, which are ratios of the maximum stresses to the allowable stresses.

The maximum vertical rebar stress of the FWS cylindrical walls is found to be 236.5 MPa (34.30 ksi) against allowable stress 372.2 MPa (53.98 ksi) as shown in Table 7.2-3. The

maximum horizontal rebar stress of the FWS cylindrical walls is found to be 160.5 MPa (23.28 ksi) against allowable stress 372.2 MPa (53.98 ksi) as shown in Table 7.2-3. The maximum rebar stress in the horizontal direction of the FPE wall is found to be 222.2 MPa (32. 23 ksi) against allowable stress 372.2 MPa (53.98 ksi) as shown in Table 7.2-3. The maximum rebar stress in the vertical direction of the FPE wall is found to be 198.4 MPa (28.78 ksi) against allowable stress 372.2 MPa (53.98 ksi) as shown in Table 7.2-3.

The maximum rebar stress in the FWS roof slab is found to be 200.4 MPa (29.07 ksi) against allowable stress 372.2 MPa (53.98 ksi) as shown in Table 7.2-3. The maximum rebar stress in the FPE roof slab is found to be 247.9 MPa (35.95 ksi) against allowable stress 372.2 MPa (53.98 ksi) as shown in Table 7.2-3.

The maximum rebar stress in the foundation mat is found to be 269.7 MPa (39.12 ksi) against allowable stress 372.2 MPa (53.98 ksi) as shown in Table 7.2-3.

The maximum rebar stress in the horizontal shear key rebar is found to be 87. 0 MPa (12.62 ksi) against allowable stress 372.2 MPa (53.98 ksi) as shown in Table 7.2-3. The maximum rebar stress in the vertical shear key rebar is found to be 128.9 MPa (18.70 ksi) against allowable stress 372.2 MPa (53.98 ksi) as shown in Table 7.2-3.

7.2.2 Calculations for Membrane Compressive Forces

The compressive stress of concrete is calculated for membrane forces. The calculations are performed for all elements for the selected design load combinations, and it is confirmed that all values are less than the allowable stress.

Table 7.2-7 gives a summary of the maximum compressive stresses for the typical elements selected in Figures 6.2-2 through 6.2-8.

The maximum concrete stress in FWS cylindrical walls is found to be 4.5 MPa (0.65 ksi) against allowable stress 20.7 MPa (3.00 ksi) as shown in Table 7.2-7.

The maximum concrete stress in the FPE walls is found to be 7.2 MPa (1.04 ksi) against allowable stress 25.88 MPa (3.75 ksi) as shown in Table 7.2-7.

The maximum concrete stress in the FWS roof slabs is found to be 1.2 MPa (0.17 ksi) against allowable stress 20.7 MPa (3.00 ksi) as shown in Table 7.2-7.

The maximum concrete stress in the FPE roof slabs is found to be 2.8 MPa (0.41 ksi) against allowable stress 20.7 MPa (3.00 ksi) as shown in Table 7.2-7.

The maximum concrete stress in the foundation mat is found to be 3.1 MPa (0.45 ksi) against allowable stress 20.7 MPa (3.00 ksi) as shown in Table 7.2-7.

The maximum concrete stress in the shear keys is found to be 5.6 MPa (0.81 ksi) against allowable stress 20.7 MPa (3.00 ksi) as shown in Table 7.2-7.

7.2.3 Calculations for Transverse Shear

The transverse shear strength is calculated and compared with shear forces generated by design loads. All elements are examined, and it is confirmed that all section forces are less than the shear strength of sections.

Table 7.2-8 gives a summary of the examinations for the typical elements shown in Figures 6.2-2 through 6.2-8. Table 7.2-9 shows calculation results for transverse shear by selected load combinations shown in Section 6.3.2.

The maximum transverse shear force in the FWS cylindrical walls is found to be 0.551 MN/m (2.92 kips/in) against the shear strength of 1.606 MN/m (9.17 kips/in) as shown in Table 7.2-8.

The maximum transverse shear force in the FPE walls is found to be 0.730 MN/m (4.17 kips/in) against the shear strength of 1.325 MN/m (7.57 kips/in) as shown in Table 7.2-8. However, the maximum ratio of shear force to shear strength in the FPE walls is found to be 0.587 as shown in Table 7.2-8.

The maximum transverse shear force in the FWS roof slab is found to be 0.118 MN/m (0.67 kips/in) against the shear strength of 0.400 MN/m (2.28 kips/in) as shown in Table 7.2-8. However, the maximum ratio of shear force to shear strength in FWS roof slab is found to be 0.299 as shown in Table 7.2-8.

The maximum transverse shear force in the FPE roof slab is found to be 0.237 MN/m (1.35 kips/in) against the shear strength of 0.363 MN/m (2.07 kips/in) as shown in Table 7.2-8.

The maximum transverse shear force in the foundation mat is found to be 2.71 MN/m (15.47 kips/in) against the shear strength of 4.493 MN/m (25.66 kips/in) as shown in Table 7.2-8.

The maximum transverse shear force in the shear keys is found to be 1.582 MN/m (9.03 kips/in) against the shear strength of 4.163 MN/m (23.77 kips/in) as shown in Table 7.2-8.

7.3 Missile Impact Evaluations

The external walls of the FWS and FPE above grade level and the roof slabs are required for the protection against tornado missile impact.

Appendix B in Reference 2.1.2-i describes the design methodology and results of evaluation for the FWSC against the tornado missile impact.

Appendix C in Reference 2.1.2-i describes the design methodology and evaluation for the effect of the impact of an automobile tornado missile on the FWSC structures including external walls and roof slabs of the FWS and FPE.

7.4 Shear Key Design for Building Sliding Stability

During the standard design phase, the height of shear keys was changed from 3.0m to 3.6m as shown in the standard design Stability Analysis of Firewater Service Complex (Reference 2.1.2-h). A structural evaluation similar to the evaluation performed for the standard design for this shear key height change is performed for NA3 and is described in Appendix D. The result of this evaluation does not impact the conclusions.

8. CONCLUSIONS

Site-specific stress check calculations for the FWSC are performed to evaluate the structural integrity of the FWSC at the NA3 site per specifications of ACI 349-01 (Reference 2.2-a), following the same methodology as that used for the standard design in Reference 2.1.2-i.

The stress checks are based on the results of the FWSC global model analyses for the site-specific seismic loads combined together with the non-seismic load results from Reference 2.1.2-i according to the site-specific seismic load combinations. The conclusions from the site-specific stress checks are summarized as follows:

- The stresses of the concrete and rebar are less than the allowable stresses specified in the code.
- The areas of the primary and shear reinforcement, which have been provided, satisfy the required values.

Therefore, it can be concluded that the standard design with some modification for rebar arrangement of the FWSC structures is adequate to resist the NA3 site-specific SSE loads in combination with non-seismic standard plant loads.

Table 3.4-1 Conditions of Applied Site Properties (Reproduced from Reference 2.1.2-i)

Site Condition	Soft Site
Shear Wave Velocity (m/s)	300
Mass Density (kN/m^3)	19.6
Poisson's Ratio	0.478
Material Damping (%)	5

Notes: The values are in accordance with Seismic Analysis of Firewater Service Complex. (Reference 2.1.2-d)
The maximum ground water table is 0.61 m below plant grade.

Table 5.1-1 Equivalent Dead Loads (Reproduced from Reference 2.1.2-i)

Load \ Applied Position	FWS (kN/m^2)			FPE (kN/m^2)			Mat
	Roof	Slab *	Wall	Roof	Slab *	Wall	
Deck & Steel Beam	-	-	-	3.00	-	-	-
Finishing	1.18	1.18	1.18	1.77	1.18	1.18	0.98
Piping	-	-	-	2.40	-	-	-
Liner	-	1.60	1.00	-	-	-	-

Notes: * For the floor area inside of the FWS and FPE
Parapet weight 9.0 kN/m is applied to the FPE roof.

Table 5.1-2 Equipment Weights (Reproduced from Reference 2.1.2-i)

Description	Weight * kN (lb.)	Number of Equipment
Diesel Pump Skid	106.8 (24,000)	1
RPV Makeup Water Pump Skid	106.8 (24,000)	1
Electric Pump Skid	89.0 (20,000)	1
Diesel Fuel Oil Storage Tank	44.5 (10,000)	2
Tank Recirculation Pump	2.2 (500)	2

Reference: Design Specification for Firewater Service Complex (Reference 2.1.2-g)
Notes: * Design margin (20 %) shall be added to this weight for future change.
Diesel Fuel Oil Storage Tank and Recirculation Pump show the weight of each piece of equipment.

Table 5.2-1 Live Loads
(Reproduced from Reference 2.1.2-i)

Region		Live Load kN/m² (psf)
FWS	Roof	2.9 (60)
FPE	Roof	2.9 (60)*
Basemat		4.8 (100)**

Notes: * Plus snow drift accumulation load per ASCE 7-02 (Reference 2.2-b).
** Except for inside areas of the FWS.

Table 5.3-1 Result of Heat Transfer Analysis, Normal Operation: Summer (Reproduced from Reference 2.1.2-i)

EL	Location	ID	Thick. (m)	Atom. Temp (°C)				Thin Film Coef. (kcal/m^2 h °C)		Resistance of Heat Conduction (m^2 h °C /kcal)				Surface Temperature (°C)		Linearized Temperature (°C)		Tg/t
			t	T1		T2		h1	h2	rc	r1	r2	R	Ta	Tb	Td	Tg	(°C/m)
SLAB																		
19,400	RF of Tank	T_RF	0.60	T	46.1	B	43.0	30.0	1E+99	0.43	0.03	0.00	0.46	45.9	43.0	44.4	2.9	4.8
7,950	RF of FPE	F_RF	0.60	T	46.1	B	26.7	30.0	6.0	0.43	0.03	0.17	0.63	45.1	31.8	38.5	13.2	22.0
3,400	FPE Mat	F_Mat	2.50	T	26.7	B	15.5	6.0	1E+99	1.79	0.17	0.00	1.95	25.7	15.5	20.6	10.2	4.1
3,400	Tank Mat	T_MAT	2.50	T	43.0	B	15.5	1E+99	1E+99	1.79	0.00	0.00	1.79	43.0	15.5	29.3	27.5	11.0
3,400	Mat	MAT	2.50	T	46.1	B	15.5	30.0	1E+99	1.79	0.03	0.00	1.82	45.5	15.5	30.5	30.0	12.0
Tank WALL																		
3400 to 17328	EAST	Wall-E	1.00	O	46.1	I	43.0	30.0	1E+99	0.71	0.03	0.00	0.75	46.0	43.0	44.5	3.0	3.0
	WEST	Wall-W	1.00	O	46.1	I	43.0	30.0	1E+99	0.71	0.03	0.00	0.75	46.0	43.0	44.5	3.0	3.0
FPE WALL																		
	North	Wall-N	0.65	I	26.7	O	46.1	6.0	30.0	0.46	0.17	0.03	0.66	31.6	45.1	38.3	-13.6	-20.9
	South	Wall-S	0.65	O	46.1	I	26.7	30.0	6.0	0.46	0.03	0.17	0.66	45.1	31.6	38.3	13.6	20.9
	East	Wall-E	0.65	I	26.7	O	46.1	6.0	30.0	0.46	0.17	0.03	0.66	31.6	45.1	38.3	-13.6	-20.9
	West	Wall-W	0.65	O	46.1	I	26.7	30.0	6.0	0.46	0.03	0.17	0.66	45.1	31.6	38.3	13.6	20.9
SHEAR KEY																		
			2.00	I	15.5	O	15.5	1E+99	1E+99	1.43	0.00	0.00	1.43	15.5	15.5	15.5	0.0	0.0

Notes: T: Top of Roof or Mat, B: Bottom of Roof or Mat, I: Inside of Wall, O: Outside of Wall
As for the other walls and slabs which have the same temperature (T1=T2) at both sides, Td is set to T1 and Tg is set to zero.

Table 5.3-2 Result of Heat Transfer Analysis, Normal Operation: Winter (Reproduced from Reference 2.1.2-i)

EL	Location	ID	Thick. (m)	Atom. Temp (°C)				Thin Film Coef. (kcal/m² h °C)		Resistance of Heat Conduction (m² h °C /kcal)				Surface Temperature (°C)		Linearized Temperature (°C)		Tg/t
			t	T1		T2		h1	h2	rc	r1	r2	R	Ta	Tb	Td	Tg	(°C/m)
SLAB																		
19,400	RF of Tank	T_RF	0.60	T	-40.0	B	4.5	35.0	1E+99	0.43	0.03	0.00	0.46	-37.2	4.5	-16.4	-41.7	-69.5
7,950	RF of FPE	F_RF	0.60	T	-40.0	B	4.5	35.0	6.0	0.43	0.03	0.17	0.62	-38.0	-7.4	-22.7	-30.6	-51.0
3,400	FPE Mat	F_Mat	2.50	T	4.5	B	15.5	6.0	1E+99	1.79	0.17	0.00	1.95	5.4	15.5	10.5	-10.1	-4.0
3,400	Tank Mat	T_MAT	2.50	T	4.5	B	15.5	1E+99	1E+99	1.79	0.00	0.00	1.79	4.5	15.5	10.0	-11.0	-4.4
3,400	Mat	MAT	2.50	T	-40.0	B	15.5	35.0	1E+99	1.79	0.03	0.00	1.81	-39.1	15.5	-11.8	-54.6	-21.9
Tank WALL																		
3400 to	EAST	Wall-E	1.00	O	-40.0	I	4.5	35.0	1E+99	0.71	0.03	0.00	0.74	-38.3	4.5	-16.9	-42.8	-42.8
17328	WEST	Wall-W	1.00	O	-40.0	I	4.5	35.0	1E+99	0.71	0.03	0.00	0.74	-38.3	4.5	-16.9	-42.8	-42.8
FPE WALL																		
	North	Wall-N	0.65	I	4.5	O	-40.0	6.0	35.0	0.46	0.17	0.03	0.66	-6.7	-38.1	-22.4	31.3	48.2
	South	Wall-S	0.65	O	-40.0	I	4.5	35.0	6.0	0.46	0.03	0.17	0.66	-38.1	-6.7	-22.4	-31.3	-48.2
	East	Wall-E	0.65	I	4.5	O	-40.0	6.0	35.0	0.46	0.17	0.03	0.66	-6.7	-38.1	-22.4	31.3	48.2
	West	Wall-W	0.65	O	-40.0	I	4.5	35.0	6.0	0.46	0.03	0.17	0.66	-38.1	-6.7	-22.4	-31.3	-48.2
SHEAR KEY																		
			2.00	I	15.5	O	15.5	1E+99	1E+99	1.43	0.00	0.00	1.43	15.5	15.5	15.5	0.0	0.0

Notes: T: Top of Roof or Mat, B: Bottom of Roof or Mat, I: Inside of Wall, O: Outside of Wall
As for the other walls and slabs which have the same temperature (T1=T2) at both sides, Td is set to T1 and Tg is set to zero.

Table 5.4-1 Design Pressures of Basic Wind Loads (Reproduced from Reference 2.1.2-i)

EL (mm)	Wall (kN/m^2)			Roof
	Windward	Leeward	Side	
FWS				
15,530 to 17,328	2.85	-2.01	-2.57	2.46*
13,810 to 15,530	2.73	-2.01	-2.57	
12,100 to 13,810	2.67	-2.01	-2.57	
11,000 to 12,100	2.60	-2.01	-2.57	
9,900 to 11,000	2.54	-2.01	-2.57	
8,810 to 9,900	2.48	-2.01	-2.57	
6,730 to 8,810	2.44	-2.01	-2.57	
4,650 to 6,730	2.44	-2.01	-2.57	
FPE				
6,730 to 7,950	2.44	-2.01	-2.57	-2.99
4,650 to 6,730	2.44	-2.01	-2.57	

Note: * The value is averaged on all roof area.

Table 5.4-2 Design Coefficient of Basic Wind Loads (Reproduced from Reference 2.1.2-i)

Coef.	Wall			Roof*2
	Windward	Leeward*1	Side	
G	0.85			
Cp	0.8	-0.5	-0.7	-1.11/-1.04
GCpi	-0.18	0.18	0.18	

Notes: *1: Maximum value in Figure 6-6 of ASCE 7-02 (Reference 2.2-b) is used conservatively.
*2: Value in Figure 6-6 of ASCE 7-02 is used and reduction factor (0.8) is included for FPE. Value in Figure 6-7 of ASCE 7-02 is used for FWS. After calculation, -1.04 is for FPE and -1.11 (average value) is for FWS.

Table 5.5-1 Design Pressures of Tornado Wind Loads
(Reproduced from Reference 2.1.2-i)

Wind Direction	Building	p (MPa)			
		Wall			Roof
		Windward	Leeward	Side	
All	FWSC (FPE)	0.00789	-0.00493	-0.00691	-0.01026
Differential		0.01655	0.01655	0.01655	0.01655
All	FWSC (FWS)	0.00753	-0.00471	-0.00659	-0.01041*
Differential		0.01655	0.01655	0.01655	0.01655

Note: *The value is an average value due to the different Cp on each element of roof.

Table 5.6-1 Site-Specific Horizontal Seismic Loads

Elevation (m)	Node No.	NS-direction*)		EW-direction*)		Calculated Torsion	Accidental Torsion	Design Torsion
		Shear (MN)	Moment (MN-m)	Shear (MN)	Moment (MN-m)	(MN-m)	(MN-m)	(MN-m)
FWS								
19.70	10	4.96	4.83	5.24	5.22	4.50	4.58	9.09
17.25	9	4.96	16.13	5.24	17.27	4.50	4.58	9.09
17.25	9	12.13	25.86	12.89	26.46	13.64	11.28	24.92
15.53	8	12.13	44.75	12.89	47.75	13.64	11.28	24.92
15.53	8	16.84	54.30	17.92	57.49	22.34	15.68	38.03
13.81	7	16.84	79.96	17.92	84.36	22.34	15.68	38.03
13.81	7	20.86	88.93	22.29	95.05	30.08	19.50	49.58
12.10	6	20.86	120.57	22.29	124.95	30.08	19.50	49.58
12.10	6	23.73	126.39	25.30	132.69	35.42	22.13	57.55
11.00	5	23.73	151.72	25.30	157.13	35.42	22.13	57.55
11.00	5	25.67	155.06	27.34	160.28	39.03	23.92	62.95
9.90	4	25.67	183.63	27.34	190.39	39.03	23.92	62.95
9.90	4	27.33	186.58	29.06	193.32	41.89	25.43	67.32
8.81	3	27.33	216.50	29.06	225.10	41.89	25.43	67.32
8.81	3	42.95	221.20	44.49	228.81	45.14	38.93	84.07
6.73	2	42.95	306.02	44.49	320.47	45.14	38.93	84.07
6.73	2	44.27	309.86	46.08	323.87	47.70	40.32	88.01
4.65	1	44.27	400.55	46.08	418.66	47.70	40.32	88.01
FPE								
8.25	405	4.93	2.32	8.09	7.71	9.58	5.38	14.95
4.65	404	4.93	18.05	8.09	30.63	9.58	5.38	14.95

Note: Obtained from Reference 2.1.2-l based on site-specific seismic response analysis in References 2.1.2-k, 2.1.2-m and 2.1.2-n.

*) NS and EW represent moments for bending the NS and EW direction, respectively.

Table 5.6-2 Maximum FWS Horizontal Hydrodynamic Loads

Elevation (m)	NS-direction (MN)	EW-direction (MN)	Remark
12.10	1.11	0.69	Convective
8.81	14.25	15.83	Impulsive

Note: Obtained from Reference 2.1.2-l based on site-specific seismic response analysis in References 2.1.2-k, 2.1.2-m and 2.1.2-n.

Table 5.6-3 Vertical Accelerations due to SSE

FWS			
Elevation (m)	Node No.	Stick Model	V (g)
19.70	10	FWS	1.43
17.25	9	FWS	1.43
15.53	8	FWS	1.40
13.81	7	FWS	1.35
12.10	6	FWS	1.27
11.00	5	FWS	1.21
9.90	4	FWS	1.15
8.81	3	FWS	1.07
6.73	2	FWS	0.92
4.65	8002	FWSC	0.95
2.15	8001	FWSC	1.00
19.70	11	Oscillator	3.98
19.70	12	Oscillator	2.78
FPE			
Elevation (m)	Node No.	Stick Model	V (g)
8.25	405	FPE	0.78
6.45	402	FPE	0.72
8.25	13	Oscillator	1.88

Note: Obtained from Reference 2.1.2-l based on site-specific seismic response analysis in References 2.1.2-k, 2.1.2-m and 2.1.2-n.

Table 5.6-4 Lateral Resistance Force on Shear Keys

Lateral Resistance Force at Shear Key (Fr')	
NS-direction (MN)	EW-direction (MN)
82	71

Note: Obtained from Reference 2.1.2-l based on site-specific sliding analysis in References 2.1.2-j and 2.1.2-n.

Table 6.2-1 Soil Spring Constants
(Reproduced from Reference 2.1.2-i)

Loads		Soil Spring Constants (MN/m/m^2)		
		Horizontal		Vertical
		NS-direction	EW-direction	
for All Loads except for Seismic Loads		15.30	17.59	23.86
for Seismic Loads	Horizontal, NS motion*	15.30	17.59	63.42
	Horizontal, EW motion*	15.30	17.59	63.42
	Vertical	15.30	17.59	23.86
	Torsion	15.30	17.59	63.42

Note: *Vertical springs for horizontal seismic loads are calculated based on the rotational spring constants.

Table 6.2-2 Properties of Structural Material
(Reproduced from Reference 2.1.2-i)

			Reinforced Concrete	
			Basemat	Others
		Temperature (°C) (*)	f'$_c$=4000psi 27.6MPa	f'$_c$=5000psi 34.5MPa
Young's Modulus (MPa)	Thermal Loads	< 21	2.49×10^4	2.78×10^4
		93	1.81×10^4	2.03×10^4
		204	1.62×10^4	1.81×10^4
	Other Loads		2.49×10^4	2.78×10^4
Poisson's Ratio			0.17	
Thermal Expansion (m/m°C)			9.90×10^{-6}	
Weight Density (MN/m^3)			0.0235	

Note:(*) Linear interpolation of material properties should be used for temperatures between the specified values.

Table 6.2-3 Design Basic Load Case List

Design Basic Load Case			Label	Combination of Analysis Cases
Dead Loads			DLO	=GRAV+DL+EL+WP
Live Loads	Max(Floor Live Loads, Snow Load)		LLO	=LL
Thermal Loads	Normal Summer		TLS0	=TLS0
	Normal Winter		TLW0	=TLW0
Wind Loads	Basic Wind Loads	North to Siuth	WON	=WON
		South to North	WOS	=WOS
		East to West	WOE	=WOE
		West to East	WOW	=WOW
	Tornado Loads	North to South	WTN	=WTN
		South to North	WTS	=WTS
		East to West	WTE	=WTE
		West to East	WTW	=WTW
	Tornado Differencial Pressure Loads	Outward	WTD	=WTD
Site-Specific Seismic Loads	X(NS) direction V & M	North to South	KXS1	=XS1
			KXS2	=XS2(*)
	Y(EW) direction V & M	West to East	KYS1	=YS1
			KYS2	=YS2(*)
	Vertical Acceleration	Upward	KZS1	=VAS1
			KZS2	=VAS2(*)
	Tortional Moment	Counterclockwise	KTS1	=TMS1
			KTS2	=TMS2(*)

Note:(*) Applied force direction see Table 6.2-4

Non-Seismic loads, shown in the red case, are from standard design report (Reference 2.1.2-i)

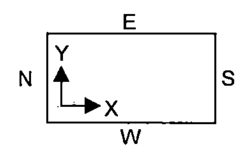

Table 6.2-4 Analysis Load Case List

Analysis Load Cases						Load ID No.	Case Label	grid weight[1]
	Applied load	Direction	Direction of North Tank	Direction of FPE	Direction of South Tank			
Dead Loads	Structural Weight					1000	GRAV	X
	Other Weight					1100	DL	X
	Equipment Loads					1200	EL	X
Live Loads	Live Loads					2000	LL	X[2]
	Snow Loads					2100	SL	
Water Pressure	Water Pressure					2300	WP	X
Thermal Loads	Normal Summer					3101	TLS0	
	Normal Winter					3102	TLW0	
Wind Loads	Basic Wind Loads	North to South				4101	WON	
		South to North				4102	WOS	
		East to West				4103	WOE	
		West to East				4104	WOW	
	Tornado Loads	North to South				4201	WTN	
		South to North				4202	WTS	
		East to West				4203	WTE	
		West to East				4204	WTW	
	Tornado Differencial Pressure Loads	Outward				4205	WTD	
Site-Specific Seismic Loads (SSE)	X (NS) direction V & M		North to South	North to South	North to South	5110	XS1	
			North to South	North to South	South to North	5111	XS2	3)
	Y (EW) direction V & M		West to East	West to East	West to East	5120	YS1	
			West to East	West to East	East to West	5121	YS2	3)
	Vertical Acceleration		Upward	Upward	Upward	5130	VAS1	
			Upward	Upward	Downward	5131	VAS2	3)
	Torsional Moment		Counterclockwise	Counterclockwise	Counterclockwise	5140	TMS1	
			Counterclockwise	Counterclockwise	Clockwise	5141	TMS2	

Note: 1) Tributary weight of each grid point
For calculating the seismic force VAS1 and VAS2, the tributary weight of each grid point is necessary. In these cases, LL is reduced to 25% of their values.
2) Choose the value of max (SL, 0.25*LL).
3) Ignore the force of basemat.
Non-Seismic loads, shown in the red case, are from standard design report (Reference 2.1.2-i).

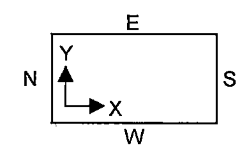

Table 6.2-5 Applied Shear and Moment for Walls, NS Input

Elevation	Height	Shear		Moment									
H (m)	DH (m)	Q (MN)	q (MN)	M (MNm)	Mq (MNm)	M-Mq (MNm)	dM (MNm)	m (MNm)	Mq+dM (MNm)	Input Level (m)	Difference (m)	dMq (MNn)	Total m + dMq (MNm)
FWS													
19.70		4.96	4.96	4.84	0.00	4.84	4.84	4.84	4.84	17.33	2.37	11.77	16.61
17.25	2.45			16.14	12.15	3.99			16.99				
17.25		12.13	7.17	25.86	12.15	13.71	13.71	8.87	25.86	17.33	-0.08	-0.56	8.31
15.53	1.72			44.76	33.02	11.74			46.72				
15.53		16.84	4.71	54.31	33.02	21.29	21.29	7.59	54.31	15.53	0.00	0.00	7.59
13.81	1.72			79.96	61.98	17.98			83.27				
13.81		20.87	4.03	88.93	61.98	26.95	26.95	5.66	88.93	13.81	0.00	0.00	5.66
12.10	1.71			120.58	97.67	22.91			124.62				
12.10		22.63 *	1.76	126.40	97.67	28.73	29.17	2.22	126.84	12.10	0.00	0.00	2.22
11.00	1.10			151.73	122.56	29.17			151.73				
11.00		24.57 *	1.94	155.06	122.56	32.50	34.04	4.87	156.60	11.00	0.00	0.00	4.87
9.90	1.10			183.63	149.59	34.04			183.63				
9.90		26.23 *	1.66	186.58	149.59	36.99	38.32	4.28	187.91	9.90	0.00	0.00	4.28
8.81	1.09			216.50	178.18	38.32			216.50				
8.81		27.59 **	1.36	221.20	178.18	43.02	70.46	32.14	248.64	8.81	0.00	0.00	32.14
6.73	2.08			306.03	235.57	70.46			306.03				
6.73		28.92**	1.33	309.87	235.57	74.30	104.84	34.38	340.41	6.73	0.00	0.00	34.38
4.65	2.08			400.56	295.72	104.84			400.56				
FPE													
8.25		4.93	4.93	2.32	0.00	2.32	2.32	2.32	2.32	7.95	0.30	1.48	3.80
4.65	3.60			18.05	17.76	0.29			20.08				

Notes :
Q : Design Shear Force — dM : Additional Moment
q : Input Shear Force — m : Input Moment
M : Design Moment — dMq : Moment Modification Considering to the Difference of Input Level
Mq : Moment due to Shear

* The convective effect (1.11 MN) is not included.
** The convective effect (1.11 MN) and Impulsive effect (14.25 MN) are not included.
The convective effect (1.11 MN) and Impulsive effect (14.25 MN) are applied to model according to ACI 350 (Reference 2.2-d) code.
The method is shown on Figure 5.6-4 and Figure 5.6-5.

Table 6.2-6 Applied Shear and Moment for Walls, EW Input

Elevation	Height	Shear		Moment									
H (m)	DH (m)	Q (MN)	q (MN)	M (MNm)	Mq (MNm)	M-Mq (MNm)	dM (MNm)	m (MNm)	Mq+dM (MNm)	Input Level (m)	Difference (m)	dMq (MNn)	Total m + dMq (MNm)
FWS													
19.70		5.24	5.24	5.22	0.00	5.22	5.22	5.22	5.22	17.33	2.37	12.43	17.65
17.25	2.45			17.27	12.84	4.43			18.06				
17.25		12.90	7.66	26.46	12.84	13.62	13.62	8.40	26.46	17.33	-0.08	-0.60	7.80
15.53	1.72			47.76	35.03	12.73			48.65				
15.53		17.93	5.03	57.50	35.03	22.47	22.47	8.85	57.50	15.53	0.00	0.00	8.85
13.81	1.72			84.36	65.87	18.49			88.34				
13.81		22.29	4.36	95.06	65.87	29.19	29.19	6.72	95.06	13.81	0.00	0.00	6.72
12.10	1.71			124.95	103.98	20.97			133.18				
12.10		24.61*	2.32	132.70	103.98	28.72	28.72	-0.48	132.70	12.10	0.00	0.00	-0.48
11.00	1.10			157.14	131.05	26.09			159.77				
11.00		26.65 *	2.04	160.28	131.05	29.23	30.02	1.30	161.08	11.00	0.00	0.00	1.30
9.90	1.10			190.39	160.37	30.02			190.39				
9.90		28.37 *	1.72	193.32	160.37	32.95	33.82	3.80	194.19	9.90	0.00	0.00	3.80
8.81	1.09			225.11	191.29	33.82			225.11				
8.81		27.96 **	0.00	228.81	191.29	37.52	71.02	37.20	262.31	8.81	0.00	0.00	37.20
6.73	2.08			320.47	249.45	71.02			320.47				
6.73		29.55**	1.59	323.88	249.45	74.43	107.76	36.74	357.21	6.73	0.00	0.00	36.74
4.65	2.08			418.67	310.91	107.76			418.67				
FPE													
8.25		8.09	8.09	7.71	0.00	7.71	7.71	7.71	7.71	7.95	0.30	2.43	10.13
4.65	3.60			30.63	29.11	1.52			36.82				

Notes :
- Q : Design Shear Force
- q : Input Shear Force
- M : Design Moment
- Mq : Moment due to Shear
- dM : Additional Moment
- m : Input Moment
- dMq : Moment Modification Considering to the Difference of Input Level

* The convective effect (0.69 MN) is not included.

** The convective effect (0.69 MN) and Impulsive effect (15.83 MN) are not included.
The convective effect (0.69 MN) and Impulsive effect (15.83 MN) are applied to model according to ACI 350 (Reference 2.2-d) code.
The method is shown on Figure 5.6-4 and Figure 5.6-5.

Table 6.2-7 Additional Overturning Moments for Basemat

NS direction			EW direction		
Q (MN)	A (g)	ΔM (MN-m)	Q (MN)	A (g)	ΔM (MN-m)
44.27	0.76	129.08	46.08	0.77	132.55

Note: Additional moment for basemat is calculated by the following equation:

$\Delta M = (Q + W_{mat} A)\, h$

where,

Q: Shear force at EL 3.40m

W_{mat}: Weight of Basemat (GRAV+DL +EL+ LL+SL) =78.05MN

A: Horizontal Acceleration of Basemat

h: Half of Basemat thickness (1.25m)

Table 6.2-8 FWS Roofs Vertical Acceleration

Elevation (m)	Location	Roof Equivalent Out-of-Plane Acceleration Load (sAave) (g)
19.70	FWS Roof	2.30
8.25	FPE Roof	1.10

Note: Obtained from Reference 2.1.2-l based on site-specific seismic response analysis in References 2.1.2-k, 2.1.2-m and 2.1.2-n.

Table 6.2-9 Applied Torsion Moment

EL (m)	Applied Torsion dMt (MN-m)	Applied Force ft (MN)
FWS		
19.70 17.25	9.09	1.10
17.25 15.53	15.83	1.92
15.53 13.81	13.11	1.59
13.81 12.10	11.56	1.40
12.10 11.00	7.98	0.97
11.00 9.90	5.40	0.65
9.90 8.81	4.38	0.53
8.81 6.73	16.75	2.03
6.73 4.65	3.95	0.48
FPE		
8.25 4.65	14.95	–

Note: Applied force on FPE see Table 6.2-10.

Table 6.2-10 Applied Force of FPE due to Torsion

Wall ID	Xi,Yi (m)	Thick-ness (m)	Height (m)	Length (m)	A (m^2)	I (m^4)	K (MN/m)	Lxi,Lyi (m)	Kt (MNm)	dMt (MNm)	Q (MN)	Input Load (MN)	Applied dir.	Applied grid No.
X 1	-5.93	0.65	3.60	12.65	8.22	110	26227	-5.93			0.612	0.08740	-X	2071~2077, Interval=1
X 2	5.93	0.65	3.60	12.65	8.22	110	26227	5.93	3.80E+06	14.95	0.612	0.08740	+X	2251~2257, Interval=1
Y 1	-6.33	0.65	3.60	11.85	7.70	90	24454	-6.33			0.609	0.08700	+Y	2071~2251, Interval=30
Y 2	6.33	0.65	3.60	11.85	7.70	90	24454	6.33			0.609	0.08700	-Y	2077~2257, Interval=30

Ec = 27800 MN/m^2
n = 0.17
G = 11880 MN/m^2

Xcr = 0.00 m
Ycr = 0.00 m

dMt = Mt (EL 4.65 ~ EL 8.25)

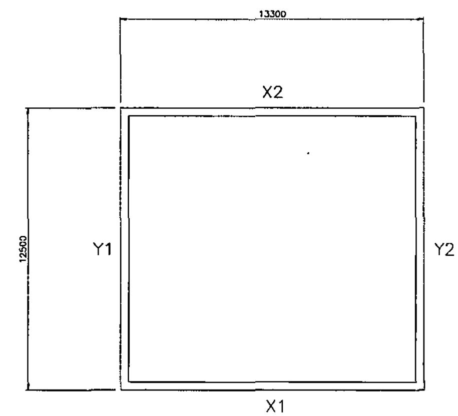

Table 6.2-11 Results of NASTRAN Analysis: Dead Load (Reproduced from Reference 2.1.2-i)

Location	Element ID	N_x (MN/m)	N_y (MN/m)	N_{xy} (MN/m)	M_x (MNm/m)	M_y (MNm/m)	M_{xy} (MNm/m)	Q_x (MN/m)	Q_y (MN/m)
Basemat EL 4.65	18	0.054	-0.019	-0.036	-0.236	0.112	0.065	-0.073	-0.084
	227	-0.042	0.132	0.089	0.046	0.129	0.077	-0.145	-0.022
	237	0.049	-0.003	-0.042	0.084	0.199	-0.132	-0.190	0.133
	16085	-0.030	0.105	0.052	0.065	0.087	0.053	0.063	0.024
Roof of FPE EL 8.25	51556	-0.036	-0.011	0.004	0.066	0.082	-0.005	0.007	0.011
	51558	-0.040	-0.156	-0.002	-0.040	0.014	-0.011	0.062	-0.003
	51576	0.125	-0.048	0.024	0.000	-0.065	-0.009	-0.004	0.078
	51578	0.029	-0.066	0.023	-0.010	-0.020	-0.025	0.002	0.019
Roof of Tank	26007	-0.160	-0.145	-0.005	0.008	0.008	0.000	0.000	0.000
	26079	0.086	-0.084	0.021	-0.001	-0.021	0.002	-0.003	0.022
	26082	-0.007	0.010	0.091	-0.012	-0.011	0.011	-0.017	0.016
	26085	-0.040	0.045	-0.082	-0.016	-0.007	-0.009	-0.020	-0.012
South Wall of FPE	66004	-0.084	-0.071	0.032	-0.001	-0.006	0.000	0.002	0.032
	66006	-0.078	-0.002	0.174	-0.002	-0.022	-0.003	-0.007	-0.024
	66024	-0.215	-0.107	0.016	-0.014	-0.081	0.003	0.001	0.034
East Wall of FPE	67004	0.084	-0.253	-0.035	-0.006	-0.045	0.001	-0.001	-0.064
	67006	0.116	-0.080	-0.195	-0.006	-0.022	0.002	-0.002	-0.038
	67024	0.179	-0.148	-0.033	0.020	0.102	-0.002	0.000	-0.068
Wall of South Tank	35007	-0.106	-0.264	0.037	-0.006	0.008	-0.002	-0.005	0.016
	35010	-0.064	-0.436	-0.015	0.008	0.023	0.001	0.004	0.018
	36507	-0.018	-0.218	0.007	-0.007	-0.003	0.001	-0.002	-0.006
	36510	0.000	-0.258	0.000	0.005	0.000	-0.001	0.001	-0.003
	38507	0.164	-0.087	0.000	-0.004	-0.016	0.000	0.000	0.027
	38510	0.171	-0.090	0.004	-0.002	-0.016	0.000	0.000	0.029
	45001	-0.081	-0.323	0.010	-0.004	0.006	-0.002	-0.004	0.012
	46501	-0.016	-0.241	0.004	-0.004	-0.001	0.001	-0.001	-0.005
	48501	0.173	-0.091	-0.001	-0.003	-0.016	0.000	0.000	0.029
Shear Key	72008	0.007	0.115	-0.059	0.002	0.001	0.000	0.000	-0.001
	73017	-0.157	0.004	-0.222	0.002	0.003	0.002	0.001	-0.001

Table 6.2-12 Results of NASTRAN Analysis: Thermal Load (Normal Operation: Winter) (Reproduced from Reference 2.1.2-i)

Location	Element ID	N_x (MN/m)	N_y (MN/m)	N_{xy} (MN/m)	M_x (MNm/m)	M_y (MNm/m)	M_{xy} (MNm/m)	Q_x (MN/m)	Q_y (MN/m)
Basemat EL 4.65	18	8.599	0.057	2.492	-8.171	-0.926	-0.375	0.060	0.553
	227	-2.901	11.308	-0.088	-3.679	-5.852	0.556	0.159	0.124
	237	3.271	4.954	2.362	-6.091	-3.626	-1.039	-0.492	-0.446
	16085	-4.574	-1.873	1.031	-1.132	-0.048	0.345	-0.640	0.006
Roof of FPE EL 8.25	51556	0.100	0.156	0.014	-0.286	-0.237	0.001	-0.006	0.007
	51558	0.190	-0.460	-0.038	-0.194	-0.238	-0.008	-0.031	-0.001
	51576	0.794	0.118	0.100	-0.295	-0.301	0.000	-0.002	0.025
	51578	0.192	-0.230	0.013	-0.256	-0.299	-0.018	-0.031	0.043
Roof of Tank	26007	0.023	-0.036	-0.006	-0.392	-0.393	0.000	0.001	0.001
	26079	0.417	0.111	0.038	-0.446	-0.535	0.011	-0.010	0.079
	26082	0.322	0.147	0.076	-0.485	-0.483	0.042	-0.051	0.051
	26085	0.240	0.181	-0.005	-0.496	-0.461	-0.035	-0.056	-0.035
South Wall of FPE	66004	2.916	-0.130	-0.123	-0.414	-0.717	0.005	-0.005	-0.184
	66006	1.811	0.944	-0.412	-0.378	-0.693	-0.024	-0.203	-0.618
	66024	-0.091	0.007	-0.037	-0.349	-0.277	0.002	0.016	-0.217
East Wall of FPE	67004	3.209	-0.623	-0.268	0.380	0.424	-0.001	0.002	0.026
	67006	3.333	0.484	-2.062	0.317	0.398	0.006	0.135	0.170
	67024	1.582	-0.137	-0.254	0.372	0.346	0.002	-0.007	0.044
Wall of South Tank	35007	3.012	-0.603	0.194	-1.162	-1.081	-0.009	-0.072	-0.324
	35010	2.650	0.030	-0.198	-1.253	-1.254	0.033	0.015	-0.396
	36507	-0.295	-0.327	0.040	-1.147	-1.126	0.000	-0.011	0.082
	36510	-0.284	-0.025	-0.256	-1.181	-1.126	-0.005	0.015	0.078
	38507	0.103	-0.062	0.007	-1.105	-0.771	0.004	0.000	-0.181
	38510	-0.050	0.003	-0.154	-1.112	-0.771	-0.018	-0.005	-0.205
	45001	3.490	0.717	-0.047	-1.173	-1.294	-0.017	0.003	-0.402
	46501	-0.329	0.464	0.093	-1.200	-1.154	-0.002	-0.004	0.080
	48501	-0.195	0.079	0.049	-1.123	-0.772	0.006	0.002	-0.229
Shear Key	72008	0.030	-0.442	0.322	0.098	0.107	0.033	0.018	-0.058
	73017	-6.179	-0.445	-0.899	0.020	0.028	0.034	0.011	-0.015

Table 6.2-13 Results of NASTRAN Analysis: Site-Specific Seismic Load (Horizontal: North to South Direction, KXS1)

Location	Element ID	N_x (MN/m)	N_y (MN/m)	N_{xy} (MN/m)	M_x (MNm/m)	M_y (MNm/m)	M_{xy} (MNm/m)	Q_x (MN/m)	Q_y (MN/m)
Basemat EL 4.65	18	0.226	0.071	-0.013	-1.324	-0.114	0.208	0.483	0.120
	227	2.073	0.056	-0.758	-3.212	-0.974	-0.233	2.019	-0.334
	237	1.010	-0.267	0.195	-3.733	-0.659	0.348	0.705	-0.583
	16085	1.001	0.082	-0.105	-2.164	-0.777	-0.072	-0.474	-0.596
Roof of FPE EL 8.25	51556	0.022	0.036	-0.065	0.000	-0.002	-0.002	0.001	0.000
	51558	0.047	0.341	-0.022	-0.010	-0.008	0.000	0.005	-0.001
	51576	0.018	0.014	-0.238	0.000	0.002	-0.003	-0.001	-0.001
	51578	0.011	0.091	-0.074	-0.003	0.003	-0.003	0.003	-0.007
Roof of Tank	26007	0.081	-0.074	0.006	-0.002	-0.002	0.000	-0.003	0.000
	26079	0.163	-0.102	-0.015	-0.006	-0.014	0.005	-0.001	0.009
	26082	0.077	-0.294	-0.083	0.003	0.000	-0.003	0.012	-0.007
	26085	-0.012	-0.325	0.189	0.018	0.007	0.009	0.024	0.013
South Wall of FPE	66004	0.082	-0.146	0.044	-0.009	-0.038	-0.004	-0.014	-0.009
	66006	0.144	0.096	-0.284	-0.011	-0.054	-0.010	-0.005	-0.104
	66024	0.421	-0.045	-0.015	-0.008	-0.018	-0.001	-0.003	-0.007
East Wall of FPE	67004	0.064	-0.087	0.441	0.001	0.005	-0.003	0.000	0.002
	67006	0.489	0.001	-0.045	0.001	0.021	-0.003	0.006	0.035
	67024	0.047	-0.023	0.322	0.000	-0.001	0.000	0.000	0.003
Wall of South Tank	35007	0.886	-0.835	-0.719	0.008	-0.123	-0.027	-0.001	-0.147
	35010	1.141	1.336	-1.219	-0.080	-0.516	0.031	0.000	-0.448
	36507	-0.067	-0.462	-1.026	0.046	0.059	-0.005	-0.031	0.016
	36510	-0.526	0.590	-1.106	0.035	0.092	-0.016	0.025	0.033
	38507	0.164	-0.091	-0.220	0.013	0.005	0.013	0.002	0.040
	38510	-0.487	0.126	-0.388	0.013	0.028	-0.030	-0.009	0.013
	45001	1.120	3.372	0.598	-0.166	-0.669	-0.008	0.008	-0.511
	46501	-0.782	1.458	0.292	-0.053	0.061	0.006	-0.012	0.024
	48501	-0.822	0.271	0.107	-0.008	0.037	0.011	0.003	-0.025
Shear Key	72008	-0.183	-0.025	-0.345	0.132	-1.807	0.259	0.328	1.513
	73017	-4.095	1.404	1.806	-0.005	-0.005	0.003	-0.003	0.001

Table 6.2-14 Results of NASTRAN Analysis: Site-Specific Seismic Load (Horizontal: West to East Direction, KYS1)

Location	Element ID	N_x (MN/m)	N_y (MN/m)	N_{xy} (MN/m)	M_x (MNm/m)	M_y (MNm/m)	M_{xy} (MNm/m)	Q_x (MN/m)	Q_y (MN/m)
Basemat EL 4.65	18	0.754	0.106	0.453	0.827	-0.495	-0.617	0.449	0.376
	227	-0.080	-0.690	1.039	-0.188	-1.339	-1.182	0.291	0.744
	237	-0.095	-0.444	0.265	0.811	1.646	-1.059	-0.856	0.906
	16085	0.018	-0.693	-0.037	-0.497	-1.285	-0.436	-0.083	0.536
Roof of FPE EL 8.25	51556	0.070	0.025	-0.082	-0.009	-0.008	-0.007	-0.001	0.011
	51558	0.015	-0.116	-0.273	0.008	0.004	-0.014	-0.010	-0.009
	51576	0.710	-0.018	0.018	-0.030	-0.072	0.002	0.000	0.025
	51578	0.227	-0.102	-0.057	0.010	-0.026	0.004	-0.031	0.031
Roof of Tank	26007	-0.003	0.004	0.027	0.000	-0.001	-0.001	0.000	-0.003
	26079	0.208	0.056	0.065	0.002	-0.001	0.002	-0.003	0.015
	26082	0.122	0.065	0.116	-0.009	-0.002	0.005	-0.011	0.011
	26085	-0.097	0.055	0.073	0.004	0.000	0.001	0.002	0.004
South Wall of FPE	66004	-0.368	0.233	-0.264	-0.003	-0.013	0.005	0.002	-0.012
	66006	-0.428	0.135	0.719	-0.024	-0.065	0.002	0.001	-0.093
	66024	-0.206	0.027	0.141	0.004	0.011	-0.001	-0.006	-0.013
East Wall of FPE	67004	0.223	-0.339	-0.121	-0.036	-0.188	0.001	-0.004	-0.110
	67006	0.251	-0.257	-0.700	-0.010	-0.113	-0.002	-0.042	-0.139
	67024	0.875	-0.113	-0.078	0.010	0.042	0.004	0.004	-0.107
Wall of South Tank	35007	-0.931	-1.401	0.012	0.004	0.302	-0.019	-0.025	0.321
	35010	-0.399	-1.864	-1.080	0.108	0.341	-0.009	0.027	0.249
	36507	0.721	-0.617	-0.020	-0.065	-0.089	0.005	-0.012	-0.028
	36510	0.530	-0.769	-0.932	0.039	-0.031	-0.010	-0.010	-0.005
	38507	0.575	-0.135	0.052	-0.021	-0.037	0.012	0.004	-0.027
	38510	0.455	-0.142	-0.183	0.004	-0.025	0.007	0.001	0.007
	45001	0.338	0.385	-1.379	-0.016	-0.078	0.011	0.029	-0.054
	46501	-0.118	0.206	-1.358	-0.012	0.004	-0.020	0.008	0.001
	48501	-0.108	0.037	-0.324	-0.003	0.005	-0.012	-0.004	-0.004
Shear Key	72008	0.473	0.158	0.222	-0.013	-0.001	0.016	0.012	0.003
	73017	-0.020	0.010	0.025	0.197	1.493	-0.245	-0.029	-1.128

Table 6.2-15 Results of NASTRAN Analysis: Site-Specific Seismic Load (Vertical: Upward Direction, KZS1)

Location	Element ID	N_x (MN/m)	N_y (MN/m)	N_{xy} (MN/m)	M_x (MNm/m)	M_y (MNm/m)	M_{xy} (MNm/m)	Q_x (MN/m)	Q_y (MN/m)
Basemat EL 4.65	18	-0.266	0.039	0.153	1.064	-0.193	-0.174	0.283	0.117
	227	-0.119	-0.413	-0.403	0.203	-0.307	-0.289	0.764	0.121
	237	-0.249	-0.014	0.062	-0.053	-0.495	0.289	0.673	-0.384
	16085	-0.395	-0.460	-0.417	0.358	-0.227	-0.271	0.503	-0.007
Roof of FPE EL 8.25	51556	0.015	-0.066	-0.010	-0.075	-0.119	0.006	-0.006	-0.017
	51558	0.012	0.431	0.012	0.019	-0.033	0.016	-0.065	0.004
	51576	-0.578	0.040	-0.085	0.014	0.104	0.011	0.006	-0.113
	51578	-0.155	0.181	-0.099	-0.002	0.030	0.035	0.016	-0.039
Roof of Tank	26007	0.456	0.408	0.013	-0.021	-0.021	0.000	0.001	0.000
	26079	-0.215	0.243	-0.058	0.002	0.054	-0.006	0.007	-0.059
	26082	0.040	-0.020	-0.254	0.031	0.027	-0.028	0.045	-0.042
	26085	0.128	-0.120	0.233	0.042	0.017	0.025	0.053	0.032
South Wall of FPE	66004	0.209	-0.058	-0.086	0.015	0.101	-0.002	-0.005	0.009
	66006	0.160	-0.309	-0.478	0.014	0.112	0.007	0.030	0.148
	66024	0.606	0.109	-0.035	0.012	0.085	-0.005	-0.004	0.009
East Wall of FPE	67004	-0.407	0.577	0.162	0.013	0.091	-0.002	0.003	0.108
	67006	-0.559	-0.036	0.837	0.015	0.049	-0.002	0.004	0.077
	67024	-0.801	0.246	0.144	-0.031	-0.150	0.001	-0.001	0.112
Wall of South Tank	35007	-0.140	0.179	-0.122	-0.006	-0.148	0.004	0.013	-0.252
	35010	-0.251	0.750	0.010	-0.042	-0.184	-0.005	-0.013	-0.255
	36507	-0.891	0.307	-0.019	0.028	0.053	-0.002	0.005	0.048
	36510	-0.950	0.459	-0.017	-0.007	0.042	0.003	-0.003	0.040
	38507	-0.503	0.192	-0.003	0.009	0.029	-0.001	0.000	-0.083
	38510	-0.536	0.209	-0.024	0.003	0.030	-0.001	-0.001	-0.090
	45001	-0.200	0.451	-0.044	-0.007	-0.119	0.009	0.021	-0.231
	46501	-0.907	0.431	-0.008	0.018	0.044	-0.003	0.004	0.047
	48501	-0.552	0.215	0.007	0.006	0.029	-0.001	0.000	-0.091
Shear Key	72008	-0.277	-0.085	-0.287	-0.013	-0.011	0.002	0.000	0.006
	73017	1.014	-0.137	0.944	-0.009	-0.014	-0.010	-0.006	0.007

Table 6.3-1 Load Combinations and Acceptance Criteria for Safety-Related Reinforced Concrete Structures

Category	Combination No.	Load *							Acceptance Criteria **
		D	WP	L	To	E'	W	Wt	
Normal	FWSC-1	1.4	1.4	1.7					U
	FWSC-2	1.05	1.05	1.3	1.3				U
Severe Environmental	FWSC-3	1.4	1.4	1.7			1.7		U
	FWSC-4	1.05	1.05	1.3	1.3		1.3		U
	FWSC-5	1.2	1.2				1.7		U
Extreme Environmental	FWSC-6	1.0	1.0	1.0	1.0	1.0			U
	FWSC-7	1.0	1.0	1.0	1.0			1.0	U

Note: * D = Dead loads
WP = Hydrostatic pressure loads
L = Live loads (For the roof, Roof Live loads or Snow loads each act independently.)
To = Thermal loads during the normal operation
E' = Seismic loads (SSE)
W = Wind loads (basic wind)
Wt = Wind loads (tornado wind)

** U = Required section strength based on the strength design method per ACI 349-01 (Reference 2.2-a).

Non-Seismic load combinations, shown in the red combination No., are analyzed as part of standard design in Reference 2.1.2-i.

Table 6.3-2 Detailed Load Combinations for Reinforced Concrete Structures

			Combination ID No.	Dead Load DLO	Hydrostatic pressure WP	Live Load: Normal Operation LLO	Thermal Load: Normal Operation, Summer TLS0	Thermal Load: Normal Operation, Winter TLW0	Seismic Load: X(NS) direction Shear & Moment KXS1	KXS2	Seismic Load: Y(EW) direction Shear & Moment KYS1	KYS2	Seismic Load: Vertical Acceleration KZS1	KZS2	Seismic Load: Torsional Moment KTS1	KTS2	Wind Load: N to S WON	Wind Load: S to N WOS	Wind Load: E to W WOE	Wind Load: W to E WOW	Tornado Load: N to S WTN	Tornado Load: S to N WTS	Tornado Load: E to W WTE	Tornado Load: W to E WTW	Tornado Differential Load WTD	Acceptance Criteria	Selected Load Combination for Tables of Combined Forces and Moments
Normal	FWSC-1 1.40D+1.40F+1.70L																										
			1001	1.40	1.40	1.70																				U	
	FWSC-2 1.05D+1.05F+1.30L+1.30T0																										
		Summer	2001	1.05	1.05	1.30	1.30																			U	
		Winter	2002	1.05	1.05	1.30		1.30																		U	
Severe Environmental	FWSC-3 1.40D+1.40F+1.70L+1.70W																										
		N to S Wind	3001	1.40	1.40	1.70											1.70									U	√
		S to N Wind	3002	1.40	1.40	1.70												1.70								U	
		E to W Wind	3003	1.40	1.40	1.70													1.70							U	
		W to E Wind	3004	1.40	1.40	1.70														1.70						U	
	FWSC-4 1.05D+1.05F+1.05L+1.70W																										
		Summer N to S Wind	4001	1.05	1.05	1.30	1.30										1.30									U	
		S to N Wind	4002	1.05	1.05	1.30	1.30											1.30								U	
		E to W Wind	4003	1.05	1.05	1.30	1.30												1.30							U	
		W to E Wind	4004	1.05	1.05	1.30	1.30													1.30						U	
		Winter N to S Wind	4011	1.05	1.05	1.30		1.30									1.30									U	√
		S to N Wind	4012	1.05	1.05	1.30		1.30										1.30								U	
		E to W Wind	4013	1.05	1.05	1.30		1.30											1.30							U	
		W to E Wind	4014	1.05	1.05	1.30		1.30												1.30						U	
	FWSC-5 1.20D+1.20F+1.70W																										
		N to S Wind	5001	1.20	1.20												1.70									U	
		S to N Wind	5002	1.20	1.20													1.70								U	
		E to W Wind	5003	1.20	1.20														1.70							U	
		W to E Wind	5004	1.20	1.20															1.70						U	
Extreme Environmental	FWSC-6 1.0D+1.0F+1.0L+1.0T0+1.0E (SSE)																										
		w/o Temp	6001	1.00	1.00	1.00			1.00		1.00		1.00		1.00											U	
			6002	1.00	1.00	1.00			1.00		1.00		1.00			1.00										U	
			6003	1.00	1.00	1.00			1.00		1.00			1.00	1.00											U	
			6004	1.00	1.00	1.00			1.00		1.00			1.00		1.00										U	
			6005	1.00	1.00	1.00			1.00			1.00	1.00		1.00											U	
			6006	1.00	1.00	1.00			1.00			1.00	1.00			1.00										U	
			6007	1.00	1.00	1.00			1.00			1.00		1.00	1.00											U	
			6008	1.00	1.00	1.00			1.00			1.00		1.00		1.00										U	
			6009	1.00	1.00	1.00				1.00	1.00		1.00		1.00											U	
			6010	1.00	1.00	1.00				1.00	1.00		1.00			1.00										U	
			6011	1.00	1.00	1.00				1.00	1.00			1.00	1.00											U	
			6012	1.00	1.00	1.00				1.00	1.00			1.00		1.00										U	
			6013	1.00	1.00	1.00				1.00		1.00	1.00		1.00											U	
			6014	1.00	1.00	1.00				1.00		1.00	1.00			1.00										U	
			6015	1.00	1.00	1.00				1.00		1.00		1.00	1.00											U	
			6016	1.00	1.00	1.00				1.00		1.00		1.00		1.00										U	
		Summer	6021	1.00	1.00	1.00	1.00		1.00		1.00		1.00		1.00											U	
			6022	1.00	1.00	1.00	1.00		1.00		1.00		1.00			1.00										U	
			6023	1.00	1.00	1.00	1.00		1.00		1.00			1.00	1.00											U	
			6024	1.00	1.00	1.00	1.00		1.00		1.00			1.00		1.00										U	
			6025	1.00	1.00	1.00	1.00		1.00			1.00	1.00		1.00											U	
			6026	1.00	1.00	1.00	1.00		1.00			1.00	1.00			1.00										U	
			6027	1.00	1.00	1.00	1.00		1.00			1.00		1.00	1.00											U	
			6028	1.00	1.00	1.00	1.00		1.00			1.00		1.00		1.00										U	
			6029	1.00	1.00	1.00	1.00			1.00	1.00		1.00		1.00											U	
			6030	1.00	1.00	1.00	1.00			1.00	1.00		1.00			1.00										U	
			6031	1.00	1.00	1.00	1.00			1.00	1.00			1.00	1.00											U	
			6032	1.00	1.00	1.00	1.00			1.00	1.00			1.00		1.00										U	
			6033	1.00	1.00	1.00	1.00			1.00		1.00	1.00		1.00											U	
			6034	1.00	1.00	1.00	1.00			1.00		1.00	1.00			1.00										U	
			6035	1.00	1.00	1.00	1.00			1.00		1.00		1.00	1.00											U	
			6036	1.00	1.00	1.00	1.00			1.00		1.00		1.00		1.00										U	
		Winter	6041	1.00	1.00	1.00		1.00	1.00		1.00		1.00		1.00											U	√
			6042	1.00	1.00	1.00		1.00	1.00		1.00		1.00			1.00										U	
			6043	1.00	1.00	1.00		1.00	1.00		1.00			1.00	1.00											U	
			6044	1.00	1.00	1.00		1.00	1.00		1.00			1.00		1.00										U	
			6045	1.00	1.00	1.00		1.00	1.00			1.00	1.00		1.00											U	
			6046	1.00	1.00	1.00		1.00	1.00			1.00	1.00			1.00										U	
			6047	1.00	1.00	1.00		1.00	1.00			1.00		1.00	1.00											U	
			6048	1.00	1.00	1.00		1.00	1.00			1.00		1.00		1.00										U	
			6049	1.00	1.00	1.00		1.00		1.00	1.00		1.00		1.00											U	
			6050	1.00	1.00	1.00		1.00		1.00	1.00		1.00			1.00										U	
			6051	1.00	1.00	1.00		1.00		1.00	1.00			1.00	1.00											U	
			6052	1.00	1.00	1.00		1.00		1.00	1.00			1.00		1.00										U	
			6053	1.00	1.00	1.00		1.00		1.00		1.00	1.00		1.00											U	
			6054	1.00	1.00	1.00		1.00		1.00		1.00	1.00			1.00										U	
			6055	1.00	1.00	1.00		1.00		1.00		1.00		1.00	1.00											U	
			6056	1.00	1.00	1.00		1.00		1.00		1.00		1.00		1.00										U	
	FWSC-7 1.0D+1.0F+1.0L+1.0T0+1.0W+1.0Wt																										
		w/o Temp N to S Wind	7001	1.00	1.00	1.00															1.00					U	
		S to N Wind	7002	1.00	1.00	1.00																1.00				U	
		E to W Wind	7003	1.00	1.00	1.00																	1.00			U	
		W to E Wind	7004	1.00	1.00	1.00																		1.00		U	
		N to S Wind+DP/2	7005	1.00	1.00	1.00															1.00				0.50	U	
		S to N Wind+DP/2	7006	1.00	1.00	1.00																1.00			0.50	U	
		E to W Wind+DP/2	7007	1.00	1.00	1.00																	1.00		0.50	U	
		W to E Wind+DP/2	7008	1.00	1.00	1.00																		1.00	0.50	U	
		Differential	7009	1.00	1.00	1.00																			1.00	U	
		Summer N to S Wind	7011	1.00	1.00	1.00	1.00														1.00					U	
		S to N Wind	7012	1.00	1.00	1.00	1.00															1.00				U	
		E to W Wind	7013	1.00	1.00	1.00	1.00																1.00			U	
		W to E Wind	7014	1.00	1.00	1.00	1.00																	1.00		U	
		N to S Wind+DP/2	7015	1.00	1.00	1.00	1.00														1.00				0.50	U	
		S to N Wind+DP/2	7016	1.00	1.00	1.00	1.00															1.00			0.50	U	
		E to W Wind+DP/2	7017	1.00	1.00	1.00	1.00																1.00		0.50	U	
		W to E Wind+DP/2	7018	1.00	1.00	1.00	1.00																	1.00	0.50	U	
		Differential	7019	1.00	1.00	1.00	1.00																		1.00	U	
		Winter N to S Wind	7021	1.00	1.00	1.00		1.00													1.00					U	√
		S to N Wind	7022	1.00	1.00	1.00		1.00														1.00				U	
		E to W Wind	7023	1.00	1.00	1.00		1.00															1.00			U	
		W to E Wind	7024	1.00	1.00	1.00		1.00																1.00		U	
		N to S Wind+DP/2	7025	1.00	1.00	1.00		1.00													1.00				0.50	U	
		S to N Wind+DP/2	7026	1.00	1.00	1.00		1.00														1.00			0.50	U	
		E to W Wind+DP/2	7027	1.00	1.00	1.00		1.00															1.00		0.50	U	
		W to E Wind+DP/2	7028	1.00	1.00	1.00		1.00																1.00	0.50	U	
		Differential	7029	1.00	1.00	1.00		1.00																	1.00	U	

Notes: Non-Seismic load combinations, shown in the red box, are analyzed as part of standard design in Reference 2.1.2-i.
Opposite sign of stresses due to the combination of seismic load to the other loads is considered.
In that case, 500 is added to the original Combination ID.

Table 6.3-3 Combined Forces and Moments: Load Combination FWSC-3 (Reproduced from Reference 2.1.2-i)

Location	Element ID		N_x (MN/m)	N_y (MN/m)	N_{xy} (MN/m)	M_x (MNm/m)	M_y (MNm/m)	M_{xy} (MNm/m)	Q_x (MN/m)	Q_y (MN/m)
Basemat EL 4.65	18	OTHR	0.220	-0.029	-0.115	-0.849	0.185	0.149	-0.185	-0.125
		TEMP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	227	OTHR	0.166	0.374	0.255	-0.232	0.217	0.212	-0.430	-0.114
		TEMP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	237	OTHR	0.265	-0.003	-0.040	-0.102	0.394	-0.246	-0.483	0.296
		TEMP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	16085	OTHR	0.284	0.396	0.281	-0.271	0.152	0.190	-0.290	-0.027
		TEMP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Roof of FPE EL 8.25	51556	OTHR	-0.039	0.031	0.006	0.101	0.138	-0.008	0.009	0.020
		TEMP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	51558	OTHR	-0.037	-0.341	-0.008	-0.047	0.030	-0.019	0.092	-0.005
		TEMP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	51576	OTHR	0.410	-0.058	0.057	-0.007	-0.113	-0.014	-0.007	0.131
		TEMP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	51578	OTHR	0.107	-0.145	0.071	-0.009	-0.033	-0.042	-0.006	0.037
		TEMP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Roof of Tank	26007	OTHR	-0.265	-0.204	-0.014	0.011	0.011	0.000	-0.002	0.000
		TEMP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	26079	OTHR	0.107	-0.123	0.041	-0.001	-0.028	0.004	-0.004	0.032
		TEMP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	26082	OTHR	-0.037	0.030	0.139	-0.017	-0.014	0.014	-0.022	0.021
		TEMP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	26085	OTHR	-0.076	0.077	-0.135	-0.023	-0.009	-0.013	-0.026	-0.016
		TEMP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
South Wall of FPE	66004	OTHR	-0.173	-0.049	0.076	-0.009	-0.061	0.001	0.004	0.028
		TEMP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	66006	OTHR	-0.134	0.168	0.383	-0.009	-0.081	-0.007	-0.023	-0.103
		TEMP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	66024	OTHR	-0.478	-0.157	0.030	-0.020	-0.122	0.005	0.003	0.024
		TEMP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
East Wall of FPE	67004	OTHR	0.289	-0.539	-0.091	-0.012	-0.087	0.002	-0.003	-0.121
		TEMP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	67006	OTHR	0.430	-0.048	-0.615	-0.014	-0.044	0.003	-0.002	-0.073
		TEMP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	67024	OTHR	0.574	-0.264	-0.091	0.034	0.173	-0.002	0.001	-0.116
		TEMP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Wall of South Tank	35007	OTHR	0.059	-0.269	0.029	0.001	0.097	-0.005	-0.011	0.169
		TEMP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	35010	OTHR	0.202	-0.655	-0.110	0.027	0.103	0.003	0.012	0.149
		TEMP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	36507	OTHR	0.595	-0.270	-0.040	-0.023	-0.038	0.001	-0.005	-0.031
		TEMP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	36510	OTHR	0.607	-0.373	-0.054	0.008	-0.023	-0.005	0.002	-0.024
		TEMP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	38507	OTHR	0.281	-0.120	0.003	-0.007	-0.016	0.002	0.000	0.042
		TEMP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	38510	OTHR	0.291	-0.134	0.025	0.000	-0.012	0.003	0.001	0.050
		TEMP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	45001	OTHR	0.171	-0.295	0.077	-0.005	0.039	-0.007	-0.015	0.120
		TEMP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	46501	OTHR	0.557	-0.328	0.025	-0.010	-0.021	0.003	-0.002	-0.030
		TEMP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	48501	OTHR	0.306	-0.143	-0.007	0.000	-0.009	0.000	0.000	0.054
		TEMP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Shear Key	72008	OTHR	0.165	0.148	0.126	0.012	0.008	0.002	0.005	-0.004
		TEMP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	73017	OTHR	-0.854	0.175	-0.613	0.006	0.010	0.007	0.004	-0.005
		TEMP	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Notes:
OTHR: Loads other than thermal loads
TEMP: Thermal loads
Load Combination ID in Table 6.3-2 = 3001

Table 6.3-4 Combined Forces and Moments: Load Combination FWSC-4 (Reproduced from Reference 2.1.2-i)

Location	Element ID		N_x (MN/m)	N_y (MN/m)	N_{xy} (MN/m)	M_x (MNm/m)	M_y (MNm/m)	M_{xy} (MNm/m)	Q_x (MN/m)	Q_y (MN/m)
Basemat EL 4.65	18	OTHR	0.165	-0.021	-0.086	-0.638	0.139	0.112	-0.138	-0.093
		TEMP	11.178	0.074	3.240	-10.622	-1.204	-0.488	0.078	0.719
	227	OTHR	0.126	0.281	0.190	-0.176	0.162	0.159	-0.321	-0.086
		TEMP	-3.772	14.700	-0.114	-4.782	-7.608	0.723	0.207	0.161
	237	OTHR	0.200	-0.002	-0.030	-0.079	0.295	-0.184	-0.361	0.222
		TEMP	4.252	6.441	3.070	-7.918	-4.714	-1.350	-0.640	-0.580
	16085	OTHR	0.214	0.297	0.210	-0.204	0.113	0.143	-0.217	-0.021
		TEMP	-5.946	-2.435	1.340	-1.471	-0.062	0.448	-0.833	0.007
Roof of FPE EL 8.25	51556	OTHR	-0.029	0.023	0.005	0.076	0.104	-0.006	0.007	0.015
		TEMP	0.130	0.203	0.018	-0.371	-0.308	0.001	-0.008	0.009
	51558	OTHR	-0.028	-0.255	-0.006	-0.035	0.023	-0.014	0.069	-0.004
		TEMP	0.247	-0.598	-0.050	-0.253	-0.309	-0.010	-0.040	-0.001
	51576	OTHR	0.307	-0.043	0.042	-0.005	-0.085	-0.011	-0.005	0.098
		TEMP	1.032	0.154	0.130	-0.384	-0.391	0.000	-0.003	0.032
	51578	OTHR	0.080	-0.109	0.053	-0.007	-0.025	-0.032	-0.004	0.028
		TEMP	0.250	-0.299	0.016	-0.333	-0.389	-0.023	-0.040	0.056
Roof of Tank	26007	OTHR	-0.199	-0.153	-0.011	0.008	0.008	0.000	-0.002	0.000
		TEMP	0.030	-0.047	-0.008	-0.510	-0.511	0.000	0.002	0.001
	26079	OTHR	0.080	-0.093	0.031	0.000	-0.021	0.003	-0.003	0.024
		TEMP	0.543	0.144	0.050	-0.580	-0.696	0.015	-0.013	0.102
	26082	OTHR	-0.028	0.023	0.105	-0.013	-0.010	0.011	-0.017	0.016
		TEMP	0.418	0.191	0.099	-0.631	-0.628	0.055	-0.067	0.066
	26085	OTHR	-0.057	0.058	-0.101	-0.017	-0.007	-0.010	-0.020	-0.012
		TEMP	0.311	0.235	-0.007	-0.644	-0.599	-0.046	-0.073	-0.045
South Wall of FPE	66004	OTHR	-0.130	-0.037	0.057	-0.007	-0.046	0.001	0.003	0.021
		TEMP	3.790	-0.169	-0.160	-0.538	-0.932	0.006	-0.006	-0.239
	66006	OTHR	-0.100	0.126	0.286	-0.006	-0.061	-0.005	-0.018	-0.078
		TEMP	2.355	1.227	-0.536	-0.492	-0.900	-0.032	-0.264	-0.803
	66024	OTHR	-0.358	-0.118	0.023	-0.015	-0.092	0.004	0.002	0.018
		TEMP	-0.119	0.009	-0.049	-0.453	-0.360	0.002	0.020	-0.282
East Wall of FPE	67004	OTHR	0.217	-0.404	-0.068	-0.009	-0.065	0.001	-0.002	-0.091
		TEMP	4.172	-0.810	-0.348	0.494	0.551	-0.002	0.002	0.034
	67006	OTHR	0.323	-0.036	-0.461	-0.010	-0.033	0.002	-0.001	-0.055
		TEMP	4.333	0.630	-2.681	0.412	0.518	0.008	0.176	0.222
	67024	OTHR	0.430	-0.198	-0.068	0.026	0.130	-0.002	0.001	-0.087
		TEMP	2.057	-0.179	-0.330	0.484	0.450	0.003	-0.009	0.057
Wall of South Tank	35007	OTHR	0.045	-0.203	0.020	0.001	0.073	-0.004	-0.008	0.127
		TEMP	3.916	-0.784	0.253	-1.510	-1.405	-0.012	-0.093	-0.422
	35010	OTHR	0.153	-0.491	-0.084	0.020	0.077	0.002	0.009	0.111
		TEMP	3.445	0.040	-0.257	-1.628	-1.630	0.043	0.020	-0.515
	36507	OTHR	0.447	-0.203	-0.031	-0.018	-0.029	0.001	-0.004	-0.023
		TEMP	-0.384	-0.425	0.052	-1.491	-1.464	-0.001	-0.014	0.106
	36510	OTHR	0.455	-0.279	-0.041	0.006	-0.017	-0.003	0.001	-0.018
		TEMP	-0.369	-0.033	-0.333	-1.535	-1.464	-0.006	0.019	0.102
	38507	OTHR	0.212	-0.090	0.002	-0.005	-0.012	0.001	0.000	0.032
		TEMP	0.134	-0.081	0.009	-1.437	-1.002	0.005	0.001	-0.236
	38510	OTHR	0.219	-0.100	0.019	0.000	-0.009	0.002	0.001	0.038
		TEMP	-0.065	0.003	-0.200	-1.446	-1.003	-0.023	-0.007	-0.266
	45001	OTHR	0.130	-0.220	0.059	-0.004	0.029	-0.005	-0.011	0.089
		TEMP	4.537	0.932	-0.061	-1.525	-1.682	-0.022	0.004	-0.522
	46501	OTHR	0.417	-0.245	0.019	-0.007	-0.016	0.002	-0.002	-0.023
		TEMP	-0.427	0.603	0.120	-1.560	-1.500	-0.003	-0.005	0.104
	48501	OTHR	0.230	-0.107	-0.005	0.000	-0.007	0.000	0.000	0.041
		TEMP	-0.253	0.103	0.064	-1.459	-1.004	0.008	0.002	-0.298
Shear Key	72008	OTHR	0.123	0.111	0.094	0.009	0.006	0.001	0.004	-0.003
		TEMP	0.038	-0.574	0.418	0.127	0.139	0.043	0.024	-0.076
	73017	OTHR	-0.643	0.132	-0.458	0.005	0.007	0.005	0.003	-0.004
		TEMP	-8.033	-0.578	-1.169	0.026	0.037	0.044	0.014	-0.019

Notes:

OTHR: Loads other than thermal loads

TEMP: Thermal loads

Load Combination ID in Table 6.3-2 = 4011

Table 6.3-5 Combined Forces and Moments: Site-Specific Seismic Load Combination FWSC-6

Location	Element ID		N_x (MN/m)	N_y (MN/m)	N_{xy} (MN/m)	M_x (MNm/m)	M_y (MNm/m)	M_{xy} (MNm/m)	Q_x (MN/m)	Q_y (MN/m)
Basemat EL 4.65	18	OTHR	0.136	-0.025	-0.082	-0.547	0.146	0.101	-0.151	-0.099
		TEMP	8.599	0.057	2.492	-8.171	-0.926	-0.375	0.060	0.553
		SEIS	0.855	0.134	0.496	1.889	0.544	0.674	0.718	0.412
	227	OTHR	0.015	0.250	0.212	-0.033	0.201	0.158	-0.382	-0.064
		TEMP	-2.901	11.308	-0.088	-3.679	-5.852	0.556	0.159	0.124
		SEIS	2.079	0.807	1.399	3.224	1.684	1.242	2.178	0.826
	237	OTHR	0.125	0.007	-0.044	0.072	0.311	-0.187	-0.371	0.229
		TEMP	3.271	4.954	2.362	-6.091	-3.626	-1.039	-0.492	-0.446
		SEIS	1.091	0.524	0.368	3.821	1.842	1.151	1.297	1.145
	16085	OTHR	0.156	0.258	0.200	-0.119	0.146	0.136	-0.186	0.007
		TEMP	-4.574	-1.873	1.031	-1.132	-0.048	0.345	-0.640	0.006
		SEIS	1.076	0.836	0.449	2.249	1.518	0.519	0.696	0.804
Roof of FPE EL 8.25	51556	OTHR	-0.033	0.013	0.006	0.080	0.108	-0.006	0.008	0.015
		TEMP	0.100	0.156	0.014	-0.286	-0.237	0.001	-0.006	0.007
		SEIS	0.075	0.079	0.107	0.075	0.119	0.009	0.006	0.020
	51558	OTHR	-0.036	-0.265	-0.005	-0.039	0.023	-0.015	0.073	-0.004
		TEMP	0.190	-0.460	-0.038	-0.194	-0.238	-0.008	-0.031	-0.001
		SEIS	0.051	0.562	0.275	0.023	0.034	0.022	0.066	0.010
	51576	OTHR	0.292	-0.052	0.047	-0.004	-0.088	-0.011	-0.005	0.102
		TEMP	0.794	0.118	0.100	-0.295	-0.301	0.000	-0.002	0.025
		SEIS	0.916	0.047	0.254	0.033	0.126	0.011	0.006	0.116
	51578	OTHR	0.074	-0.112	0.053	-0.008	-0.026	-0.032	-0.003	0.028
		TEMP	0.192	-0.230	0.013	-0.256	-0.299	-0.018	-0.031	0.043
		SEIS	0.275	0.227	0.137	0.011	0.040	0.035	0.035	0.050
Roof of Tank	26007	OTHR	-0.217	-0.194	-0.006	0.010	0.010	0.000	0.000	0.000
		TEMP	0.023	-0.036	-0.006	-0.392	-0.393	0.000	0.001	0.001
		SEIS	0.463	0.415	0.031	0.021	0.021	0.001	0.003	0.003
	26079	OTHR	0.103	-0.115	0.028	-0.001	-0.025	0.003	-0.003	0.028
		TEMP	0.417	0.111	0.038	-0.446	-0.535	0.011	-0.010	0.079
		SEIS	0.341	0.269	0.089	0.006	0.055	0.009	0.008	0.062
	26082	OTHR	-0.019	0.010	0.121	-0.015	-0.013	0.013	-0.021	0.020
		TEMP	0.322	0.147	0.076	-0.485	-0.483	0.042	-0.051	0.051
		SEIS	0.150	0.302	0.291	0.033	0.028	0.028	0.048	0.043
	26085	OTHR	-0.061	0.058	-0.111	-0.020	-0.008	-0.012	-0.025	-0.015
		TEMP	0.240	0.181	-0.005	-0.496	-0.461	-0.035	-0.056	-0.035
		SEIS	0.161	0.350	0.309	0.046	0.019	0.026	0.058	0.035

Notes:

OTHR: Loads other than thermal and seismic loads TEMP: Thermal loads

SEIS: Seismic loads evaluated by SRSS

Load Combination IDs in Table 6.3-2 = 6041 and 6541

Table 6.3-5 Combined Forces and Moments: Site-Specific Seismic Load Combination FWSC-6 (Continued)

Location	Element ID		N_x (MN/m)	N_y (MN/m)	N_{xy} (MN/m)	M_x (MNm/m)	M_y (MNm/m)	M_{xy} (MNm/m)	Q_x (MN/m)	Q_y (MN/m)
South Wall of FPE	66004	OTHR	-0.132	-0.039	0.053	-0.006	-0.040	0.001	0.003	0.023
		TEMP	2.916	-0.130	-0.123	-0.414	-0.717	0.005	-0.005	-0.184
		SEIS	0.431	0.282	0.293	0.017	0.109	0.007	0.016	0.017
	66006	OTHR	-0.109	0.109	0.291	-0.006	-0.055	-0.005	-0.016	-0.069
		TEMP	1.811	0.944	-0.412	-0.378	-0.693	-0.024	-0.203	-0.618
		SEIS	0.480	0.353	0.911	0.030	0.140	0.013	0.030	0.203
	66024	OTHR	-0.367	-0.122	0.023	-0.016	-0.095	0.004	0.002	0.025
		TEMP	-0.091	0.007	-0.037	-0.349	-0.277	0.002	0.016	-0.217
		SEIS	0.766	0.121	0.163	0.015	0.088	0.005	0.008	0.017
East Wall of FPE	67004	OTHR	0.205	-0.394	-0.083	-0.009	-0.065	0.001	-0.002	-0.088
		TEMP	3.209	-0.623	-0.268	0.380	0.424	-0.001	0.002	0.026
		SEIS	0.468	0.675	0.486	0.038	0.209	0.003	0.005	0.154
	67006	OTHR	0.283	-0.042	-0.435	-0.010	-0.033	0.002	-0.002	-0.054
		TEMP	3.333	0.484	-2.062	0.317	0.398	0.006	0.135	0.170
		SEIS	0.785	0.262	1.093	0.018	0.125	0.004	0.042	0.163
	67024	OTHR	0.410	-0.200	-0.075	0.026	0.133	-0.002	0.001	-0.092
		TEMP	1.582	-0.137	-0.254	0.372	0.346	0.002	-0.007	0.044
		SEIS	1.188	0.272	0.361	0.032	0.156	0.005	0.005	0.155
Wall of South Tank	35007	OTHR	0.019	-0.186	0.072	0.000	0.070	-0.003	-0.008	0.121
		TEMP	3.012	-0.603	0.194	-1.162	-1.081	-0.009	-0.072	-0.324
		SEIS	1.294	1.641	0.757	0.011	0.358	0.034	0.028	0.434
	35010	OTHR	0.088	-0.517	-0.014	0.022	0.093	0.003	0.008	0.123
		TEMP	2.650	0.030	-0.198	-1.253	-1.254	0.033	0.015	-0.396
		SEIS	1.236	2.412	1.642	0.140	0.645	0.033	0.030	0.573
	36507	OTHR	0.401	-0.211	0.011	-0.016	-0.026	0.002	-0.003	-0.023
		TEMP	-0.295	-0.327	0.040	-1.147	-1.126	0.000	-0.011	0.082
		SEIS	1.148	0.829	1.036	0.084	0.119	0.008	0.034	0.058
	36510	OTHR	0.436	-0.296	0.006	0.005	-0.020	-0.002	0.002	-0.019
		TEMP	-0.284	-0.025	-0.256	-1.181	-1.126	-0.005	0.015	0.078
		SEIS	1.209	1.072	1.454	0.053	0.106	0.020	0.027	0.053
	38507	OTHR	0.237	-0.106	0.001	-0.005	-0.014	0.001	0.000	0.039
		TEMP	0.103	-0.062	0.007	-1.105	-0.771	0.004	0.000	-0.181
		SEIS	0.781	0.251	0.233	0.026	0.048	0.018	0.004	0.096
	38510	OTHR	0.254	-0.115	0.012	-0.001	-0.015	0.001	0.000	0.043
		TEMP	-0.050	0.003	-0.154	-1.112	-0.771	-0.018	-0.005	-0.205
		SEIS	0.855	0.282	0.434	0.014	0.048	0.031	0.009	0.091
	45001	OTHR	0.057	-0.328	0.025	0.002	0.058	-0.005	-0.011	0.111
		TEMP	3.490	0.717	-0.047	-1.173	-1.294	-0.017	0.003	-0.402
		SEIS	1.188	3.424	1.521	0.167	0.684	0.018	0.037	0.564
	46501	OTHR	0.409	-0.273	0.006	-0.010	-0.021	0.002	-0.003	-0.023
		TEMP	-0.329	0.464	0.093	-1.200	-1.154	-0.002	-0.004	0.080
		SEIS	1.204	1.534	1.397	0.057	0.075	0.021	0.015	0.053
	48501	OTHR	0.262	-0.117	-0.003	-0.003	-0.014	0.000	0.000	0.043
		TEMP	-0.195	0.079	0.049	-1.123	-0.772	0.006	0.002	-0.229
		SEIS	0.996	0.348	0.346	0.011	0.047	0.016	0.005	0.094
Shear Key	72008	OTHR	0.130	0.104	0.106	0.006	0.005	-0.001	0.000	-0.003
		TEMP	0.030	-0.442	0.322	0.098	0.107	0.033	0.018	-0.058
		SEIS	0.578	0.181	0.501	0.133	1.807	0.259	0.328	1.513
	73017	OTHR	-0.472	0.064	-0.497	0.005	0.007	0.005	0.003	-0.003
		TEMP	-6.179	-0.445	-0.899	0.020	0.028	0.034	0.011	-0.015
		SEIS	4.219	1.411	2.038	0.199	1.493	0.246	0.030	1.128

Notes:

OTHR: Loads other than thermal and seismic loads. TEMP: Thermal loads SEIS: Seismic loads evaluated by SRSS

Load Combination IDs in Table 6.3-2 = 6041 and 6541

Table 6.3-6 Combined Forces and Moments: Load Combination FWSC-7 (Reproduced from Reference 2.1.2-i)

Location	Element ID		N_x (MN/m)	N_y (MN/m)	N_{xy} (MN/m)	M_x (MNm/m)	M_y (MNm/m)	M_{xy} (MNm/m)	Q_x (MN/m)	Q_y (MN/m)
Basemat EL 4.65	18	OTHR	0.182	-0.015	-0.085	-0.690	0.111	0.118	-0.114	-0.073
		TEMP	8.599	0.057	2.492	-8.171	-0.926	-0.375	0.060	0.553
	227	OTHR	0.259	0.286	0.149	-0.352	0.101	0.147	-0.228	-0.107
		TEMP	-2.901	11.308	-0.088	-3.679	-5.852	0.556	0.159	0.124
	237	OTHR	0.269	-0.015	-0.012	-0.258	0.245	-0.158	-0.316	0.189
		TEMP	3.271	4.954	2.362	-6.091	-3.626	-1.039	-0.492	-0.446
	16085	OTHR	0.267	0.311	0.209	-0.294	0.070	0.142	-0.250	-0.054
		TEMP	-4.574	-1.873	1.031	-1.132	-0.048	0.345	-0.640	0.006
Roof of FPE EL 8.25	51556	OTHR	-0.015	0.042	0.002	0.046	0.070	-0.004	0.004	0.010
		TEMP	0.100	0.156	0.014	-0.286	-0.237	0.001	-0.006	0.007
	51558	OTHR	-0.004	-0.215	-0.008	-0.014	0.018	-0.010	0.040	-0.002
		TEMP	0.190	-0.460	-0.038	-0.194	-0.238	-0.008	-0.031	-0.001
	51576	OTHR	0.306	-0.017	0.032	-0.007	-0.059	-0.006	-0.003	0.066
		TEMP	0.794	0.118	0.100	-0.295	-0.301	0.000	-0.002	0.025
	51578	OTHR	0.086	-0.089	0.046	0.000	-0.017	-0.021	-0.008	0.022
		TEMP	0.192	-0.230	0.013	-0.256	-0.299	-0.018	-0.031	0.043
Roof of Tank	26007	OTHR	-0.124	-0.051	-0.015	0.003	0.004	0.000	-0.004	0.000
		TEMP	0.023	-0.036	-0.006	-0.392	-0.393	0.000	0.001	0.001
	26079	OTHR	0.023	-0.033	0.030	0.000	-0.008	0.003	-0.001	0.010
		TEMP	0.417	0.111	0.038	-0.446	-0.535	0.011	-0.010	0.079
	26082	OTHR	-0.034	0.036	0.053	-0.006	-0.003	0.004	-0.005	0.005
		TEMP	0.322	0.147	0.076	-0.485	-0.483	0.042	-0.051	0.051
	26085	OTHR	-0.037	0.044	-0.059	-0.008	-0.003	-0.004	-0.006	-0.004
		TEMP	0.240	0.181	-0.005	-0.496	-0.461	-0.035	-0.056	-0.035

Notes:

OTHR: Loads other than thermal loads
TEMP: Thermal loads
Load Combination ID in Table 6.3-2 = 7021

Table 6.3-6 Combined Forces and Moments: Selected Load Combination FWSC-7 (Continued)

Location	Element ID		N_x (MN/m)	N_y (MN/m)	N_{xy} (MN/m)	M_x (MNm/m)	M_y (MNm/m)	M_{xy} (MNm/m)	Q_x (MN/m)	Q_y (MN/m)
South Wall of FPE	66004	OTHR	-0.114	-0.002	0.058	-0.008	-0.054	0.001	0.002	0.005
		TEMP	2.916	-0.130	-0.123	-0.414	-0.717	0.005	-0.005	-0.184
	66006	OTHR	-0.082	0.139	0.253	-0.008	-0.064	-0.005	-0.017	-0.084
		TEMP	1.811	0.944	-0.412	-0.378	-0.693	-0.024	-0.203	-0.618
	66024	OTHR	-0.309	-0.074	0.021	-0.008	-0.055	0.003	0.002	-0.006
		TEMP	-0.091	0.007	-0.037	-0.349	-0.277	0.002	0.016	-0.217
East Wall of FPE	67004	OTHR	0.215	-0.353	-0.045	-0.008	-0.055	0.001	-0.002	-0.073
		TEMP	3.209	-0.623	-0.268	0.380	0.424	-0.001	0.002	0.026
	67006	OTHR	0.341	-0.019	-0.454	-0.009	-0.028	0.002	-0.001	-0.047
		TEMP	3.333	0.484	-2.062	0.317	0.398	0.006	0.135	0.170
	67024	OTHR	0.426	-0.150	-0.053	0.018	0.090	-0.001	0.001	-0.059
		TEMP	1.582	-0.137	-0.254	0.372	0.346	0.002	-0.007	0.044
Wall of South Tank	35007	OTHR	0.060	-0.180	-0.040	0.001	0.071	-0.005	-0.007	0.123
		TEMP	3.012	-0.603	0.194	-1.162	-1.081	-0.009	-0.072	-0.324
	35010	OTHR	0.209	-0.397	-0.158	0.016	0.052	0.001	0.010	0.086
		TEMP	2.650	0.030	-0.198	-1.253	-1.254	0.033	0.015	-0.396
	36507	OTHR	0.451	-0.152	-0.075	-0.019	-0.031	0.001	-0.005	-0.020
		TEMP	-0.295	-0.327	0.040	-1.147	-1.126	0.000	-0.011	0.082
	36510	OTHR	0.428	-0.216	-0.091	0.008	-0.013	-0.005	0.000	-0.014
		TEMP	-0.284	-0.025	-0.256	-1.181	-1.126	-0.005	0.015	0.078
	38507	OTHR	0.115	-0.043	0.005	-0.005	-0.004	0.003	0.000	0.012
		TEMP	0.103	-0.062	0.007	-1.105	-0.771	0.004	0.000	-0.181
	38510	OTHR	0.112	-0.056	0.026	0.003	0.003	0.004	0.001	0.021
		TEMP	-0.050	0.003	-0.154	-1.112	-0.771	-0.018	-0.005	-0.205
	45001	OTHR	0.195	-0.053	0.094	-0.011	-0.009	-0.004	-0.011	0.054
		TEMP	3.490	0.717	-0.047	-1.173	-1.294	-0.017	0.003	-0.402
	46501	OTHR	0.379	-0.173	0.032	-0.003	-0.007	0.003	-0.001	-0.019
		TEMP	-0.329	0.464	0.093	-1.200	-1.154	-0.002	-0.004	0.080
	48501	OTHR	0.126	-0.068	-0.007	0.004	0.006	-0.001	0.000	0.026
		TEMP	-0.195	0.079	0.049	-1.123	-0.772	0.006	0.002	-0.229
Shear Key	72008	OTHR	0.112	0.106	0.084	0.012	0.007	0.004	0.007	-0.003
		TEMP	0.030	-0.442	0.322	0.098	0.107	0.033	0.018	-0.058
	73017	OTHR	-0.800	0.216	-0.375	0.004	0.007	0.005	0.003	-0.003
		TEMP	-6.179	-0.445	-0.899	0.020	0.028	0.034	0.011	-0.015

Notes:

OTHR: Loads other than thermal loads

TEMP: Thermal loads

Load Combination ID in Table 6.3-2 = 7021

Table 6.4-1 Material Constants for Stress Calculations

Material	Property	Value	
Concrete	Compressive strength, f_c'	Basemat	27.6 MPa
		Others	34.5 MPa
	Young's modulus	Basemat	2.49×10^4 MPa
		Others	2.78×10^4 MPa
	Poisson's ratio	0.17	
Reinforcement	Yield stress, f_y	413.6 MPa	
	Young's modulus	2.00×10^5 MPa	

Table 6.4-2 Allowable Stress of Concrete for Membrane Plus Bending

Load Condition	Allowable Compressive Stress (MPa)		
Primary	Basemat	20.7	(0.75 f_c')
	Others	25.9	
Primary plus secondary	Basemat	23.5	(0.85 f_c')
	Others	29.3	

Note: Concrete allowable stress for load condition of "Primary plus secondary" is applied to the load combinations that include thermal loads.

Table 6.4-3 Allowable Stress of Reinforcement for Membrane Plus Bending

	Allowable Stress (MPa)
Tension	372.2 (0.90 f_y)
Compression	372.2 (0.90 f_y)

Table 6.4-4 Allowable Stress of Concrete for Membrane Compression

Load Condition	Allowable Compressive Stress (MPa)		
Primary	Basemat	16.6	(0.60 f_c')
	Others	20.7	
Primary plus secondary	Basemat	20.7	(0.75 f_c')
	Others	25.9	

Table 7.1-1 Sectional Thickness and Rebar Ratios Used in the Evaluation

Location	Element ID	Thickness (m)	Primary Reinforcement					Shear Tie	
			Position	Direction 1*1		Direction 2*1			
				Arrangement	Ratio (%)	Arrangement	Ratio (%)	Arrangement	Ratio (%)
Basemat EL 4.65m	18	2.50	Top	3-#11@200	0.604	3-#11@200	0.604	#7@400×400	0.242
			Bottom	3-#11@200	0.604	3-#11@200	0.604		
	227		Top	3-#11@200 + 1-#11@400	0.705	3-#11@200 + 1-#11@400	0.705	#7@400×200	0.484
			Bottom	3-#11@200	0.604	3-#11@200 + 1-#11@400	0.705		
	237		Top	3-#11@200 + 1-#11@400	0.705	3-#11@200 + 1-#11@400	0.705	#7@400×200	0.484
			Bottom	3-#11@200	0.604	3-#11@200	0.604		
	16085		Top	3-#11@200 + 1-#11@400	0.705	3-#11@200 + 1-#11@400	0.705	#7@400×400	0.242
			Bottom	3-#11@200	0.604	3-#11@200	0.604		
Roof of FPE EL 8.25m	51556 51558 51576 51578	0.60	Top	1-#11@200	0.839	1-#11@200	0.839	-	-
			Bottom	1-#11@200	0.839	1-#11@200	0.839		
Roof of Tank	26007 26079 26082 26085	0.60	Top	1-#9@200	0.538	1-#9@200	0.538	-	-
			Bottom	1-#9@200	0.538	1-#9@200	0.538		

Note *1: Wall Direction 1: Horizontal, Direction 2: Vertical
Basemat, Roof Direction 1: N-S, Direction 2: E-W

Note: Reinforcement revised from Reference 2.1.2-i is shown in red.

Table 7.1-1 Sectional Thickness and Rebar Ratios Used in the Evaluation (Continued)

Location	Element ID	Thickness (m)	Position	Primary Reinforcement: Direction 1[*1] Arrangement	Direction 1[*1] Ratio (%)	Direction 2[*1] Arrangement	Direction 2[*1] Ratio (%)	Shear Tie Arrangement	Shear Tie Ratio (%)
South Wall of FPE	66004	0.65	Inside	1-#11@200	0.774	1-#11@200	0.774	-	-
			Outside	2-#11@200	1.548	2-#11@200	1.548		
	66006		Inside	1-#11@200	0.774	1-#11@133	1.164	#6@200×200	0.710
			Outside	2-#11@200	1.548	1-#11@133 + 1-#11@200	1.938		
	66024		Inside	1-#11@200	0.774	1-#11@200	0.774	-	-
			Outside	1-#11@200 + 1-#11@400	1.161	1-#11@200 + 1-#11@400	1.161		
East Wall of FPE	67004	0.65	Inside	1-#11@200	0.774	1-#11@133	1.164	-	-
			Outside	2-#11@200	1.548	2-#11@200	1.548		
	67006		Inside	1-#11@200	0.774	1-#11@133	1.164	#6@200×200	0.710
			Outside	2-#11@200	1.548	1-#11@133 + 1-#11@200	1.938		
	67024		Inside	1-#11@200	0.774	1-#11@133	1.164	-	-
			Outside	1-#11@200 + 1-#11@400	1.161	1-#11@200 + 1-#11@400	1.161		
Wall of South Tank	35007 35010 45001	1.00	Inside	1-#11@150 + 1-#11@300	1.006	2-#11@150[*2]	1.342	#6@150[*2]×300	0.631
			Outside	2-#11@150 + 1-#11@300	1.677	2-#11@150[*2] + 1-#11@300[*3]	1.677		
	36507 36510 46501		Inside	1-#11@150	0.671	1-#11@150[*2]	0.671	-	-
			Outside	2-#11@150	1.342	2-#11@150[*2]	1.342		
	38507 38510 48501		Inside	1-#11@150	0.671	1-#11@150[*2]	0.671	-	-
			Outside	1-#11@150	0.671	1-#11@150[*2]	0.671		
Shear Key	72008	2.00	Inside	1-#11@200 + 1-#11@400	0.377	2-#11@200 + 1-#11@400	0.629	#7@400×200	0.484
			Outside	1-#11@200 + 1-#11@400	0.377	2-#11@200 + 1-#11@400	0.629		
	73017		Inside	3-#11@200	0.755	2-#11@200 + 1-#11@400	0.629	#7@400×200	0.484
			Outside	3-#11@200	0.755	2-#11@200 + 1-#11@400	0.629		

Note *1: Wall — Direction 1: Horizontal, Direction 2: Vertical
Basemat, Roof — Direction 1: N-S, Direction 2: E-W

*2: Rebar described as @150 is arranged by @1°

*3: Rebar described as @300 is arranged by @2°

Reinforcement revised from Reference 2.1.2-i is shown in red.

Table 7.2-1 Rebar and Concrete Stresses: Selected Load Combination FWSC-3

Location	Element ID	Concrete Stress (MPa)		Primary Reinforcement Stress (MPa)				
		Calculated	Allowable	Calculated				Allowable
				X-direction*		Y-direction*		
				+Z side*	-Z side*	+Z side*	-Z side*	
Basemat EL 4.65	18	-1.6	-20.7	40.2	-5.6	5.9	6.0	372.2
	227	-0.8		13.2	14.2	3.9	30.3	
	237	-1.1		21.5	8.1	-10.0	30.0	
	16085	-0.7		19.5	15.6	9.1	33.0	
Roof of FPE EL 8.25	51556	-5.0	-25.9	-4.9	39.6	2.3	69.8	372.2
	51558	-1.5		18.3	-3.8	-4.5	-1.4	
	51576	-5.2		56.6	23.1	62.9	-5.1	
	51578	-2.8		34.1	6.2	23.3	-1.4	
Roof of Tank	26007	-0.6	-25.9	-3.2	-1.9	-2.3	-1.2	372.2
	26079	-0.8		18.4	17.9	4.9	-1.9	
	26082	-1.0		18.9	17.1	26.1	21.9	
	26085	-0.9		19.5	9.5	28.4	28.3	
South Wall of FPE	66004	-1.9	-25.9	1.3	-0.9	15.3	-1.7	372.2
	66006	-2.8		23.2	7.9	45.1	5.0	
	66024	-3.5		-3.8	-4.3	29.4	-4.0	
East Wall of FPE	67004	-2.5	-25.9	32.5	14.1	4.1	-6.5	372.2
	67006	-2.0		89.6	52.5	83.0	16.8	
	67024	-6.1		25.2	62.5	-9.0	45.2	
Wall of South Tank	35007	-0.9	-25.9	1.7	3.3	-3.4	2.5	372.2
	35010	-1.1		4.3	16.1	-5.2	-1.0	
	36507	-0.4		24.9	39.7	2.6	-4.7	
	36510	-0.5		21.4	48.8	-1.5	-1.4	
	38507	-0.2		20.1	21.8	-0.6	-0.9	
	38510	-0.2		19.4	24.7	-0.7	-0.8	
	45001	-0.5		6.2	8.6	-1.6	-0.3	
	46501	-0.4		21.6	40.0	-1.7	-1.8	
	48501	-0.2		20.4	25.2	-0.5	-1.1	
Shear Key	72008	-0.1	-20.7	16.8	18.9	11.4	12.5	372.2
	73017	-0.7		5.8	5.6	20.8	21.4	

Note: Negative value means compression.
* For denominations of table columns, see the definition of local coordinate in Figure 6.2-39.
Load Combination ID in Table 6.3-2 = 3001

Table 7.2-2 Rebar and Concrete Stresses: Selected Load Combination FWSC-4

Location	Element ID	Concrete Stress (MPa)		Primary Reinforcement Stress (MPa)				
		Calculated	Allowable	Calculated				Allowable
				X-direction*		Y-direction*		
				+Z side*	-Z side*	+Z side*	-Z side*	
Basemat EL 4.65	18	-3.9	-23.5	179.4	0.6	62.2	6.8	372.2
	227	-4.9		15.6	-29.1	85.6	29.3	
	237	-4.9		129.0	-7.5	87.7	15.1	
	16085	-3.9		-8.4	-24.1	-5.0	-2.1	
Roof of FPE EL 8.25	51556	-2.7	-29.3	45.4	-5.3	26.3	6.5	372.2
	51558	-4.4		47.4	-2.0	5.4	-15.9	
	51576	-9.0		121.0	19.9	124.3	0.0	
	51578	-7.3		69.1	3.9	59.0	-7.3	
Roof of Tank	26007	-3.3	-29.3	32.3	-8.6	28.7	-2.8	372.2
	26079	-5.3		92.7	6.5	78.8	1.7	
	26082	-6.2		141.1	0.1	127.4	14.7	
	26085	-4.7		105.0	-2.9	97.8	15.0	
South Wall of FPE	66004	-9.6	-29.3	55.3	23.3	71.4	-13.9	372.2
	66006	-9.5		82.7	26.7	120.4	13.9	
	66024	-5.1		16.5	-11.0	48.0	-2.0	
East Wall of FPE	67004	-5.5	-29.3	42.4	72.7	-24.6	8.5	372.2
	67006	-8.9		51.7	148.5	11.9	135.5	
	67024	-9.4		35.0	111.7	-9.4	76.3	
Wall of South Tank	35007	-7.1	-29.3	82.5	19.3	38.2	-10.2	372.2
	35010	-6.7		84.5	17.8	44.2	-5.9	
	36507	-5.8		73.6	-5.0	44.4	-9.8	
	36510	-6.4		74.9	-4.5	48.4	-7.2	
	38507	-3.7		87.6	2.2	35.6	-1.2	
	38510	-4.0		86.1	0.8	34.9	-0.7	
	45001	-5.4		85.2	25.1	48.0	0.8	
	46501	-5.9		73.5	-6.0	50.9	-3.3	
	48501	-4.1		86.1	-0.5	35.0	0.1	
Shear Key	72008	-0.5	-23.5	23.5	31.0	6.2	12.1	372.2
	73017	-4.1		-31.0	-30.6	3.2	3.8	

Note: Negative value means compression.
* For denominations of table columns, see the definition of local coordinate in Figure 6.2-39.
Load Combination ID in Table 6.3-2 = 4011

Table 7.2-3 Rebar and Concrete Stresses: Selected Load Combination FWSC-6

Location	Element ID	Concrete Stress (MPa)		Primary Reinforcement Stress (MPa)				
		Calculated	Allowable	Calculated				Allowable
				X-direction*		Y-direction*		
				+Z side*	-Z side*	+Z side*	-Z side*	
Basemat EL 4.65	18	-5.5	-23.5	224.3	21.4	54.2	12.2	372.2
	227	-11.1		50.4	74.7	144.7	109.9	
	237	-13.0		269.7	100.3	178.3	94.6	
	16085	-5.5		-13.1	-35.2	26.4	16.8	
Roof of FPE EL 8.25	51556	-6.5	-29.3	95.0	8.7	103.6	53.4	372.2
	51558	-4.8		58.5	4.0	48.8	-19.5	
	51576	-14.8		247.9	70.5	225.5	3.2	
	51578	-8.8		115.9	15.6	63.1	-12.3	
Roof of Tank	26007	-2.5	-29.3	78.7	-12.1	70.3	14.4	372.2
	26079	-6.8		144.4	32.3	70.1	14.2	
	26082	-4.2		186.2	24.3	200.4	45.2	
	26085	-3.0		182.2	14.9	187.1	75.0	
South Wall of FPE	66004	-11.2	-29.3	93.1	40.7	81.0	-15.9	372.2
	66006	-13.4		152.9	74.0	197.2	12.8	
	66024	-7.2		70.8	-16.0	65.5	6.7	
East Wall of FPE	67004	-12.1	-29.3	54.3	114.9	-32.6	42.2	372.2
	67006	-7.3		148.6	218.6	-11.1	198.4	
	67024	-17.0		97.7	222.2	-16.7	149.5	
Wall of South Tank	35007	-11.5	-29.3	120.5	59.4	59.7	-25.7	372.2
	35010	-11.3		145.8	55.0	65.2	174.4	
	36507	-6.9		141.0	33.7	84.5	18.3	
	36510	-8.3		150.5	60.9	107.0	44.2	
	38507	-3.0		142.7	31.3	43.8	7.3	
	38510	-4.2		155.1	50.3	58.1	13.1	
	45001	-11.3		134.9	86.3	69.9	236.5	
	46501	-4.3		149.1	39.4	126.3	110.4	
	48501	-3.2		160.5	42.9	55.9	13.5	
Shear Key	72008	-4.6	-23.5	83.4	87.0	88.9	107.6	372.2
	73017	-6.9		-37.1	-33.9	128.9	48.6	

Note: Negative value means compression.

* For denominations of table columns, see the definition of local coordinate in Figure 6.2-39.

Load Combination ID in Table 6.3-2 = 6041 or 6541, whichever is greater.

Table 7.2-4 Rebar and Concrete Stresses: Selected Load Combination FWSC-7

Location	Element ID	Concrete Stress (MPa)		Primary Reinforcement Stress (MPa)				
		Calculated	Allowable	Calculated				Allowable
				X-direction*		Y-direction*		
				+Z side*	-Z side*	+Z side*	-Z side*	
Basemat EL 4.65	18	-3.2	-23.5	144.8	-0.3	46.0	5.7	372.2
	227	-4.2		20.6	-23.0	68.7	23.7	
	237	-4.3		114.4	-6.3	79.4	11.2	
	16085	-3.1		-5.6	-18.9	-3.7	-1.4	
Roof of FPE EL 8.25	51556	-2.7	-29.3	7.0	-6.4	-1.9	25.9	372.2
	51558	-3.3		32.2	-0.2	3.4	-12.8	
	51576	-5.8		93.7	18.9	79.8	-0.1	
	51578	-5.3		50.8	3.9	41.9	-5.7	
Roof of Tank	26007	-2.9	-29.3	32.7	-5.9	34.0	0.8	372.2
	26079	-3.8		67.8	4.6	64.3	3.4	
	26082	-4.8		105.3	-1.6	95.9	12.0	
	26085	-4.6		97.0	-4.1	84.9	12.9	
South Wall of FPE	66004	-10.3	-29.3	44.6	26.6	57.3	-14.5	372.2
	66006	-7.8		67.6	16.8	101.5	9.3	
	66024	-3.5		10.7	-9.1	33.2	-1.0	
East Wall of FPE	67004	-4.3	-29.3	37.3	58.1	-19.0	4.3	372.2
	67006	-6.9		44.3	124.3	10.8	109.8	
	67024	-7.4		30.8	94.2	-8.2	58.5	
Wall of South Tank	35007	-4.7	-29.3	61.2	14.0	19.6	-9.0	372.2
	35010	-5.5		71.2	16.8	37.6	-4.3	
	36507	-5.1		63.3	-1.3	38.7	-6.8	
	36510	-5.9		69.4	-1.3	55.4	-3.9	
	38507	-2.9		64.0	0.6	28.3	-0.4	
	38510	-3.1		62.1	-0.6	26.2	0.2	
	45001	-4.8		72.7	21.1	52.5	4.4	
	46501	-4.5		59.1	-3.5	40.0	-1.9	
	48501	-3.2		61.9	-1.5	25.7	0.5	
Shear Key	72008	-0.4	-23.5	19.5	26.5	5.6	10.8	372.2
	73017	-3.3		-23.9	-24.1	11.8	12.8	

Note: Negative value means compression.
* For denominations of table columns, see the definition of local coordinate in Figure 6.2-39.
Load Combination ID in Table 6.3-2 = 7021

Table 7.2-5 Maximum Stress Ratios (Basemat and Roofs) for Flexure and Membrane Forces

Location	Element	Concrete		Primary Reinforcement							
				NS direction				EW direction			
				Top		Bottom		Top		Bottom	
	ID	σ/σ_a	Load ID	σ/σ_a	Load ID	σ/σ_a	Load ID	σ/σ_a	Load ID	σ/σ_a	Load ID
Basemat EL 4.65	18	0.384	6045	0.736	6050	0.190	6536	0.187	6016	0.337	6056
	227	0.604	6047	0.531	6016	0.553	6027	0.389	6041	0.594	6013
	237	0.619	6027	0.866	6056	0.697	6016	0.552	6054	0.526	6014
	16085	0.342	6028	0.394	6015	0.508	6034	0.084	6551	0.399	6010
Roof of FPE EL 8.25	51556	0.308	6005	0.524	6055	0.452	6027	0.530	6053	0.529	6005
	51558	0.197	6046	0.485	6055	0.442	6535	0.479	6526	0.395	6526
	51576	0.532	6045	0.744	6053	0.470	6025	0.838	6045	0.318	6525
	51578	0.366	6053	0.580	6053	0.263	6507	0.503	6055	0.329	6533
Roof of Tank	26007	0.113	4011	0.237	6547	0.142	6527	0.209	6545	0.130	6525
	26079	0.306	6029	0.403	6045	0.254	6025	0.226	6053	0.161	6505
	26082	0.215	4013	0.542	6047	0.331	6025	0.564	6047	0.292	6027
	26085	0.177	2002	0.541	6047	0.223	6527	0.536	6047	0.362	6027

Note: σ_a is shown in Tables 6.4-2 and 6.4-3.

Table 7.2-6 Maximum Stress Ratios (Walls) for Flexure and Membrane Forces

Location	Element	Concrete		Primary Reinforcement							
				Horizontal direction				Vertical direction			
				Inside		Outside		Inside		Outside	
	ID	σ/σ_a	Load ID	σ/σ_a	Load ID	σ/σ_a	Load ID	σ/σ_a	Load ID	σ/σ_a	Load ID
South Wall of FPE	66004	0.573	6053	0.451	6513	0.417	6053	0.596	6513	0.541	6053
	66006	0.479	6050	0.323	6529	0.431	6049	0.287	6022	0.739	6053
	66024	0.363	6007	0.498	6533	0.471	6545	0.417	6536	0.455	6055
East Wall of FPE	67004	0.437	6052	0.365	6014	0.340	6054	0.312	6016	0.226	6522
	67006	0.574	6056	0.668	6014	0.657	6054	0.601	6010	0.534	6042
	67024	0.597	6054	0.528	6022	0.639	6054	0.298	6526	0.590	6046
Wall of South Tank	35007	0.435	6055	0.272	6010	0.346	6054	0.139	6016	0.285	6032
	35010	0.394	6047	0.392	6001	0.392	6041	0.672	6528	0.474	6508
	36507	0.246	6052	0.430	6029	0.396	6051	0.351	6501	0.237	6056
	36510	0.294	6043	0.587	6025	0.419	6045	0.512	6507	0.314	6545
	38507	0.128	4012	0.296	6033	0.390	6045	0.126	6036	0.137	6056
	38510	0.145	6045	0.366	6027	0.438	6047	0.166	6027	0.161	6547
	45001	0.421	6047	0.410	6007	0.393	6047	0.740	6547	0.599	6507
	46501	0.260	6051	0.555	6014	0.437	6055	0.573	6507	0.370	6547
	48501	0.142	4014	0.364	6027	0.452	6047	0.120	6507	0.172	6547
Shear Key	72008	0.250	6023	0.350	6023	0.245	6051	0.431	6023	0.322	6003
	73017	0.293	6042	0.546	6022	0.559	6025	0.383	6501	0.481	6522

Note: σ_a is shown in Tables 6.4-2 and 6.4-3.

Table 7.2-7 Maximum Stress Ratios for Membrane Compressive Forces

Location	Element ID	Load ID	Section Forces (MN/m)			Thickness	Calculated Concrete Stress				Allowable	
			N_x	N_y	N_{xy}	h (m)	σ_x (MPa)	σ_y (MPa)	τ_{xy} (MPa)	σ_c (MPa)	Stress σ_a (MPa)	σ_c/σ_a
Basemat EL 4.65	18	6030	7.356	-0.217	-1.751	2.50	2.9	-0.1	-0.7	3.1	20.7	0.15
	227	6056	6.476	-11.520	1.353	2.50	2.6	-4.6	0.5	2.6	20.7	0.13
	237	6034	4.879	0.667	0.800	2.50	2.0	0.3	0.3	2.0	20.7	0.10
	16085	6053	6.711	2.187	1.289	2.50	2.7	0.9	0.5	2.8	20.7	0.14
Roof of FPE EL 8.25	51556	6007	0.099	-0.006	0.913	0.60	0.2	0.0	1.5	1.6	20.7	0.08
	51558	6005	0.085	0.675	1.243	0.60	0.1	1.1	2.1	2.8	20.7	0.13
	51576	6005	0.150	0.035	1.046	0.60	0.3	0.1	1.7	1.9	20.7	0.09
	51578	6013	0.000	0.339	1.084	0.60	0.0	0.6	1.8	2.1	20.7	0.10
Roof of Tank	26007	6008	0.723	0.552	-0.052	0.60	1.2	0.9	-0.1	1.2	20.7	0.06
	26079	6006	-0.305	0.429	0.027	0.60	-0.5	0.7	0.0	0.7	20.7	0.03
	26082	6006	-0.033	0.054	0.421	0.60	-0.1	0.1	0.7	0.7	20.7	0.03
	26085	6007	0.138	-0.308	-0.507	0.60	0.2	-0.5	-0.8	0.8	20.7	0.04
South Wall of FPE	66004	6025	1.055	0.537	1.720	0.65	1.6	0.8	2.6	3.9	25.9	0.15
	66006	6013	0.554	1.678	1.331	0.65	0.9	2.6	2.0	3.9	20.7	0.19
	66024	6005	0.906	0.128	-1.514	0.65	1.4	0.2	-2.3	3.2	20.7	0.15
East Wall of FPE	67004	6034	2.315	-0.273	0.640	0.65	3.6	-0.4	1.0	3.8	25.9	0.15
	67006	6034	2.881	1.593	2.368	0.65	4.4	2.5	3.6	7.2	25.9	0.28
	67024	6030	1.881	-0.100	0.343	0.65	2.9	-0.2	0.5	3.0	25.9	0.12
Wall of South Tank	35007	6010	1.005	0.533	1.498	1.00	1.0	0.5	1.5	2.3	20.7	0.11
	35010	6013	0.497	4.056	-0.684	1.00	0.5	4.1	-0.7	4.2	20.7	0.20
	36507	6004	-0.262	0.851	-1.166	1.00	-0.3	0.9	-1.2	1.6	20.7	0.08
	36510	6005	-1.178	1.431	-1.476	1.00	-1.2	1.4	-1.5	2.1	20.7	0.10
	38507	6014	0.509	-0.078	-0.324	1.00	0.5	-0.1	-0.3	0.7	20.7	0.03
	38510	6008	0.690	-0.180	-0.395	1.00	0.7	-0.2	-0.4	0.8	20.7	0.04
	45001	6007	1.063	3.765	-1.628	1.00	1.1	3.8	-1.6	4.5	20.7	0.22
	46501	6007	-1.248	1.490	1.639	1.00	-1.2	1.5	1.6	2.3	20.7	0.11
	48501	6007	0.873	-0.280	-0.129	1.00	0.9	-0.3	-0.1	0.9	20.7	0.04
Shear Key	72008	6048	-0.439	0.364	0.927	2.00	-0.2	0.2	0.5	0.5	20.7	0.02
	73017	6044	11.184	-1.145	0.728	2.00	5.6	-0.6	0.4	5.6	20.7	0.27

Note: Compressive forces are positive.

Table 7.2-8 Calculation Results for Maximum Transverse Shear

Location	Element ID	Load ID	Section Forces and Moments(MN/m, MN-m/m)								d (m)	ρw (%)	ρv (%)	Shear Forces (MN/m)				$V_u/\phi V_n$
			N_x	N_y	N_{xy}	M_x	M_y	M_{xy}	Q_x	Q_y				V_u	V_c	V_s	ϕV_n	
Basemat EL 4.65	18	6041	2.219	-0.159	1.009	-4.535	-1.299	0.775	-0.860	-0.511	2.240	0.674	0.242	1.001	1.391	2.244	3.090	0.324
	227	6001	2.094	1.057	1.611	-3.257	1.885	1.399	-2.560	-0.891	2.053	0.859	0.484	2.710	1.172	4.114	4.493	0.603
	237	6041	2.139	1.917	-0.410	-6.049	-2.777	-1.339	-1.807	1.249	2.044	0.862	0.484	2.195	1.275	4.096	4.565	0.481
	16085	6001	1.232	1.094	0.649	-2.368	1.664	0.655	-0.882	0.811	2.039	0.865	0.242	1.199	1.672	2.043	3.158	0.380
Roof of FPE EL 8.25	51556	6041	0.100	0.169	0.114	-0.150	-0.139	-0.014	0.010	0.039	0.453	1.111	0.000	0.040	0.395	0.000	0.336	0.120
	51558	6041	0.089	-1.228	-0.280	-0.105	-0.142	-0.036	0.126	-0.015	0.499	1.008	0.000	0.127	0.455	0.000	0.386	0.329
	51576	6041	1.458	0.085	0.302	-0.134	-0.336	-0.022	-0.012	0.237	0.450	1.118	0.000	0.237	0.427	0.000	0.363	0.653
	51578	6041	0.395	-0.520	0.203	-0.091	-0.213	-0.068	-0.045	0.112	0.457	1.102	0.000	0.121	0.667	0.000	0.567	0.213
Roof of Tank	26007	6541	0.256	0.202	0.022	-0.046	-0.041	-0.001	-0.003	-0.003	0.475	0.679	0.000	0.005	0.407	0.000	0.346	0.014
	26079	6041	0.524	-0.359	0.117	-0.074	-0.158	0.012	-0.013	0.108	0.451	0.716	0.000	0.109	0.458	0.000	0.389	0.279
	26082	6041	0.229	0.361	0.422	-0.161	-0.136	0.053	-0.085	0.080	0.476	0.678	0.000	0.117	0.459	0.000	0.390	0.299
	26085	6041	0.176	0.466	-0.421	-0.160	-0.094	-0.047	-0.101	-0.061	0.486	0.664	0.000	0.118	0.471	0.000	0.400	0.294
South Wall of FPE	66004	4014	0.755	-0.196	0.044	-0.051	-0.286	0.003	0.002	-0.215	0.422	2.387	0.000	0.215	0.459	0.000	0.390	0.551
	66006	6041	1.259	1.136	-0.929	-0.102	-0.425	-0.030	-0.146	-0.714	0.436	2.872	0.710	0.730	0.278	1.282	1.325	0.551
	66024	4011	-0.425	-0.112	0.008	-0.147	-0.167	0.004	0.014	-0.192	0.443	1.701	0.000	0.192	0.491	0.000	0.418	0.460
East Wall of FPE	67004	6021	-2.108	-0.815	-0.544	-0.196	-0.274	0.005	-0.007	-0.230	0.485	1.037	0.000	0.230	0.647	0.000	0.550	0.418
	67006	6041	1.313	-0.304	-2.136	0.143	0.319	0.013	0.050	-0.217	0.436	2.864	0.710	0.223	0.290	1.282	1.335	0.167
	67024	6001	1.597	-0.472	-0.436	0.058	0.289	-0.007	0.005	-0.247	0.443	1.702	0.000	0.247	0.496	0.000	0.421	0.587
Wall of South Tank	35007	6021	-2.345	1.696	0.789	0.013	-0.372	-0.036	0.046	0.540	0.735	2.285	0.631	0.542	0.343	1.920	1.923	0.282
	35010	6541	-0.281	1.896	1.582	-0.171	0.297	-0.031	-0.017	-0.449	0.698	1.919	0.631	0.450	0.283	1.823	1.791	0.251
	36507	6021	1.572	-0.857	1.038	-0.095	0.127	0.009	-0.036	-0.105	0.764	0.878	0.000	0.112	0.740	0.000	0.629	0.177
	36510	4011	0.309	-0.312	-0.144	-0.586	-0.539	-0.009	0.009	0.084	0.772	1.735	0.000	0.084	0.753	0.000	0.640	0.132
	38507	6041	1.048	-0.384	0.236	-0.311	-0.230	0.020	0.004	-0.136	0.835	0.804	0.000	0.136	0.950	0.000	0.808	0.169
	38510	4011	0.200	-0.097	-0.022	-0.382	-0.218	-0.013	-0.001	-0.228	0.835	0.804	0.000	0.228	0.896	0.000	0.762	0.299
	45001	6541	-0.106	3.271	1.518	-0.103	0.361	0.003	0.027	-0.551	0.698	1.918	0.631	0.551	0.066	1.823	1.606	0.343
	46501	6541	-0.925	1.471	-1.379	-0.410	-0.276	-0.020	0.011	-0.039	0.775	1.730	0.000	0.040	0.316	0.000	0.269	0.150
	48501	6041	1.201	-0.433	0.352	-0.321	-0.215	0.021	0.005	-0.147	0.835	0.804	0.000	0.147	1.161	0.000	0.987	0.149
Shear Key	72008	6021	1.037	0.658	0.510	-0.148	-1.837	-0.260	-0.333	1.546	1.738	0.711	0.484	1.582	1.415	3.483	4.163	0.380
	73017	6001	-4.690	1.475	-2.535	0.204	1.501	0.250	0.033	-1.131	1.735	0.725	0.484	1.131	1.159	3.477	3.940	0.287

Table 7.2-9 Calculation Results for Transverse Shear by Selected Load Combination

Location	Element ID	Load ID	d (m)	ρ_w (%)	ρ_v (%)	Shear Forces (MN/m)				$V_u/\phi V_n$
						V_u	V_c	V_s	ϕV_n	
Basemat EL 4.65	18	FWSC-6	2.240	0.674	0.242	1.001	1.391	2.244	3.090	0.324
	227	FWSC-6	2.052	0.859	0.484	2.557	2.918	4.112	5.975	0.428
	237	FWSC-6	2.044	0.862	0.484	2.195	1.275	4.096	4.565	0.481
	16085	FWSC-6	2.048	0.861	0.242	1.729	4.102	2.052	5.231	0.330
Roof of FPE EL 8.25	51556	FWSC-6	0.453	1.111	0.000	0.040	0.395	0.000	0.336	0.120
	51558	FWSC-6	0.499	1.008	0.000	0.127	0.455	0.000	0.386	0.329
	51576	FWSC-6	0.450	1.118	0.000	0.237	0.427	0.000	0.363	0.653
	51578	FWSC-6	0.457	1.102	0.000	0.121	0.667	0.000	0.567	0.213
Roof of Tank	26007	FWSC-6	0.475	0.679	0.000	0.005	0.407	0.000	0.346	0.014
	26079	FWSC-6	0.451	0.716	0.000	0.109	0.458	0.000	0.389	0.279
	26082	FWSC-6	0.476	0.678	0.000	0.117	0.459	0.000	0.390	0.299
	26085	FWSC-6	0.486	0.664	0.000	0.118	0.471	0.000	0.400	0.294
South Wall of FPE	66004	FWSC-4	0.422	2.387	0.000	0.197	0.454	0.000	0.386	0.512
	66006	FWSC-6	0.436	2.872	0.710	0.730	0.278	1.282	1.325	0.551
	66024	FWSC-4	0.443	1.701	0.000	0.192	0.491	0.000	0.418	0.460
East Wall of FPE	67004	FWSC-6	0.423	2.382	0.000	0.216	0.961	0.000	0.817	0.264
	67006	FWSC-6	0.436	2.864	0.710	0.223	0.290	1.282	1.335	0.167
	67024	FWSC-6	0.443	1.702	0.000	0.210	0.461	0.000	0.392	0.537
Wall of South Tank	35007	FWSC-6	0.735	2.286	0.631	0.248	0.528	1.920	2.081	0.119
	35010	FWSC-6	0.698	1.919	0.631	0.450	0.283	1.823	1.791	0.251
	36507	FWSC-6	0.782	1.713	0.000	0.053	0.538	0.000	0.457	0.116
	36510	FWSC-4	0.772	1.735	0.000	0.084	0.753	0.000	0.640	0.132
	38507	FWSC-6	0.835	0.804	0.000	0.136	0.950	0.000	0.808	0.169
	38510	FWSC-4	0.835	0.804	0.000	0.228	0.896	0.000	0.762	0.299
	45001	FWSC-6	0.698	1.918	0.631	0.551	0.066	1.823	1.606	0.343
	46501	FWSC-6	0.775	1.730	0.000	0.040	0.316	0.000	0.269	0.150
	48501	FWSC-6	0.835	0.804	0.000	0.147	1.161	0.000	0.987	0.149
Shear Key	72008	FWSC-6	1.738	0.710	0.484	1.488	1.768	3.483	4.463	0.333
	73017	FWSC-6	1.735	0.725	0.484	1.112	1.279	3.477	4.042	0.275

Note: Load Combination ID of FWSC-6 in Table 6.3-5 = 6041 or 6541, whichever is greater.

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Figure 3.3-1 Concrete Outline Plan at EL 4.65m

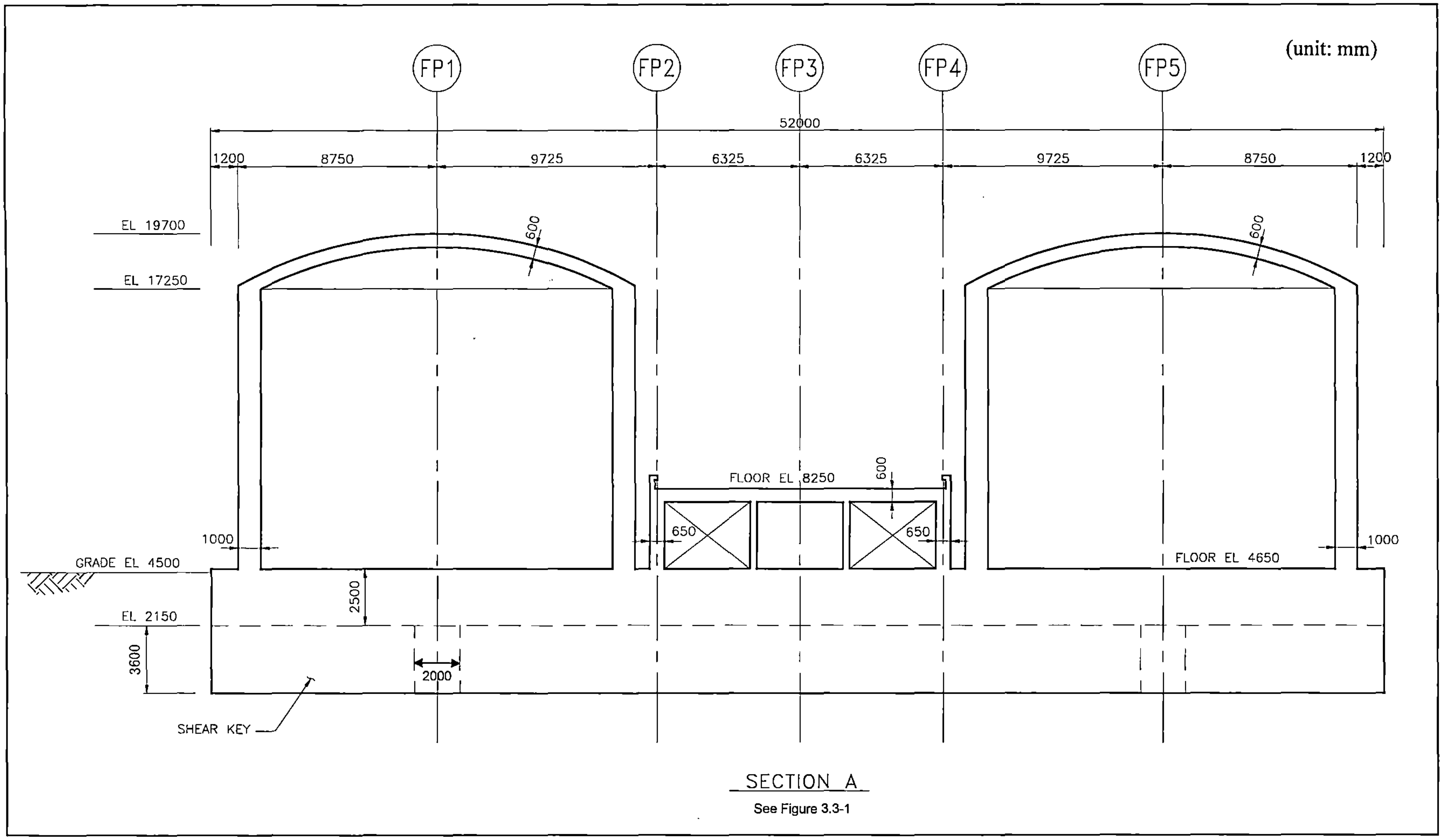


Figure 3.3-2 Concrete Outline N-S Section

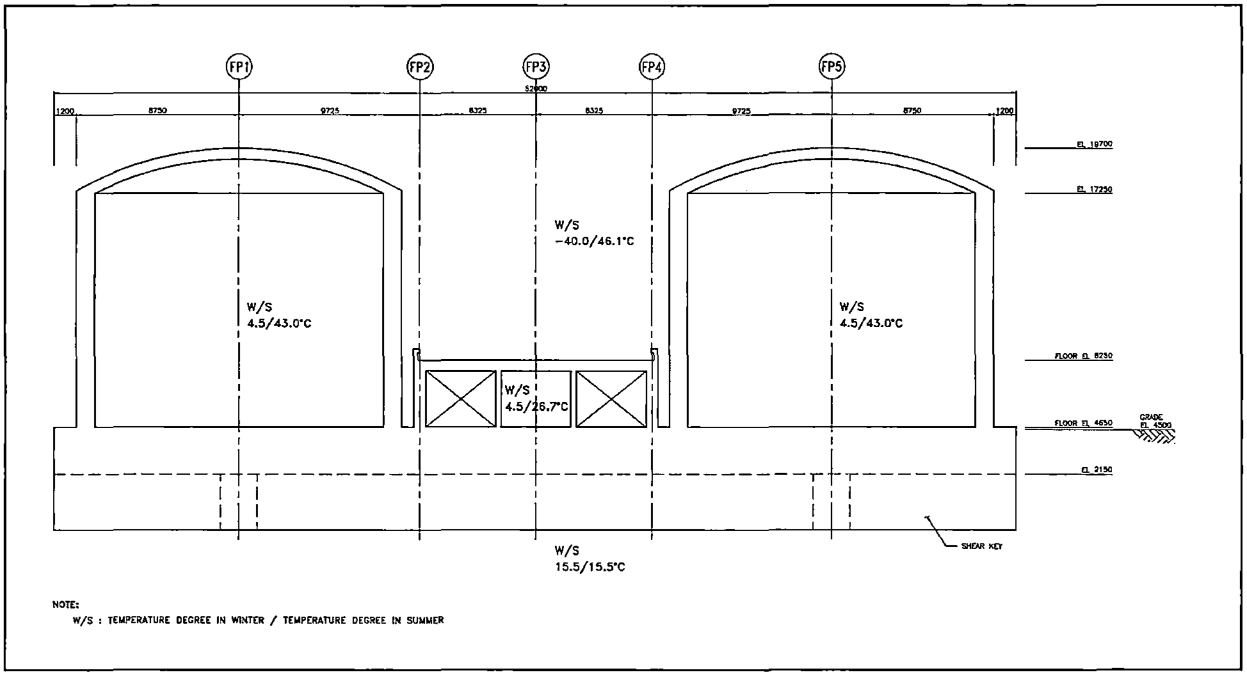
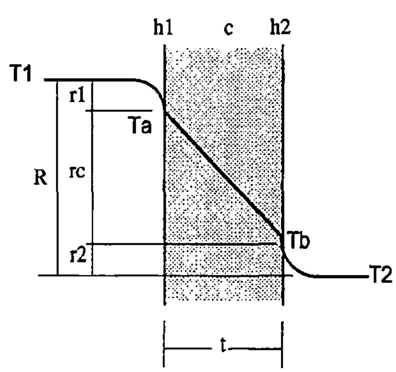


Figure 5.3-1 Normal Operation Temperatures

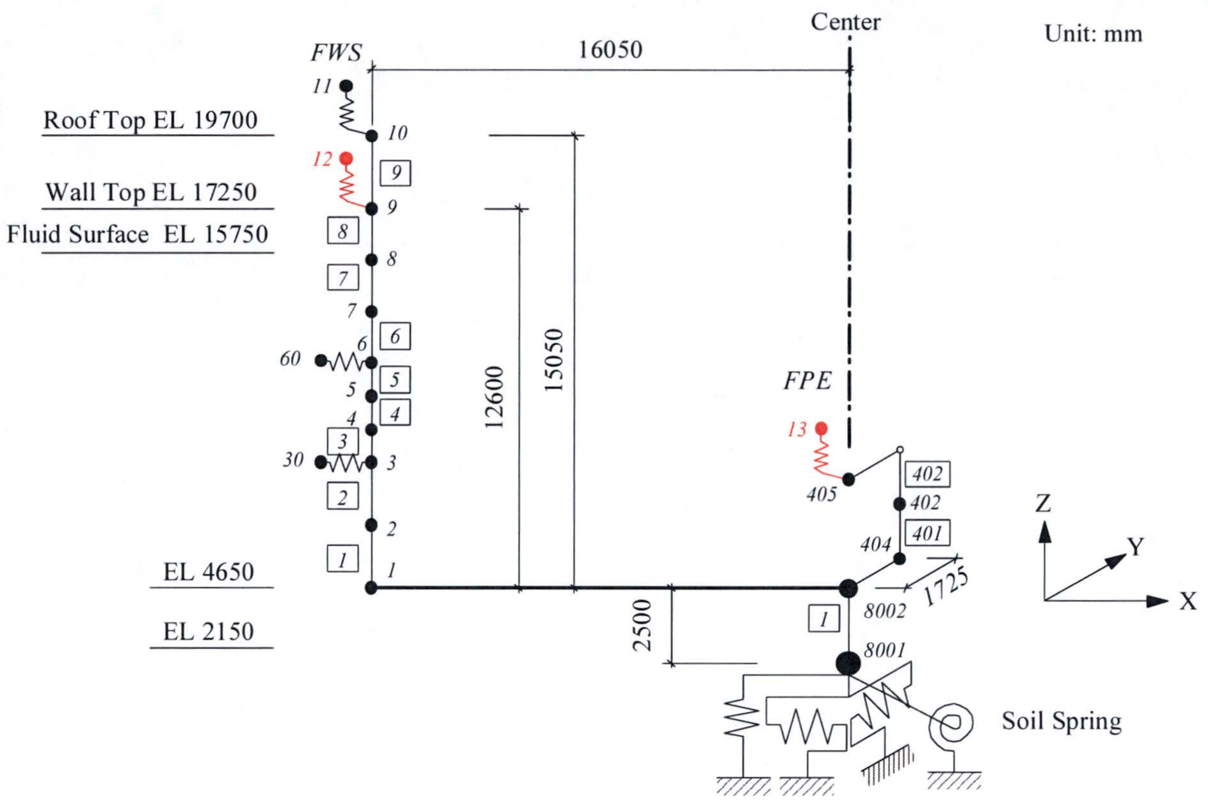


c = thermal conductivity of concrete
1.4 (kcal/m h °C)
h1, h2 = thin film coefficient (kcal/m2 h °C)

r1, r2, rc = resistance of heat conduction
r1, r2 = 1/h1, 1/h2 (m2 h °C/kcal)
rc = t/c (m2 h °C/kcal)
R = total thermal resistance = r1 + r2 + rc

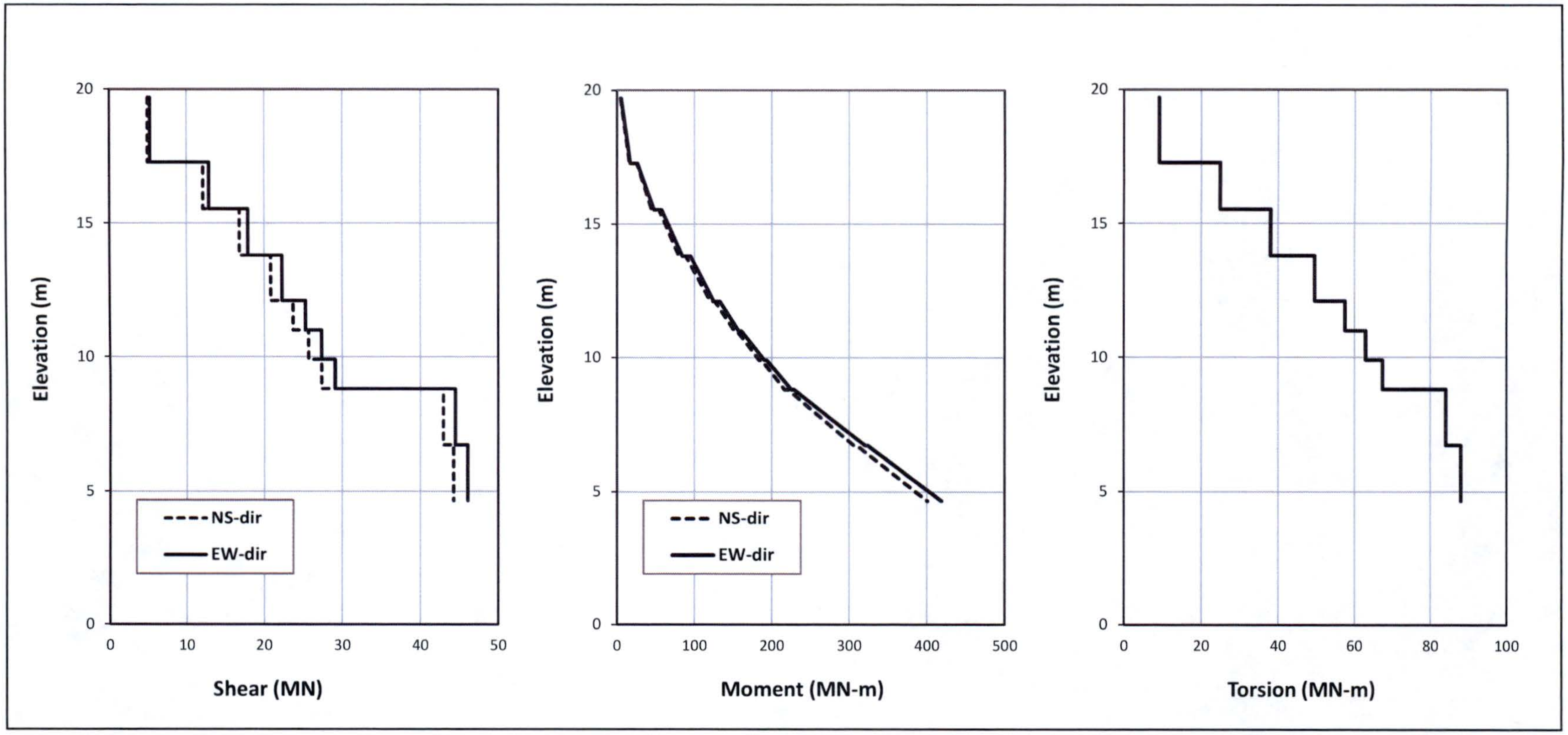
Ta = T1 - (T1-T2) r1/ R
Tb = T1 - (T1-T2) (r1+rc)/ R
Td = (Ta+Tb) / 2
Tg = Ta-Tb

Figure 5.3-2 Heat Transfer Analysis



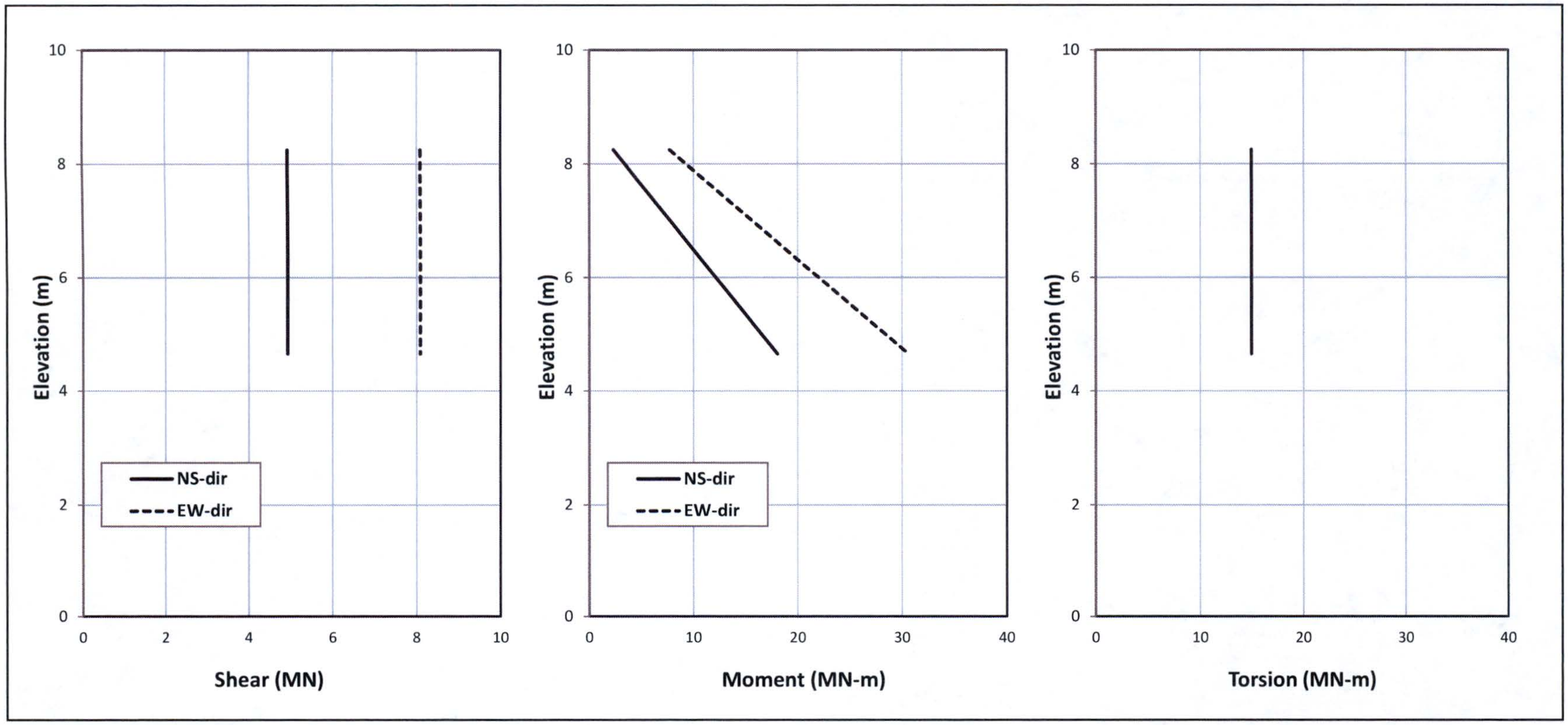
Note : Oscillators in red are only added in Cracked model.
Mass at Node 30 represents the impulsive mode.
Mass at Node 60 represents the fundamental sloshing (convective) mode.
The model is assumed to be symmetric about YZ-plane including the center line.

Figure 5.6-1 Dynamic Analysis Model



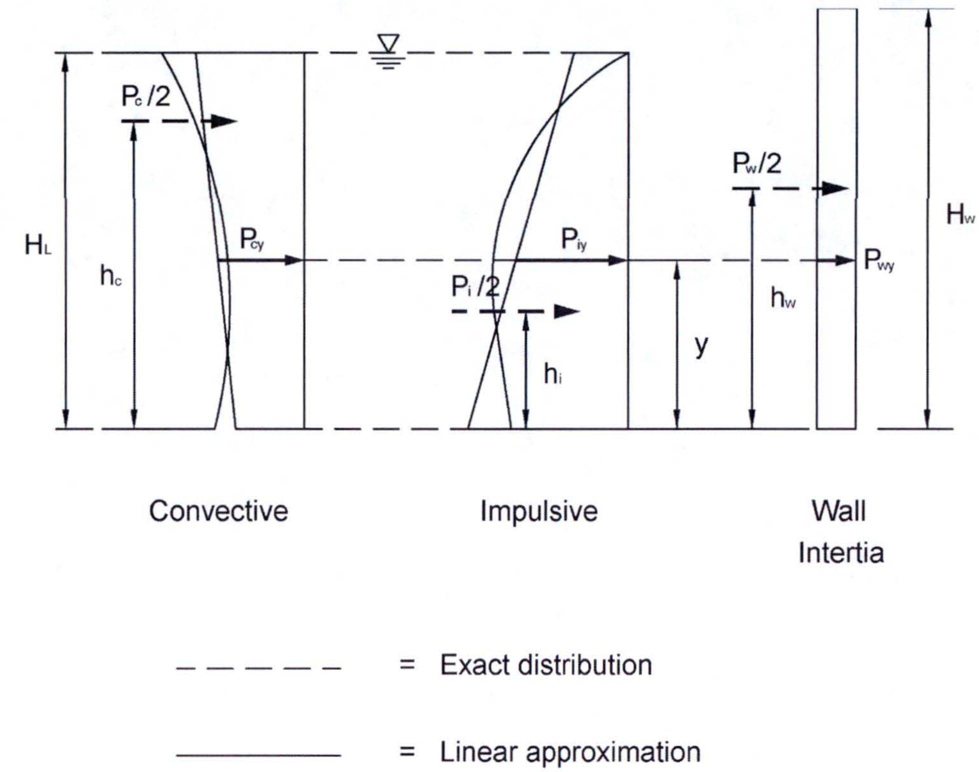
Note: Obtained from Reference 2.1.2-l, based on site-specific Seismic Analysis of Fire Water Service Complex in References 2.1.2-k, 2.1.2-m and 2.1.2-n.

Figure 5.6-2 Design Seismic Shear and Moments for FWSC (FWS)



Note: Obtained from Reference 2.1.2-l, based on site-specific Seismic Analysis of Fire Water Service Complex in References 2.1.2-k, 2.1.2-m and 2.1.2-n.

Figure 5.6-3 Design Seismic Shear and Moments for FWSC (FPE)



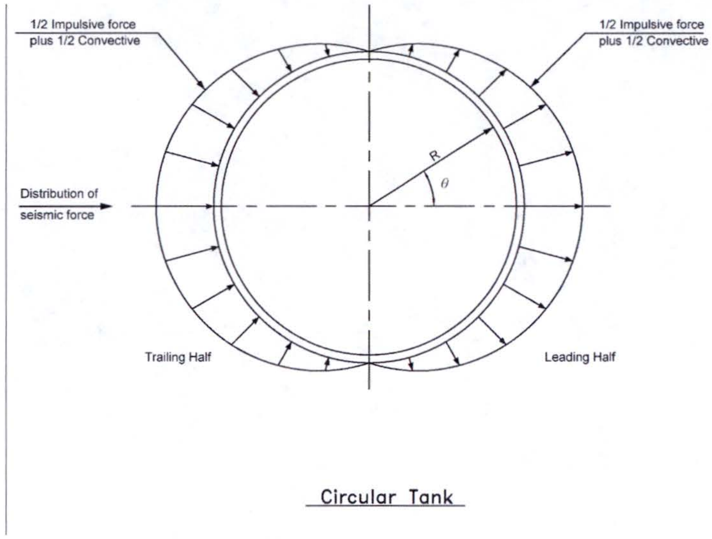
$$P_{wy} = \frac{P_w}{2H_w} \text{(for constant-thickness wall. For tapered wall, modify accordingly)}$$

$$P_{iy} = \frac{\frac{P_i}{2}\left[4H_L - 6h_i - (6H_L - 12h_i) \times \left(\frac{y}{H_L}\right)\right]}{H_L^2}$$

$$P_{cy} = \frac{\frac{P_c}{2}\left[4H_L - 6h_c - (6H_L - 12h_c) \times \left(\frac{y}{H_L}\right)\right]}{H_L^2}$$

Note: This figure is referred to Figure R5.5 in Reference 2.2-d.

Figure 5.6-4 Vertical Distribution of Hydrodynamic Pressure in Tank



$$p_{cy} = \frac{16P_{cy}}{9\pi R} \times \cos\theta$$

$$p_{iy} = \frac{2P_{iy}}{\pi R} \times \cos\theta$$

where,

P_{cy} : convective pressure (MN/m)
P_{iy} : impulsive pressure (MN/m)
R : inside radius of circular tank (m)
θ : polar coordinate angle

Note: This figure is referred to Figure R5.2 in Reference 2.2-d.

Figure 5.6-5 Hydrodynamic Pressure Distribution in Tank

Water Depth	H_L	11.10	m
Tank Diameter	D	15.50	m
Wall Thickness	t_w	1.00	m
Concrete Young's Modulus	E_c	2.78E+7	kN/m^2
Water Density	γ_L	9.807	kN/m^3
Acceleration Gravity	g	9.807	m/s^2

- per ACI 350.3 (Eq. 4-17)

$$T_v = 2\pi\sqrt{\frac{\gamma_L D H_L^2}{24 g t_w E_c}} \qquad (4\text{-}17)$$

$$[T_v = 2\pi\sqrt{\frac{\gamma_L D H_L^2}{2 g t_w E_c}} \text{ in SI system}]$$

T_v :0.0368sec

f_v :27.2Hz

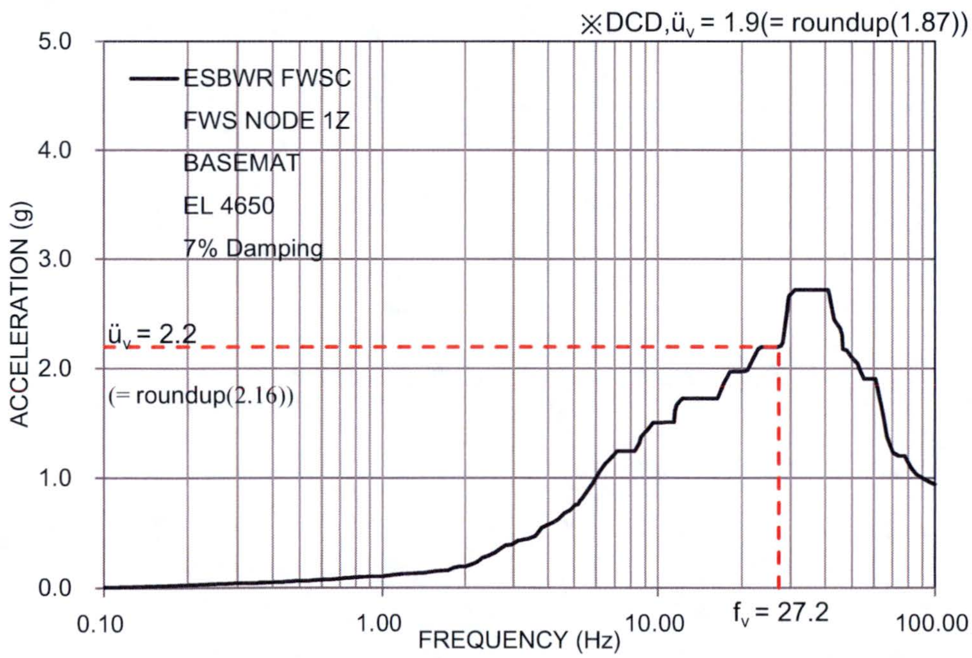


Figure 5.6-6 Effective Spectral Acceleration

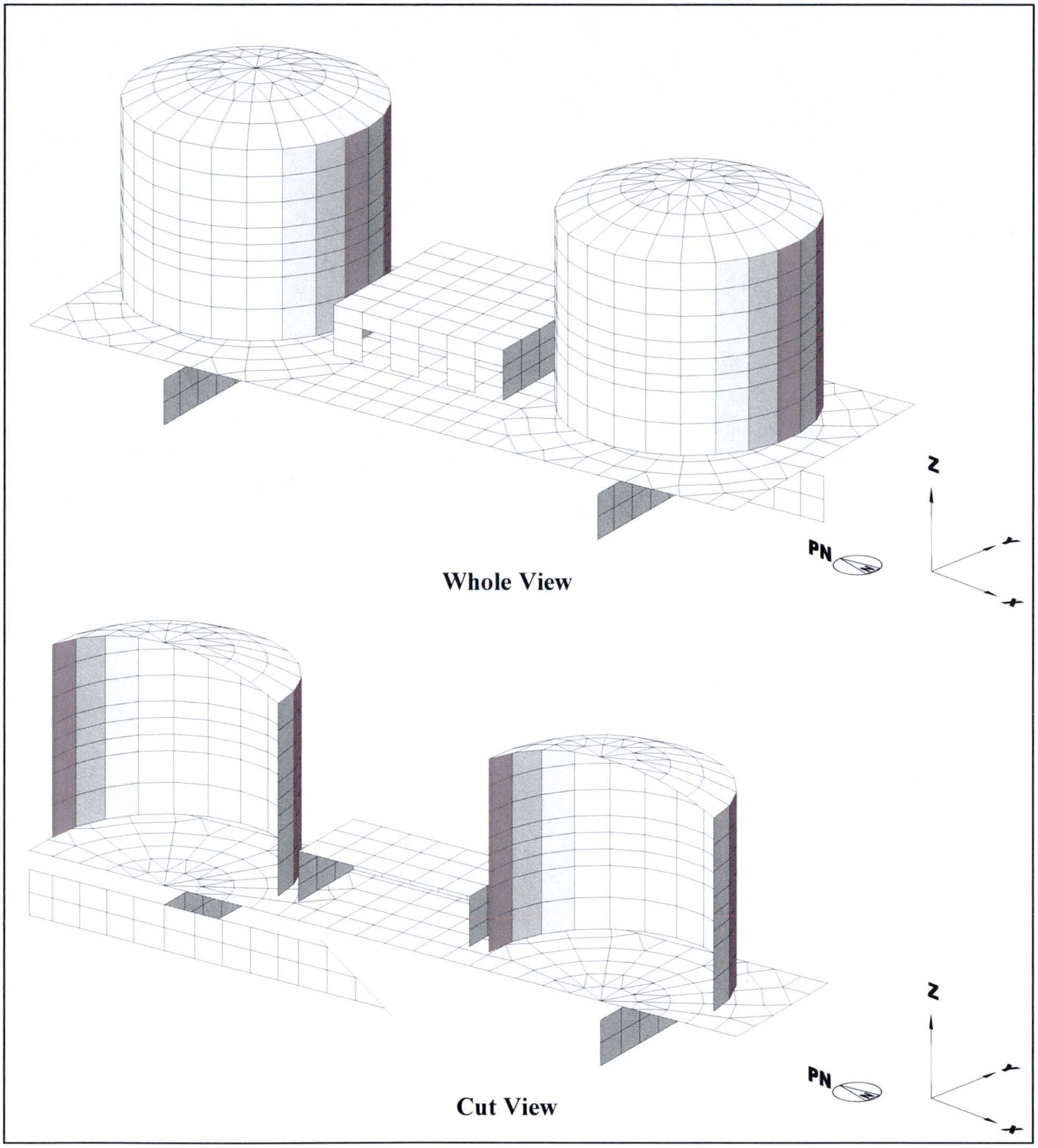
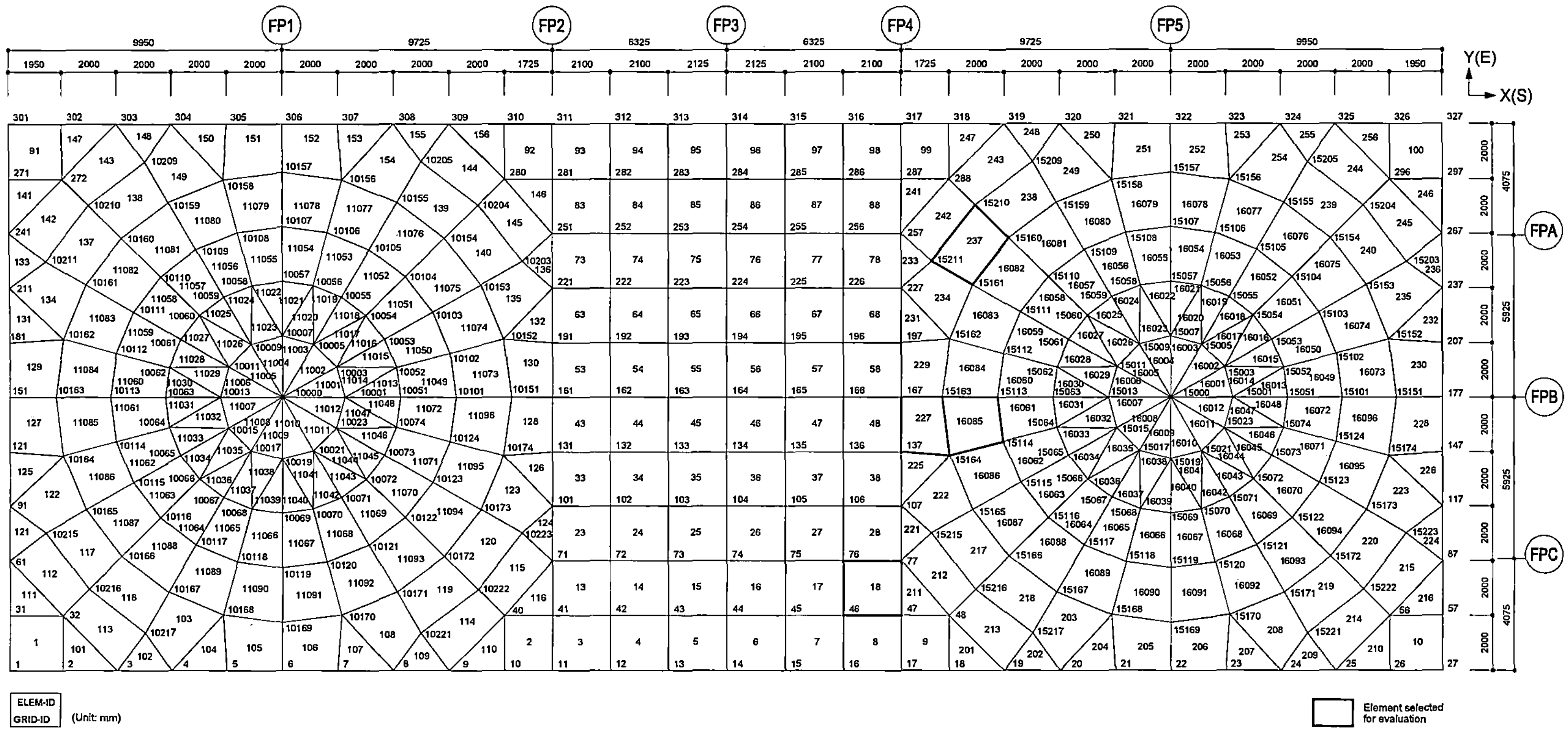


Figure 6.2-1 FE Model (Isometric View)



Note: The effect of the shear key height change from 3000mm to 3600mm is evaluated in Appendix D.

Figure 6.2-2 FE Model, Basemat EL 4.65m

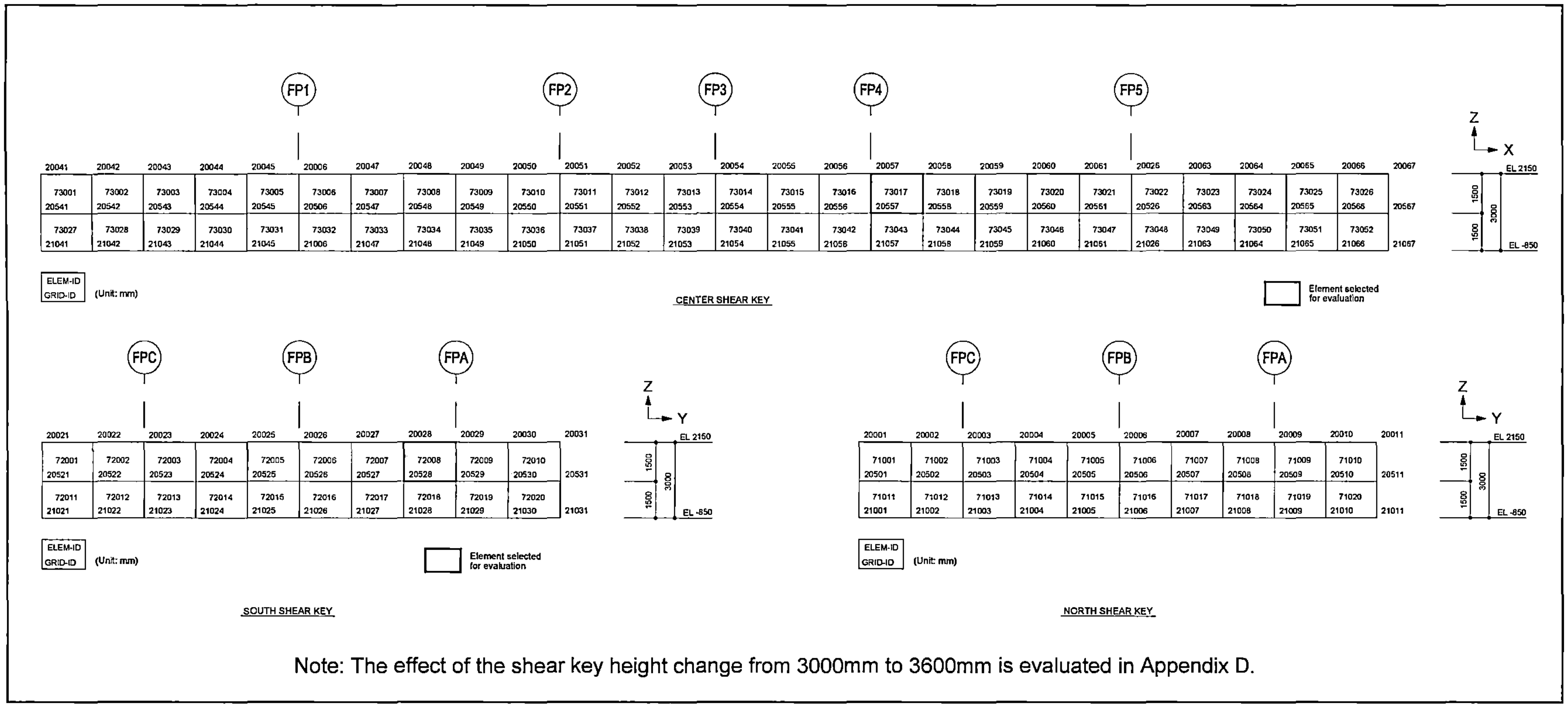


Figure 6.2-3 FE Model, Center Shear Key and North / South Shear Key of Basemat

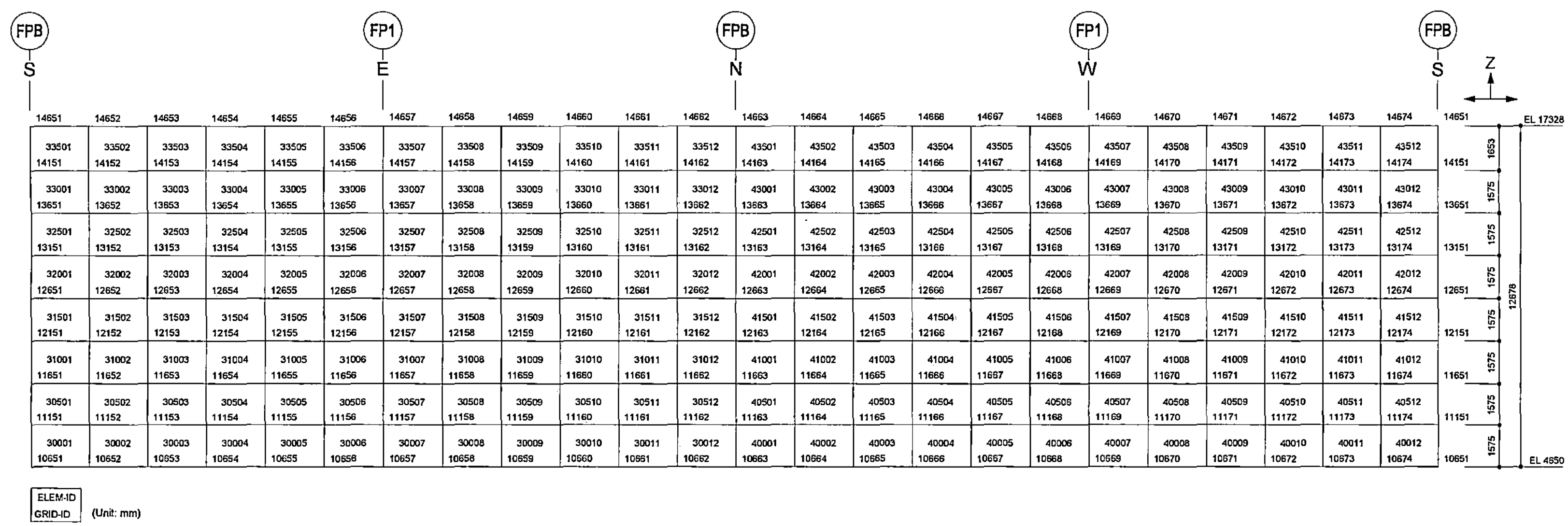


Figure 6.2-4 FE Model, FWS North Tank Wall

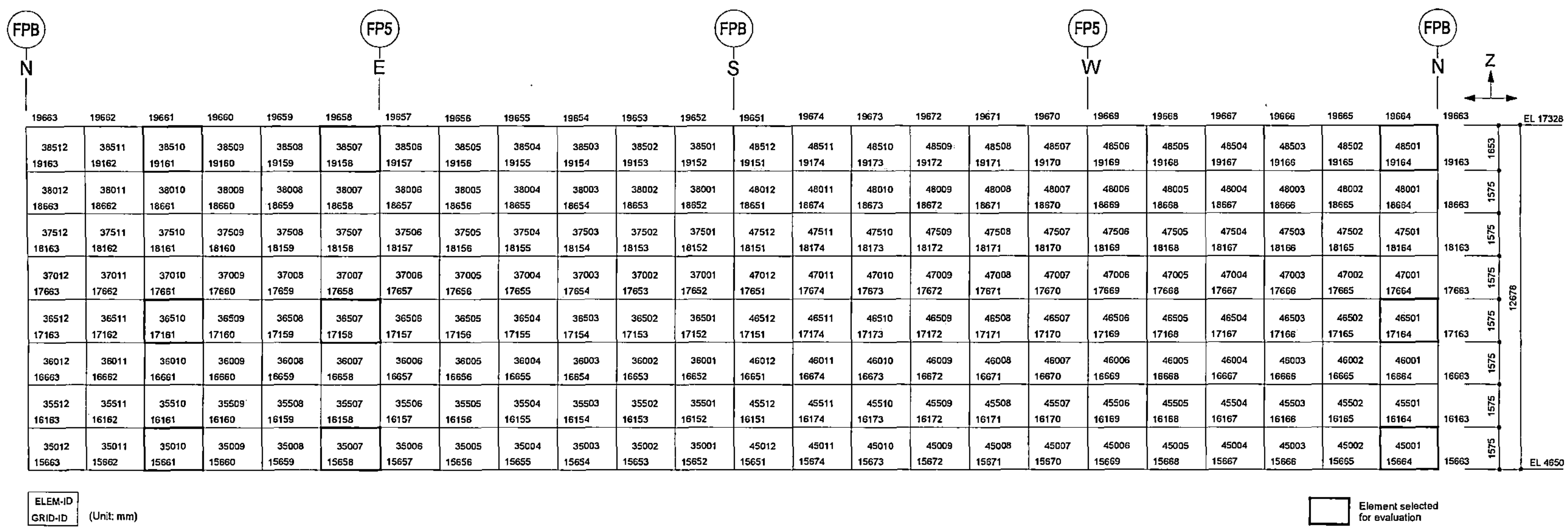


Figure 6.2-5 FE Model, FWS South Tank Wall

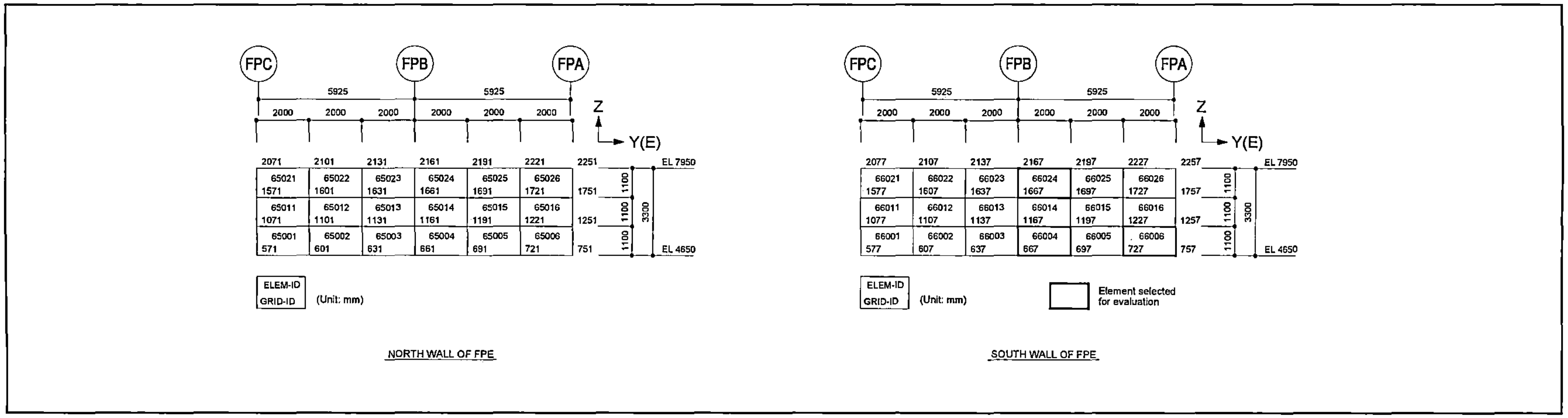


Figure 6.2-6 FE Model, FPE North and South Walls

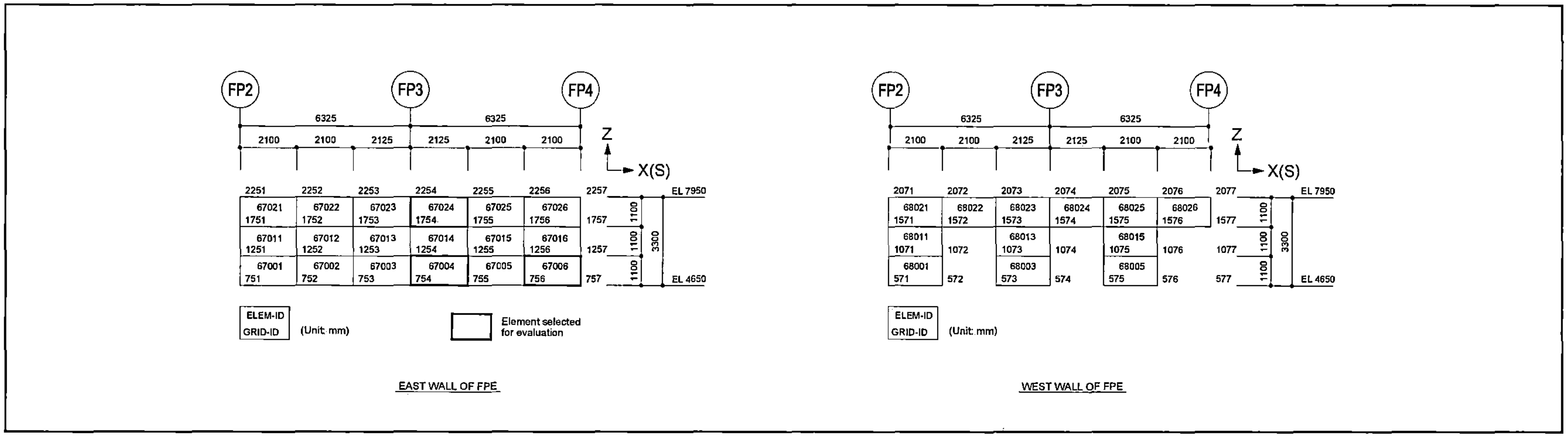


Figure 6.2-7 FE Model, FPE East and West Walls

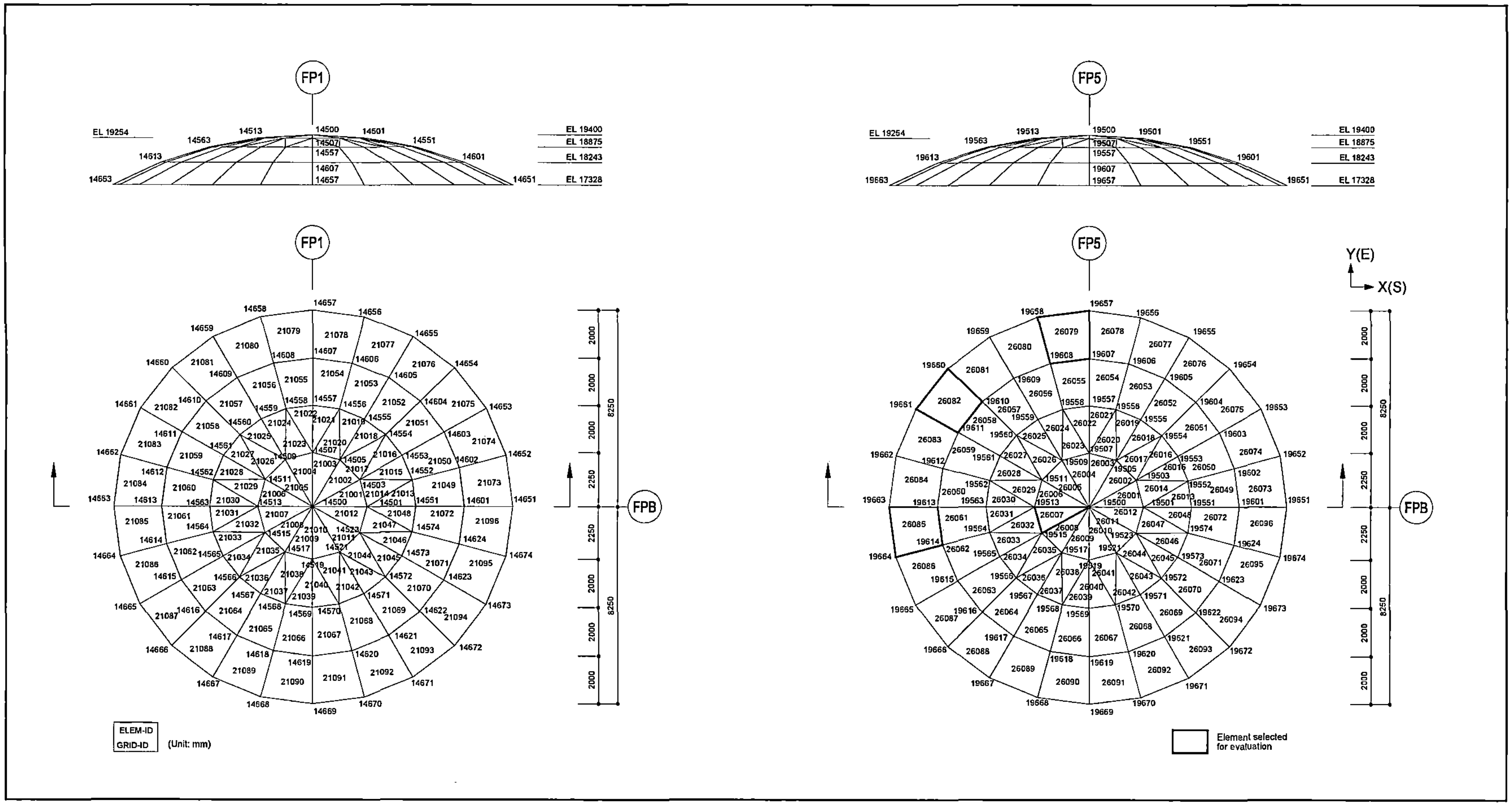


Figure 6.2-8 FE Model, FWS Roofs

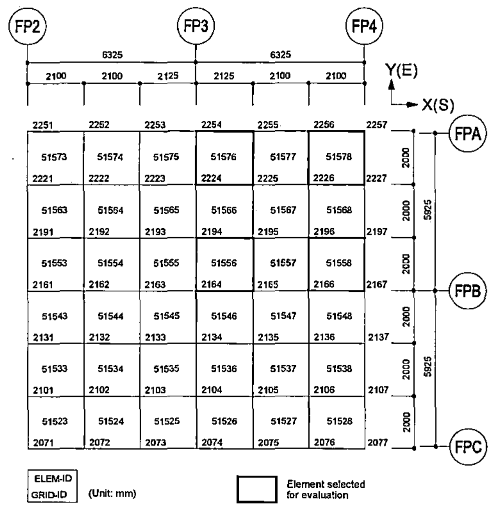


Figure 6.2-9 FE Model, FPE Roof

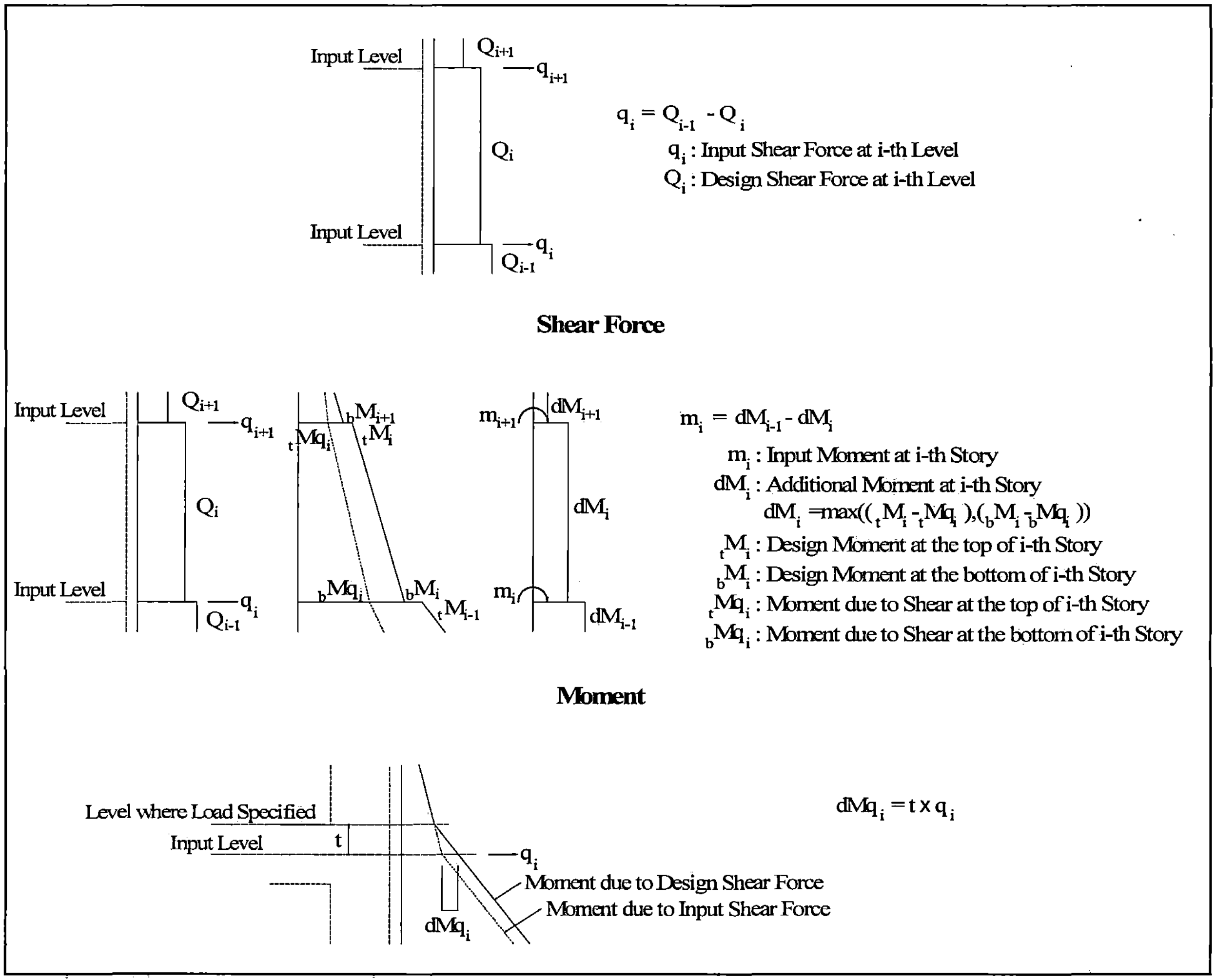
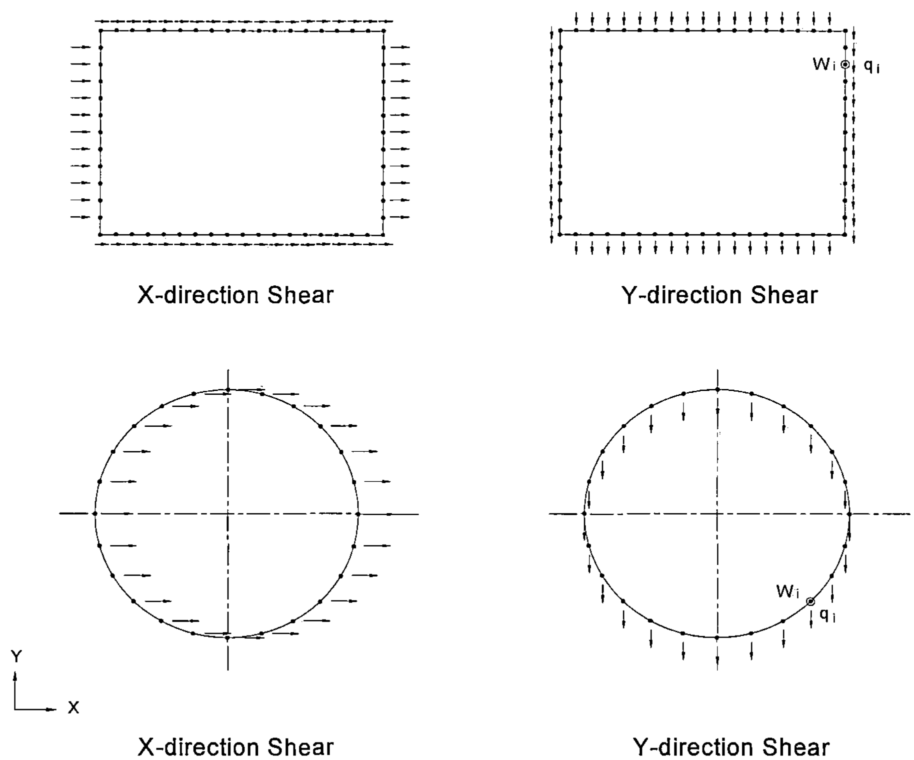


Figure 6.2-10 Calculation Method for Shear Forces and Overturning Moments



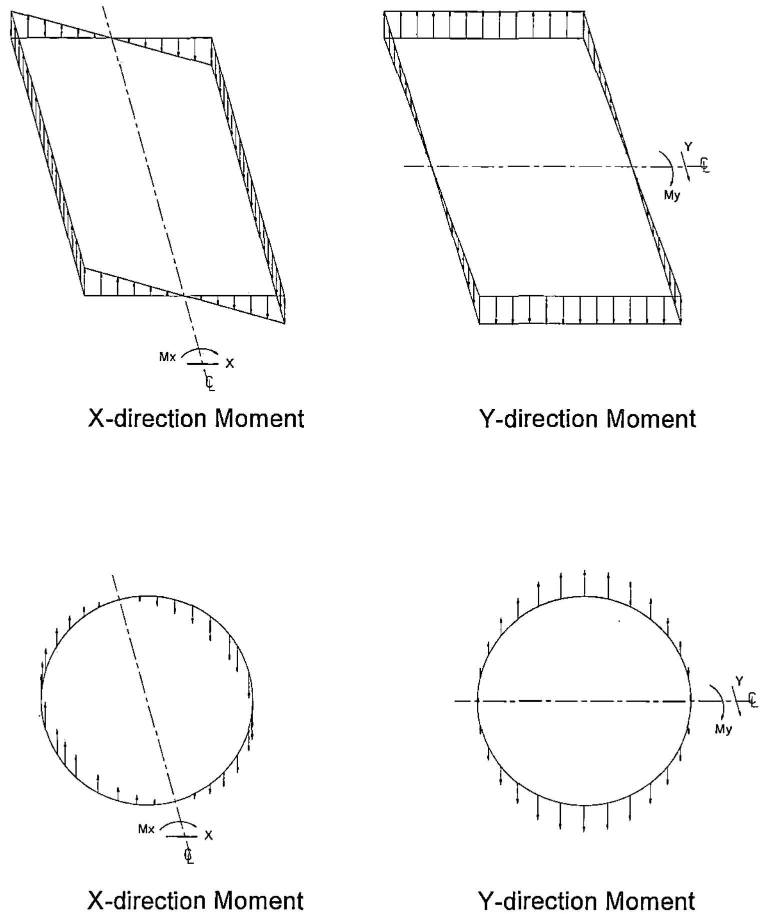
Note: Shear force applied to each grid point q_i is calculated as follows:

$$q_i = q\frac{w_i}{\sum w_i}$$

where, q : Input shear force

w_i : Weight of each grid point

Figure 6.2-11 Method of Applying Shear Forces



Note: Vertical nodal force applied to each grid point due to overturning moment F_i is calculated as follows:

$$F_i = M_X \frac{X_i}{I_X} A_i \quad \text{(for X-direction)} \qquad F_i = M_Y \frac{Y_i}{I_Y} A_i \quad \text{(for Y-direction)}$$

where,

Mx, *My*:	Overturning moment
Ix, *Iy*:	Moment inertia of total walls around Y-axis and X-axis respectively
Xi, *Yi*:	Distance from the center line to each wall
Ai:	Tributary wall area at the Grid Point

Figure 6.2-12 Method of Applying Overturning Moments

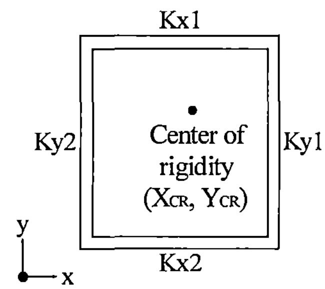
Calculation of Wall Stiffness K

$$K = \frac{12EI}{h^3(1+\phi)}, \quad \phi = \frac{12EI}{AGh^2}$$

where : A = shear area, E = Young's modulus
I = moment inertia, G = shear modulus
h = height

Calculation of Center of Rigidity X_{CR}, Y_{CR}

$$X_{CR} = \frac{\Sigma(K_{yi} X_i)}{\Sigma K_{yi}}, \quad Y_{CR} = \frac{\Sigma(K_{xi} Y_i)}{\Sigma K_{xi}}$$



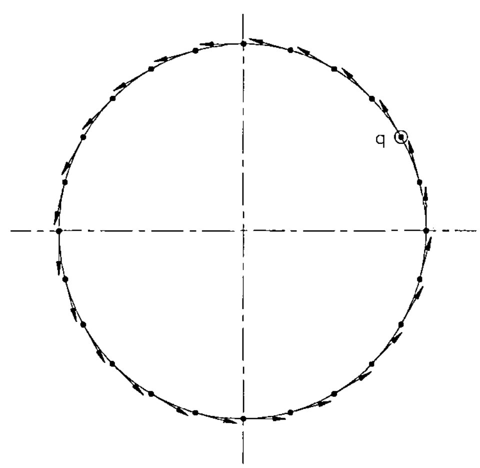
Calculation of Torsional Stiffness of Boxwalls Kt

$$K_t = \Sigma(K_{xi}(Y_i - Y_{CR})^2) + \Sigma(K_{yi}(X_i - X_{CR})^2)$$

Calculation of Shear Force

$$Q_{xi} = \frac{M_t}{K_t} K_{xi}(Y_i - Y_{CR}), \quad Q_{yi} = \frac{M_t}{K_t} K_{yi}(X_i - X_{CR})$$

For FPE



Shear force applied to each grid point $q = dM_t/(R*N)$
Where, R = Center radius of tank
N = Total number of grid points at a given elevation

For FWS

Figure 6.2-13 Method of Calculation Shear Forces due to Torsion

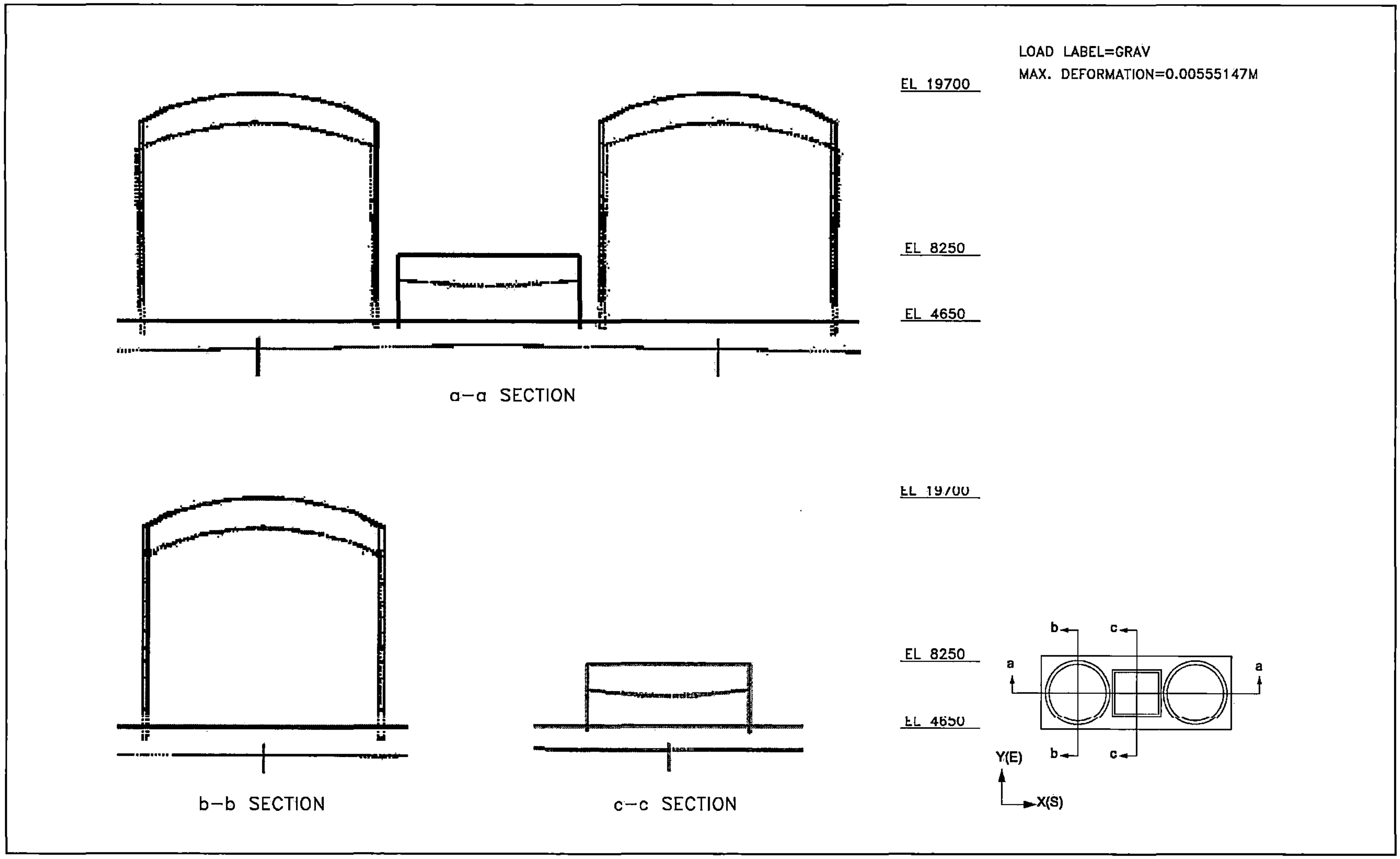


Figure 6.2-14 Deformation due to Structure Load, GRAV

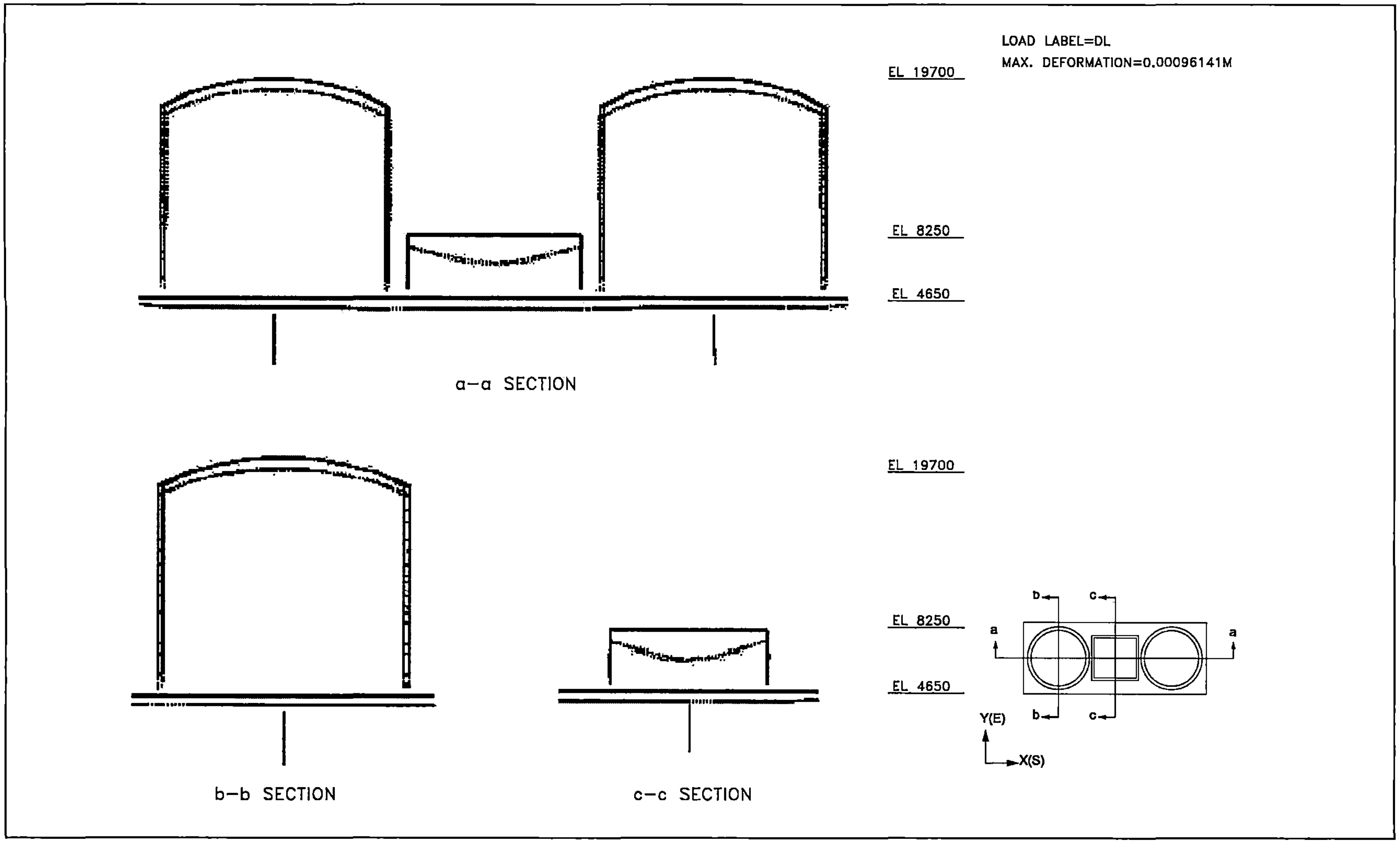


Figure 6.2-15 Deformation due to Structure Load, DL

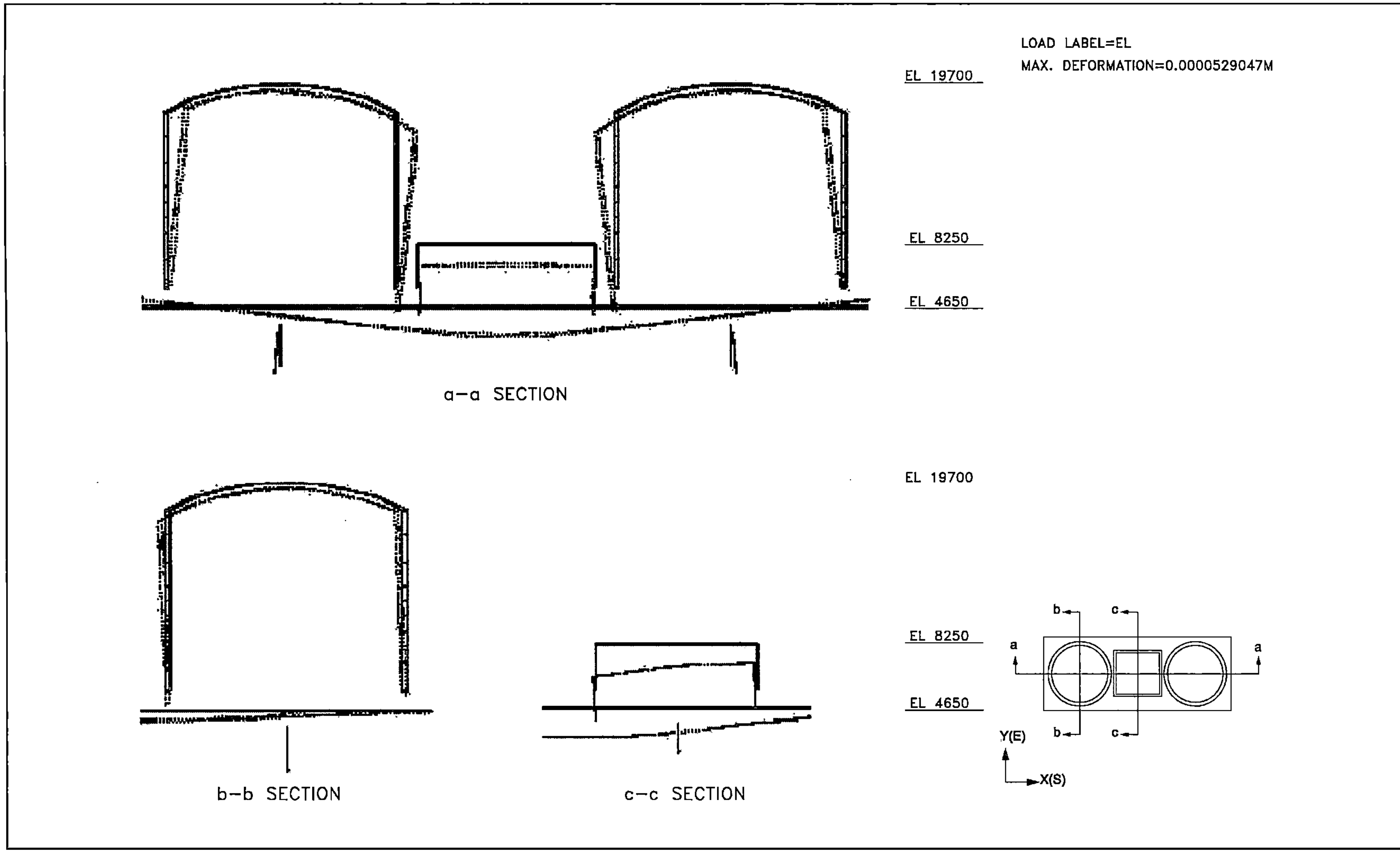


Figure 6.2-16 Deformation due to Structure Load, EL

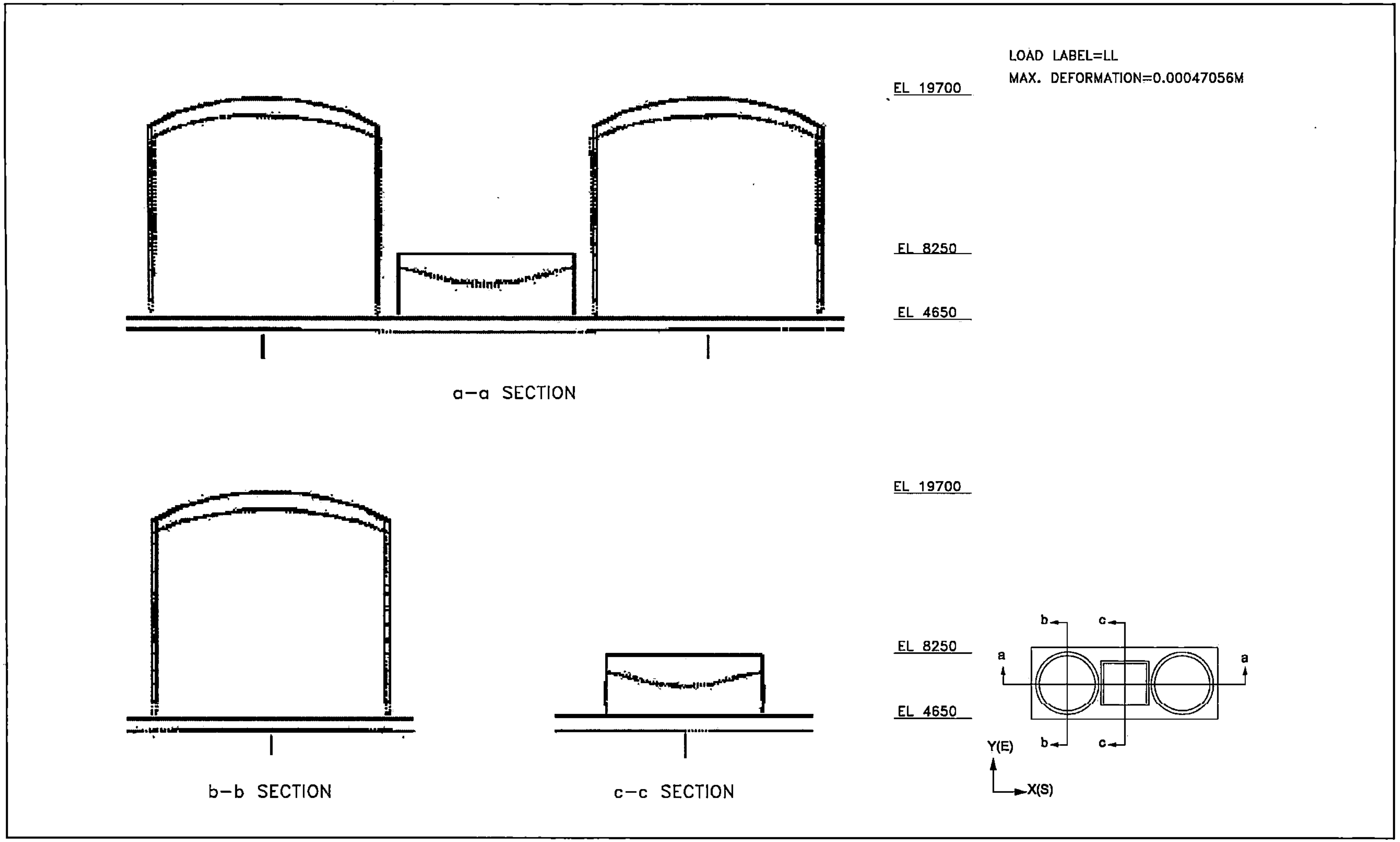


Figure 6.2-17 Deformation due to Structure Load, LL

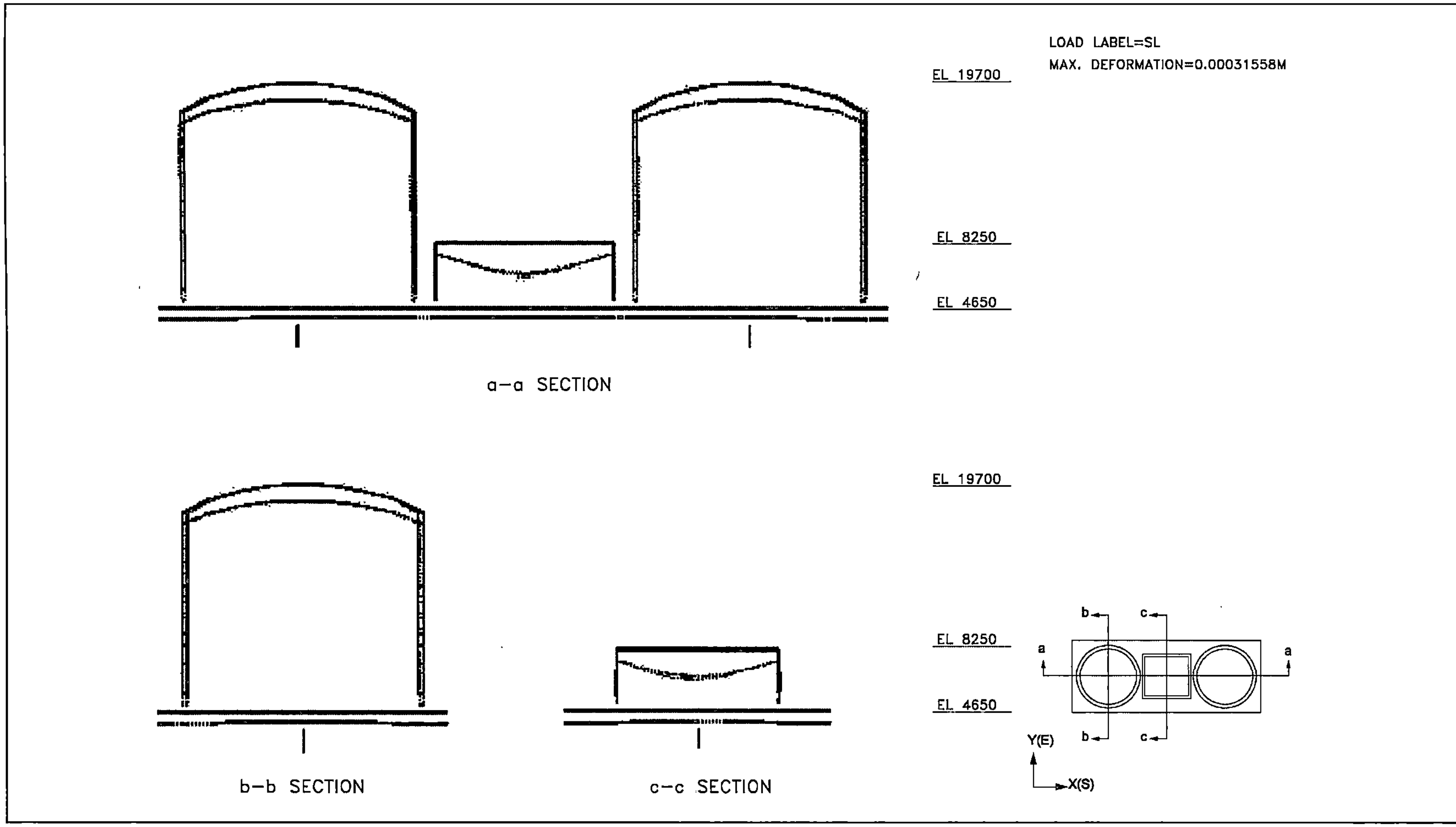


Figure 6.2-18 Deformation due to Structure Load, SL

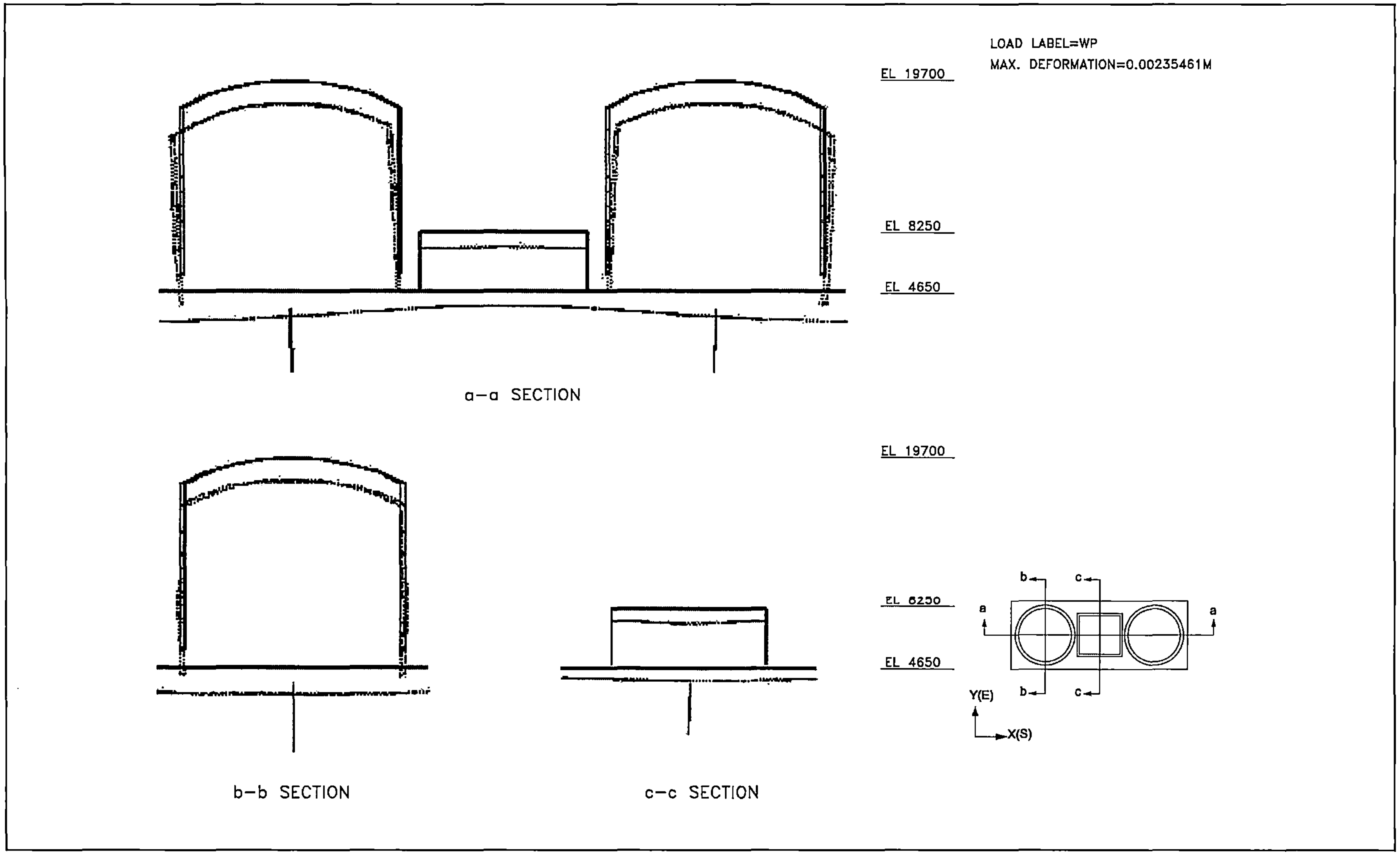


Figure 6.2-19 Deformation due to Structure Load, WP

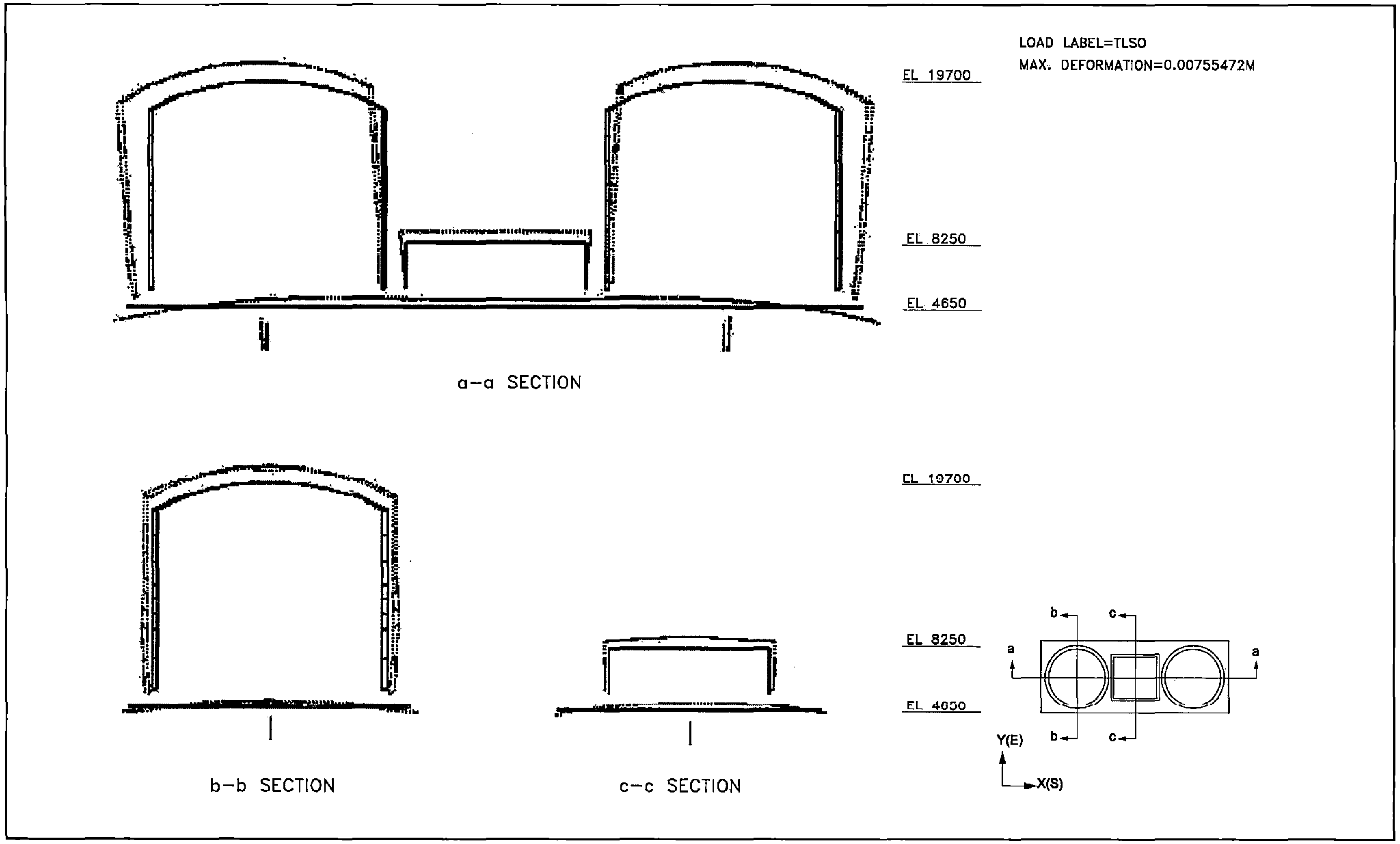


Figure 6.2-20 Deformation due to Structure Load, TLS0

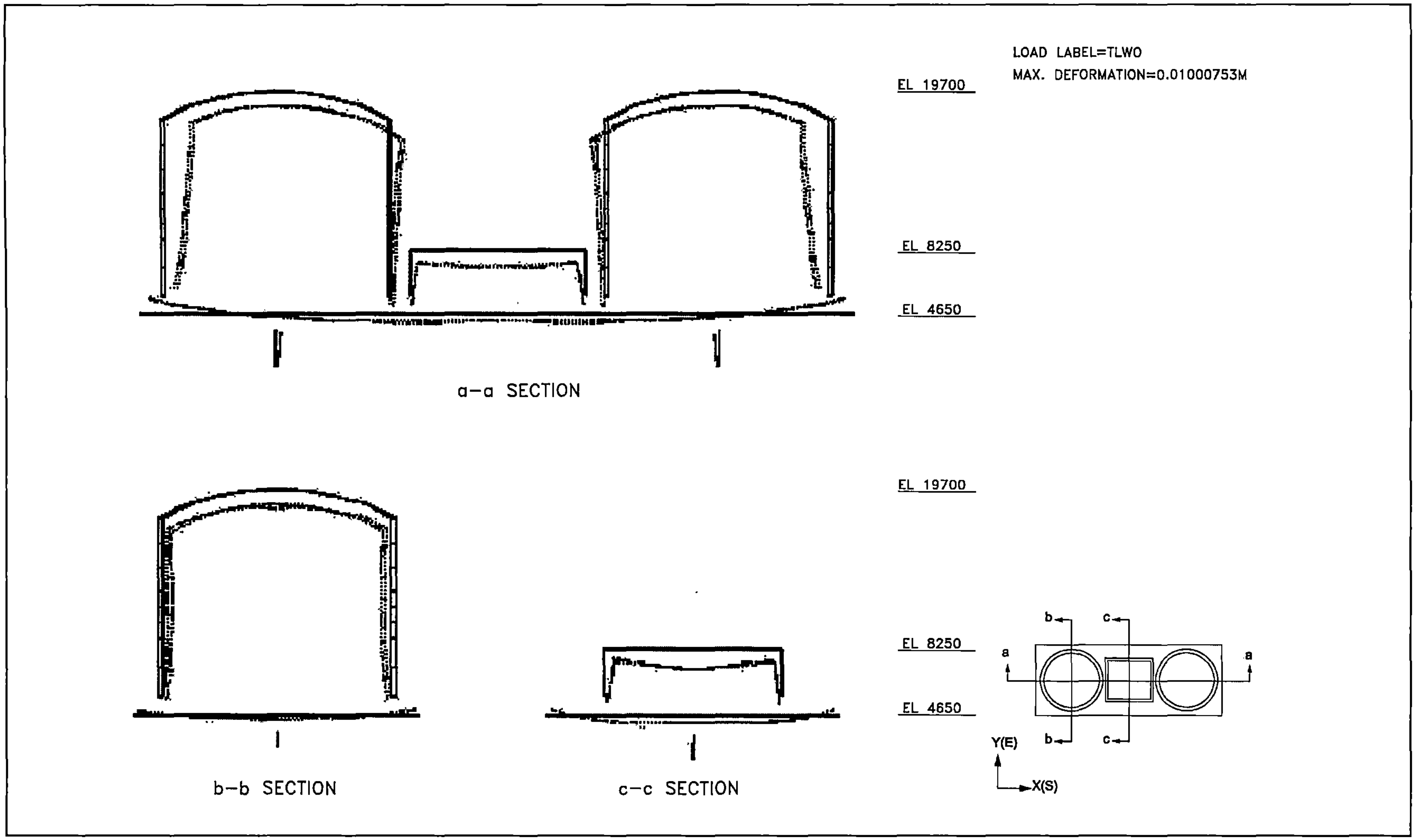


Figure 6.2-21 Deformation due to Structure Load, TLW0

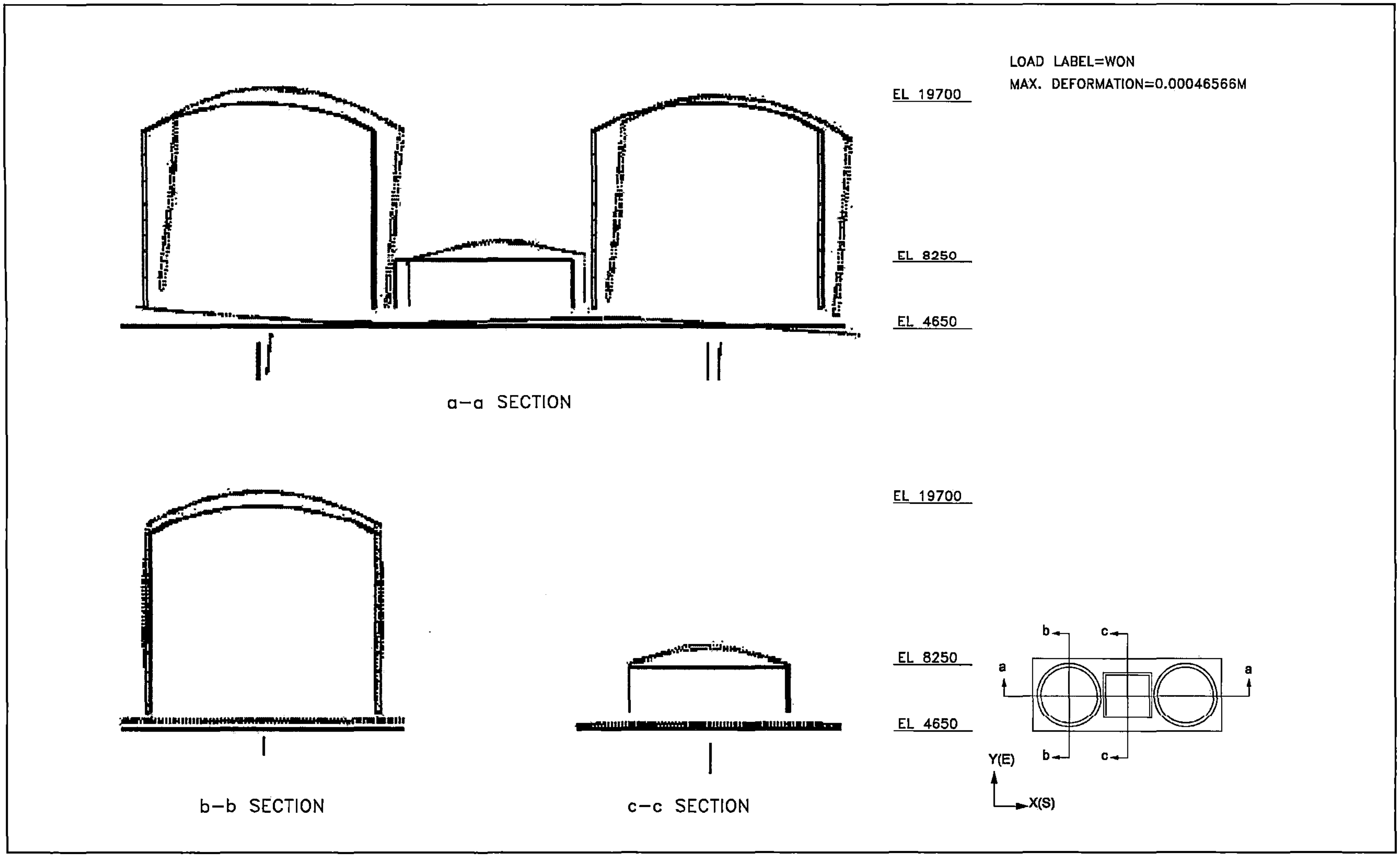


Figure 6.2-22 Deformation due to Structure Load, WON

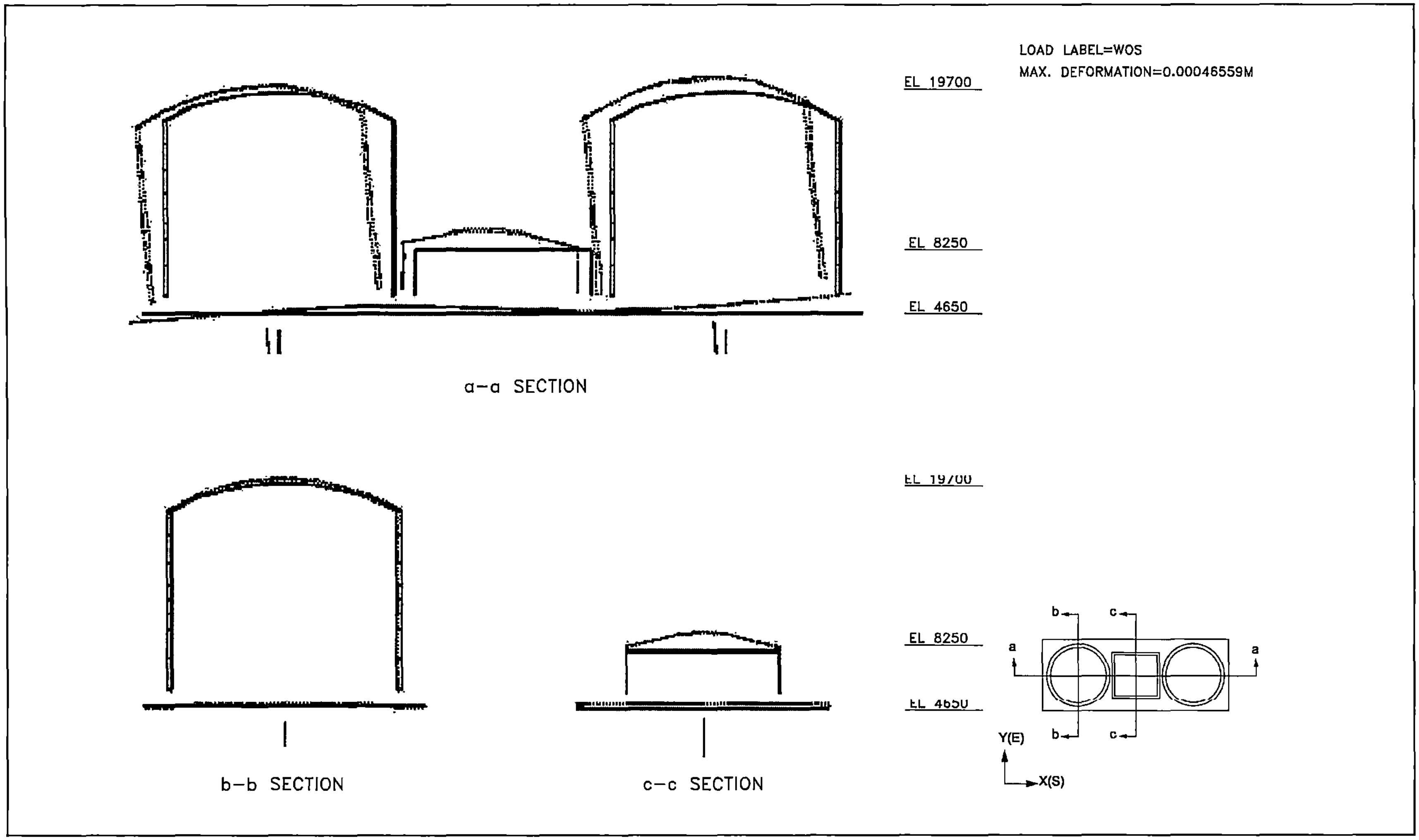


Figure 6.2-23 Deformation due to Structure Load, WOS

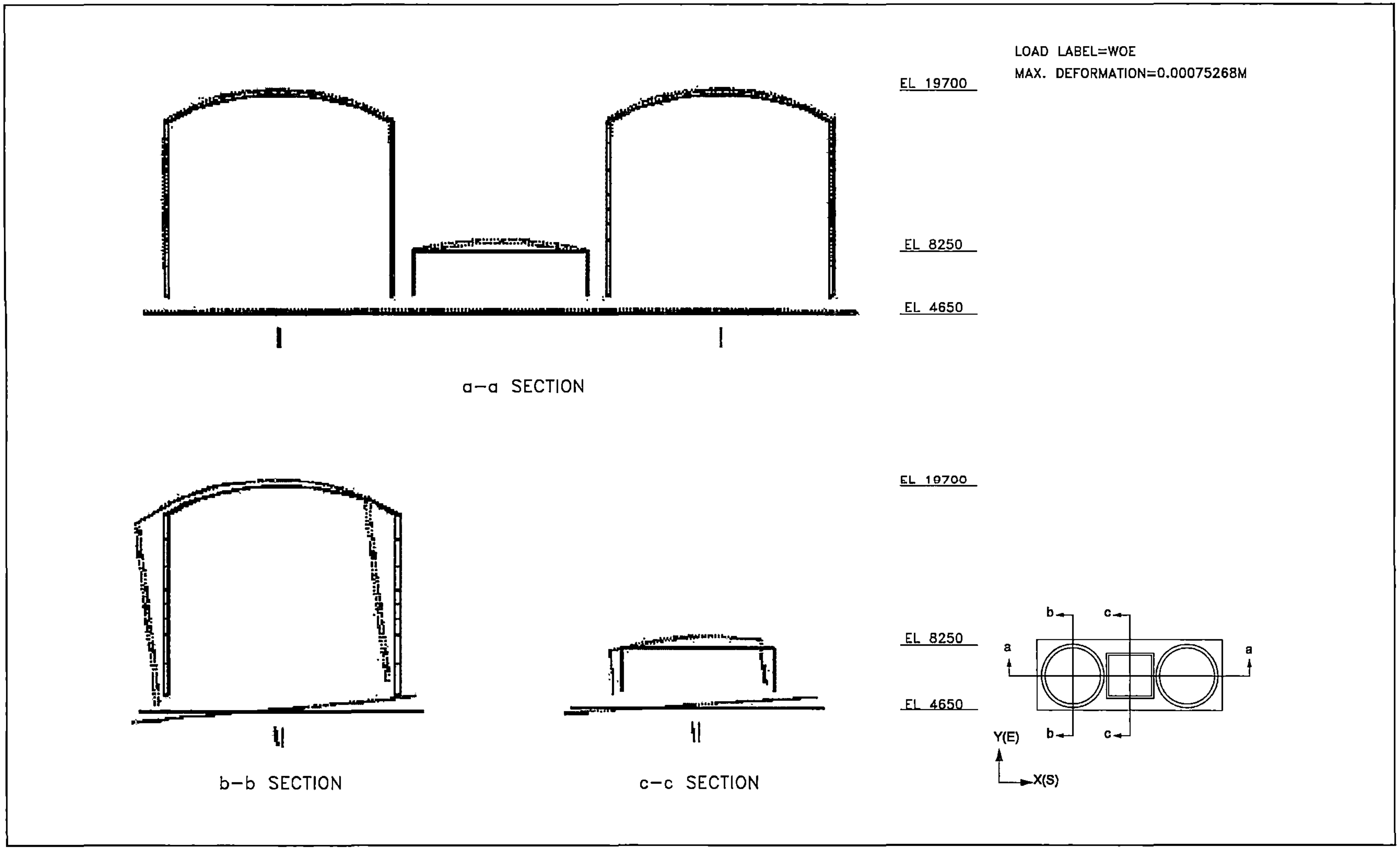


Figure 6.2-24 Deformation due to Structure Load, WOE

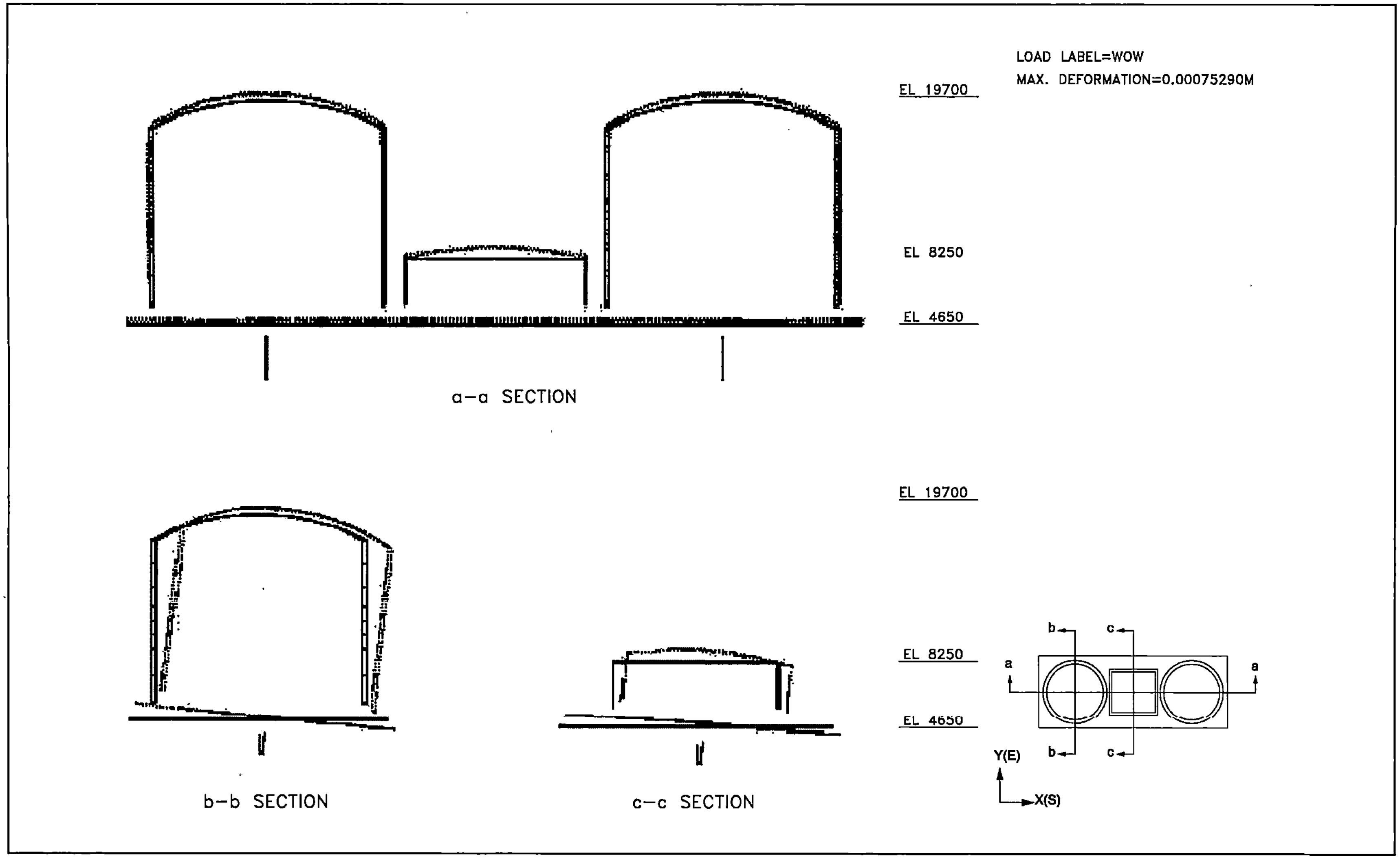


Figure 6.2-25 Deformation due to Structure Load, WOW

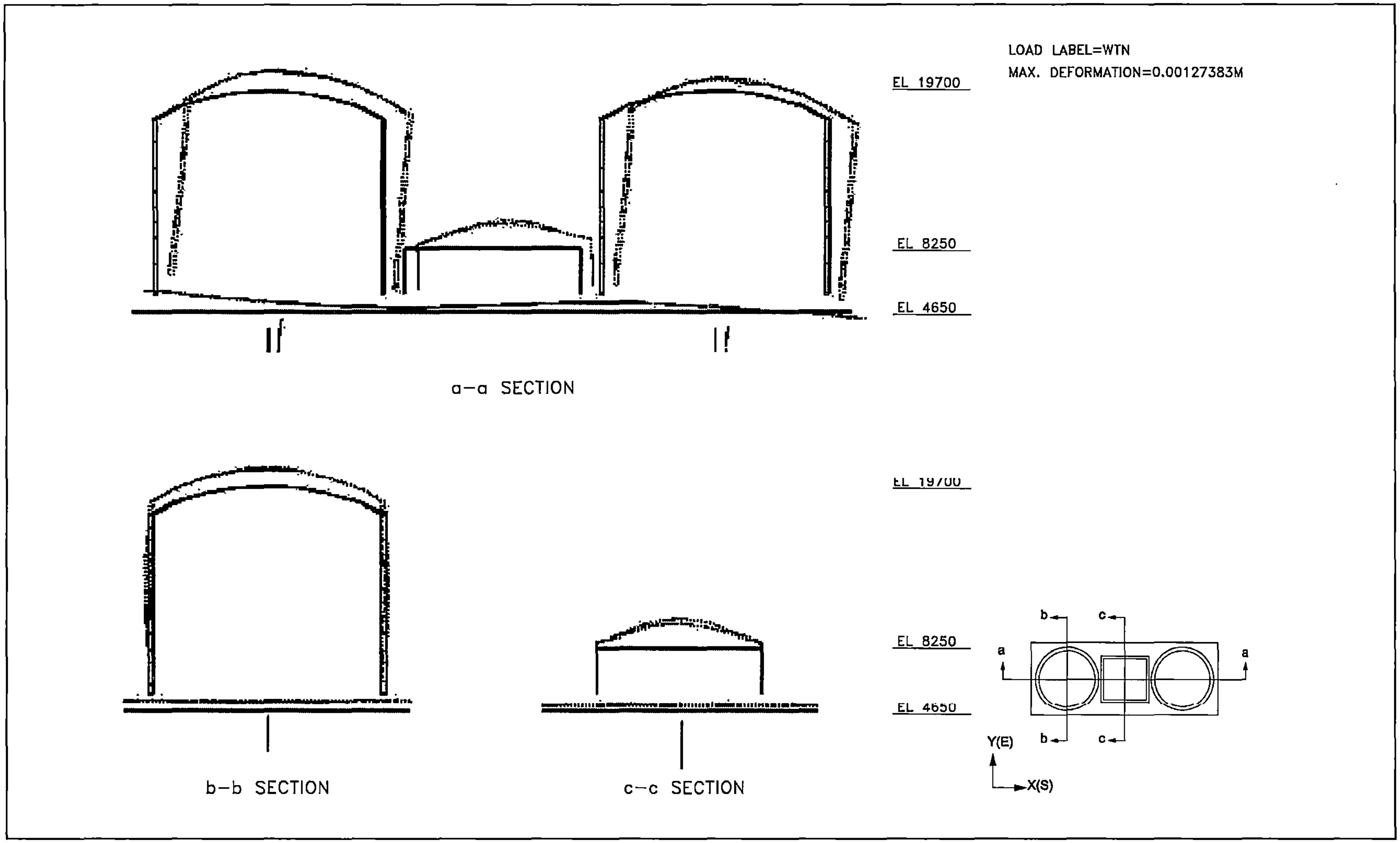


Figure 6.2-26 Deformation due to Structure Load, WTN

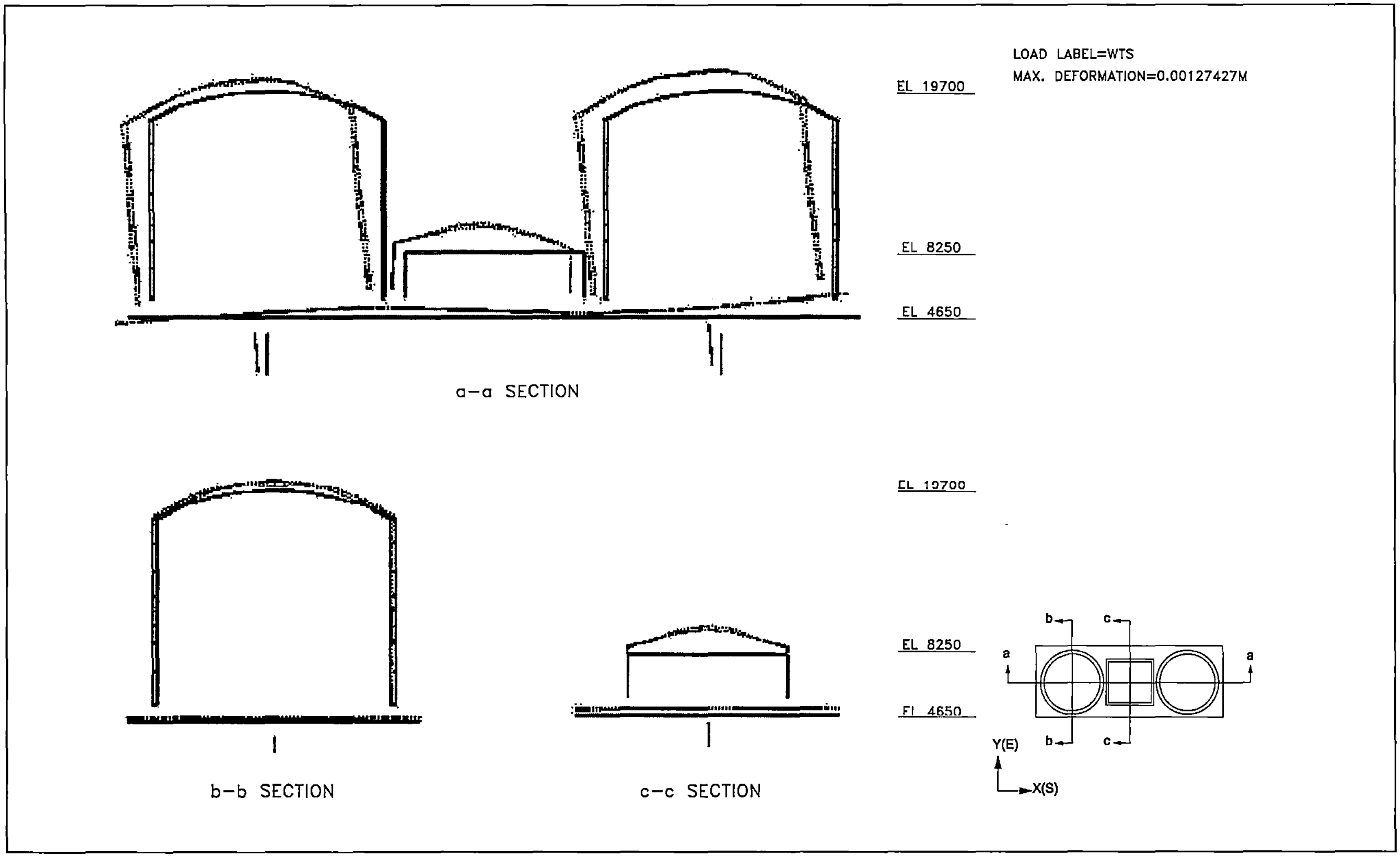


Figure 6.2-27 Deformation due to Structure Load, WTS

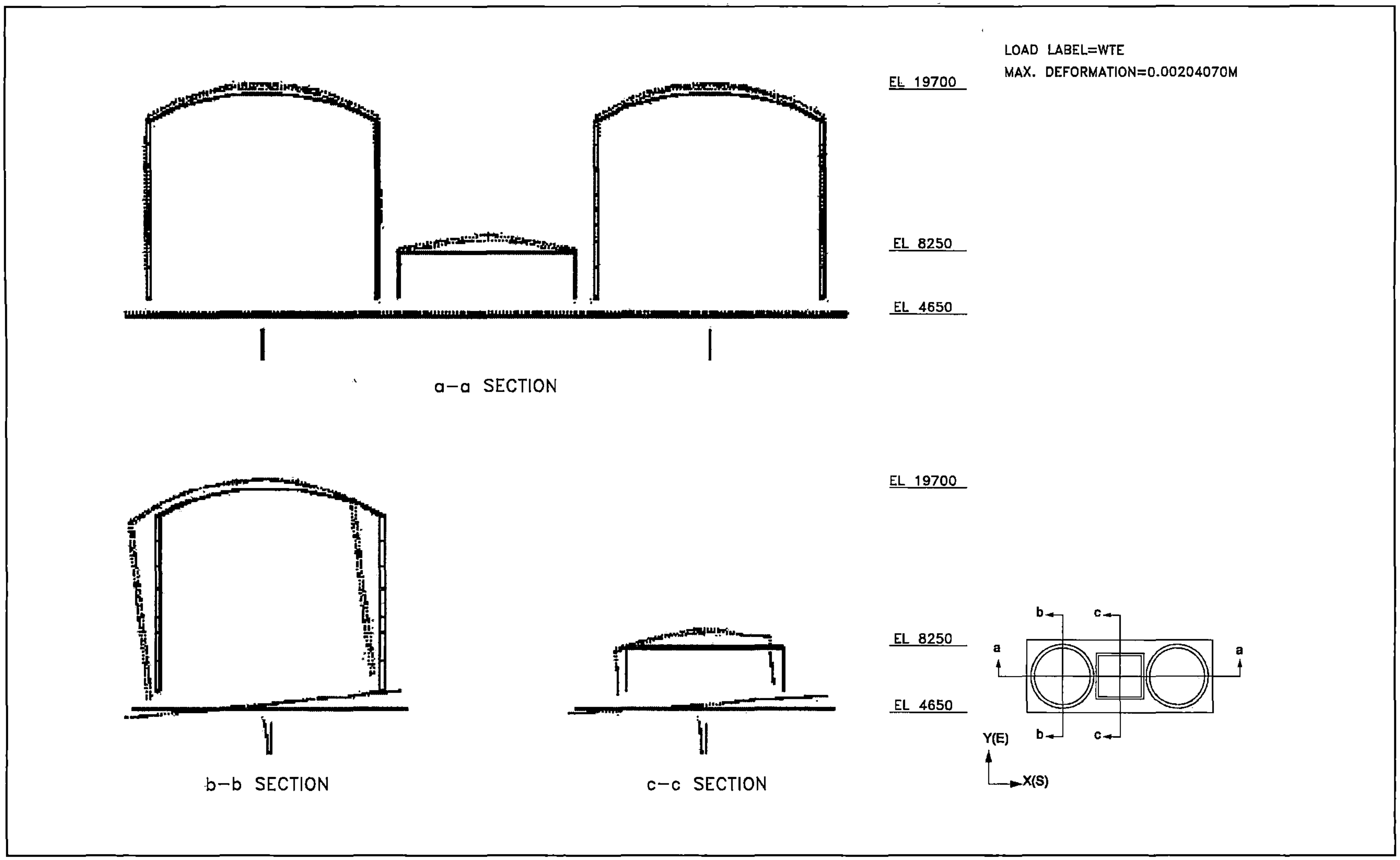


Figure 6.2-28 Deformation due to Structure Load, WTE

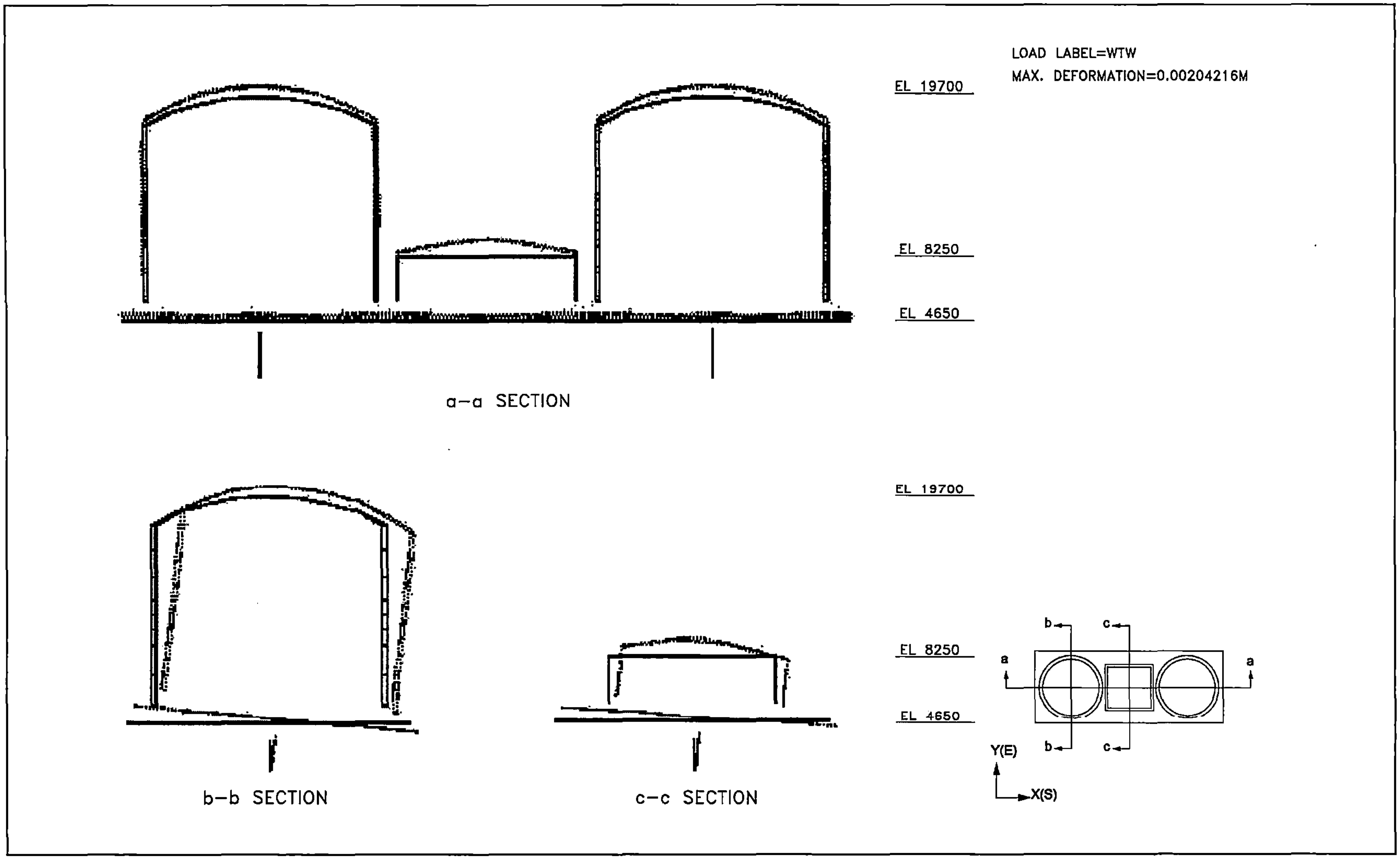


Figure 6.2-29 Deformation due to Structure Load, WTW

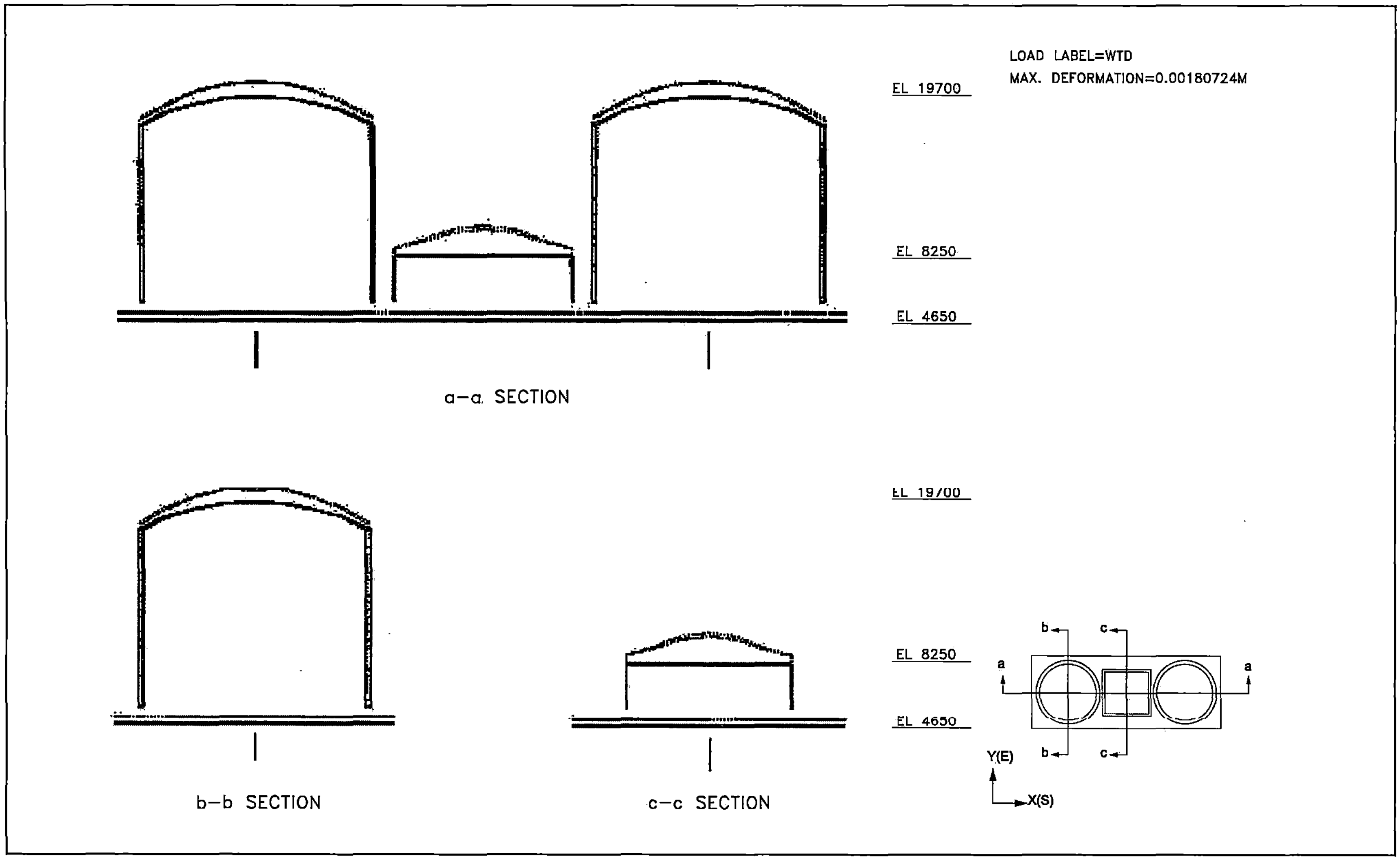


Figure 6.2-30 Deformation due to Structure Load, WTD

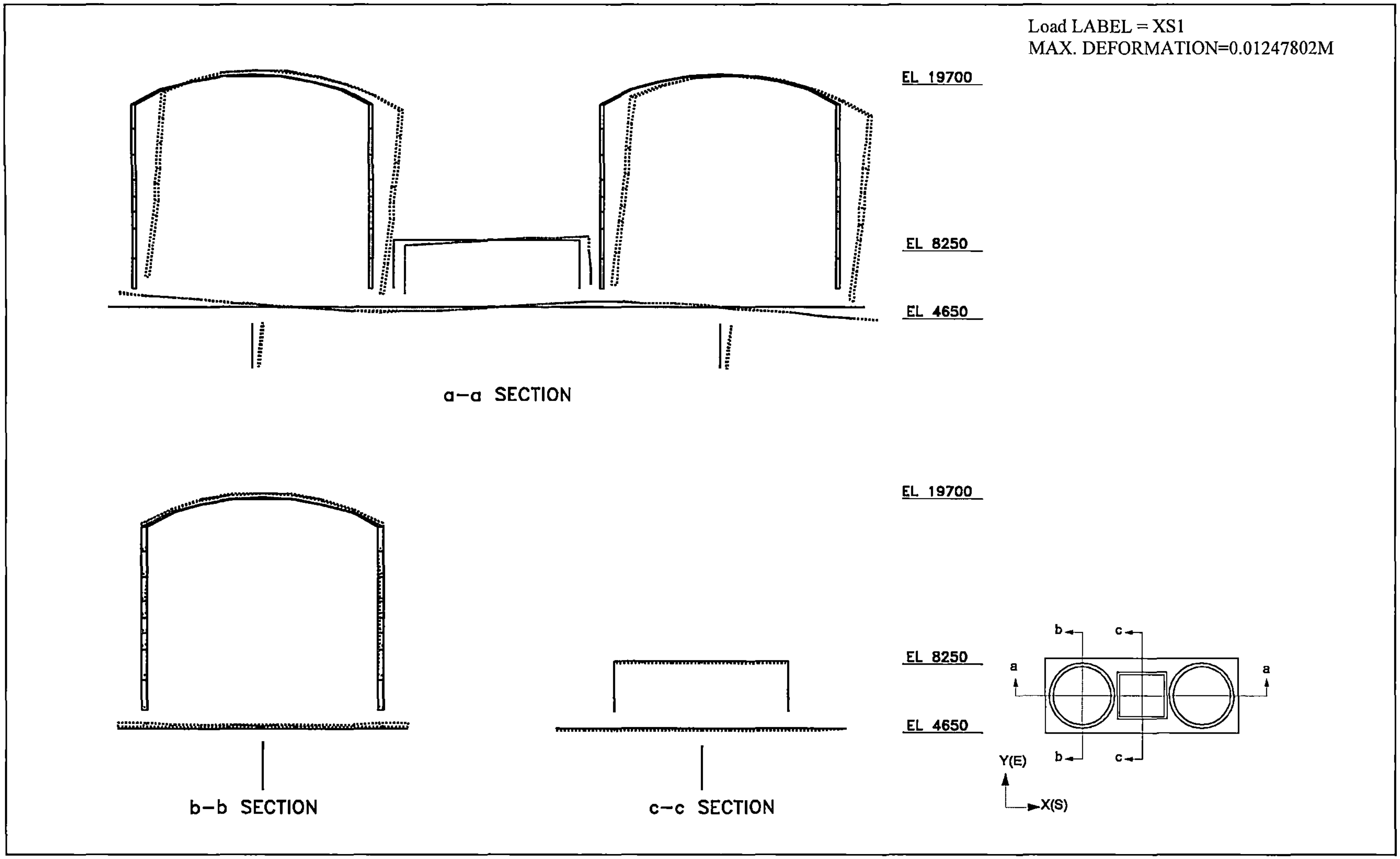


Figure 6.2-31 Deformation due to Structure Load, XS1

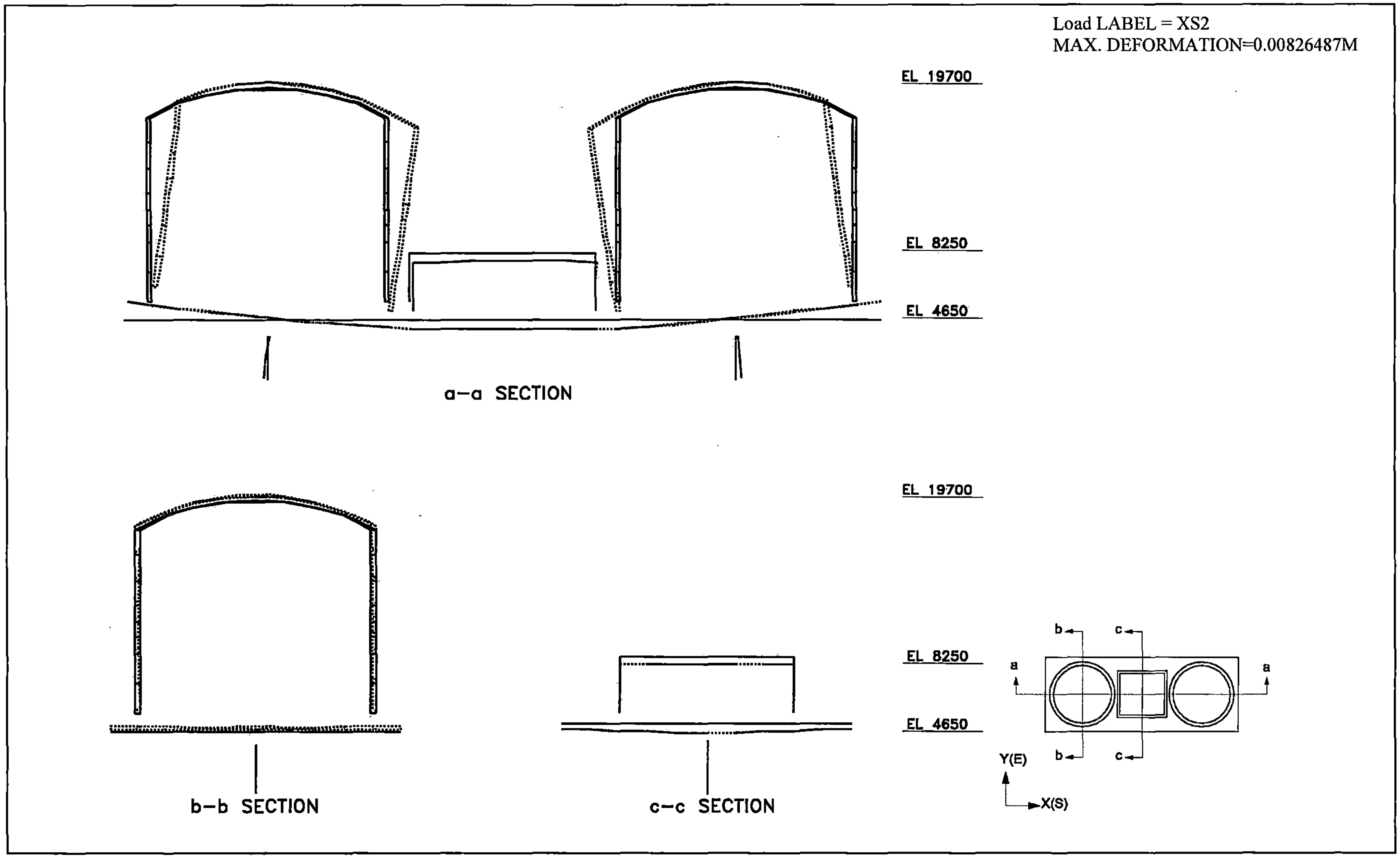


Figure 6.2-32 Deformation due to Structure Load, XS2

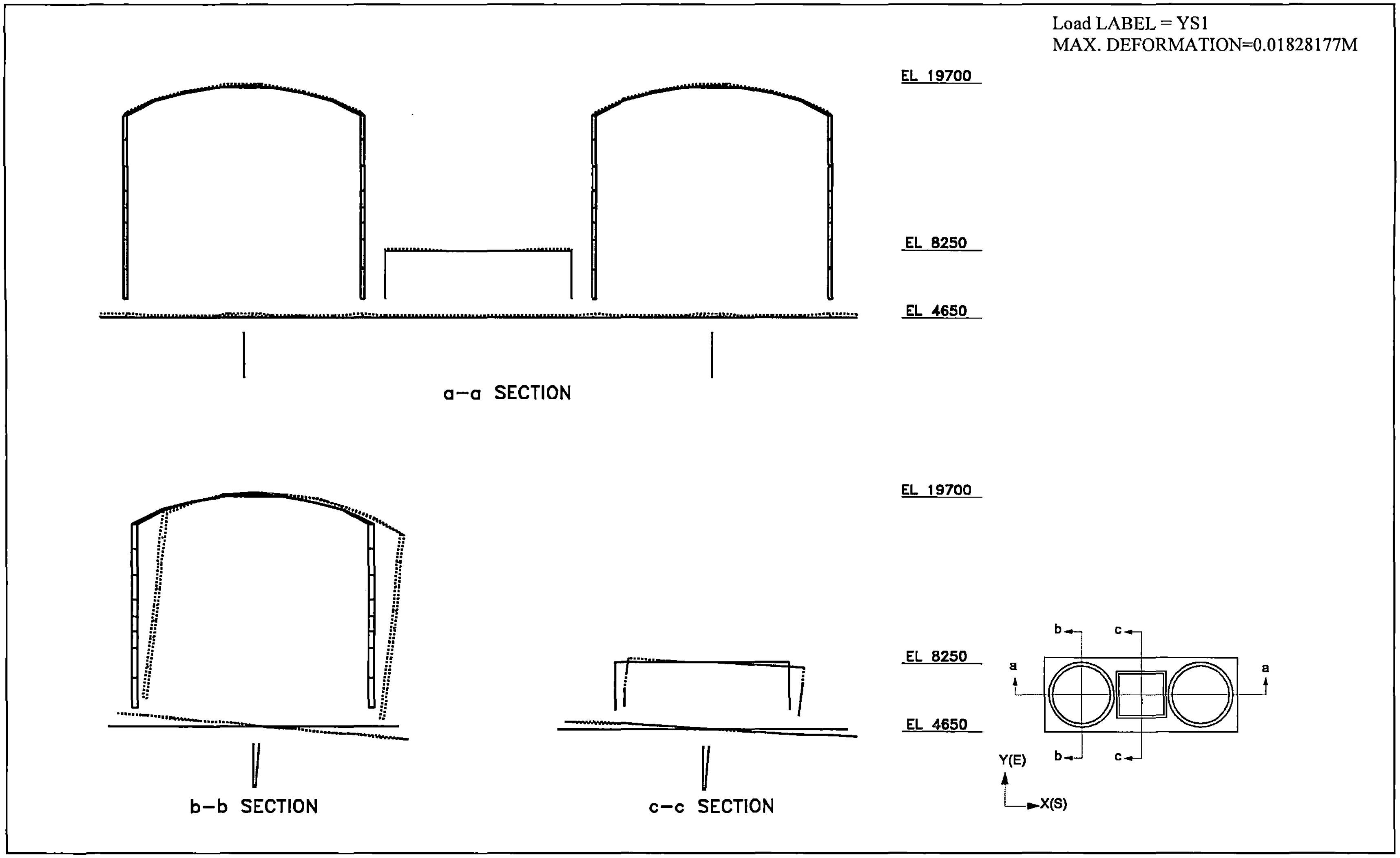


Figure 6.2-33 Deformation due to Structure Load, YS1

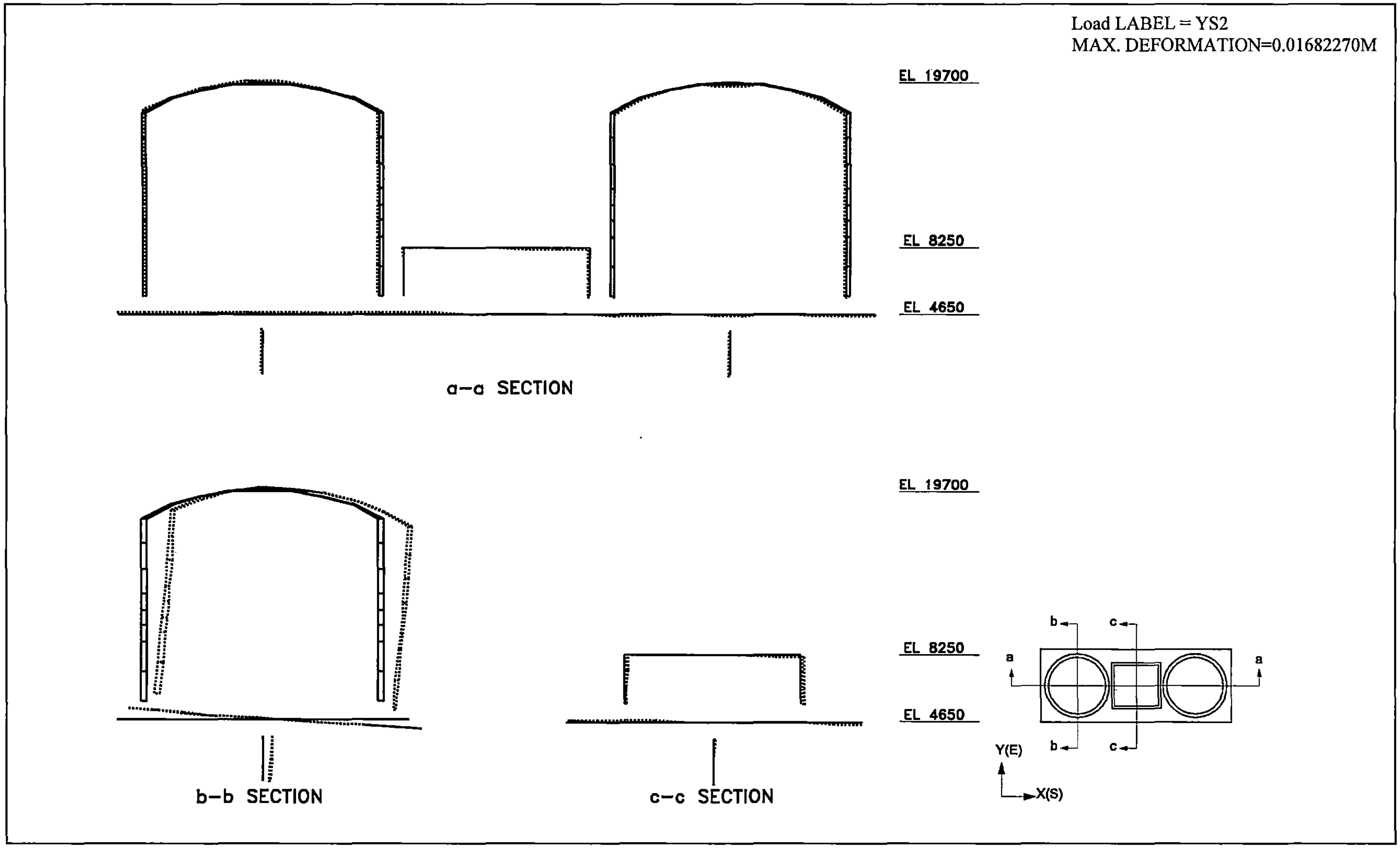


Figure 6.2-34 Deformation due to Structure Load, YS2

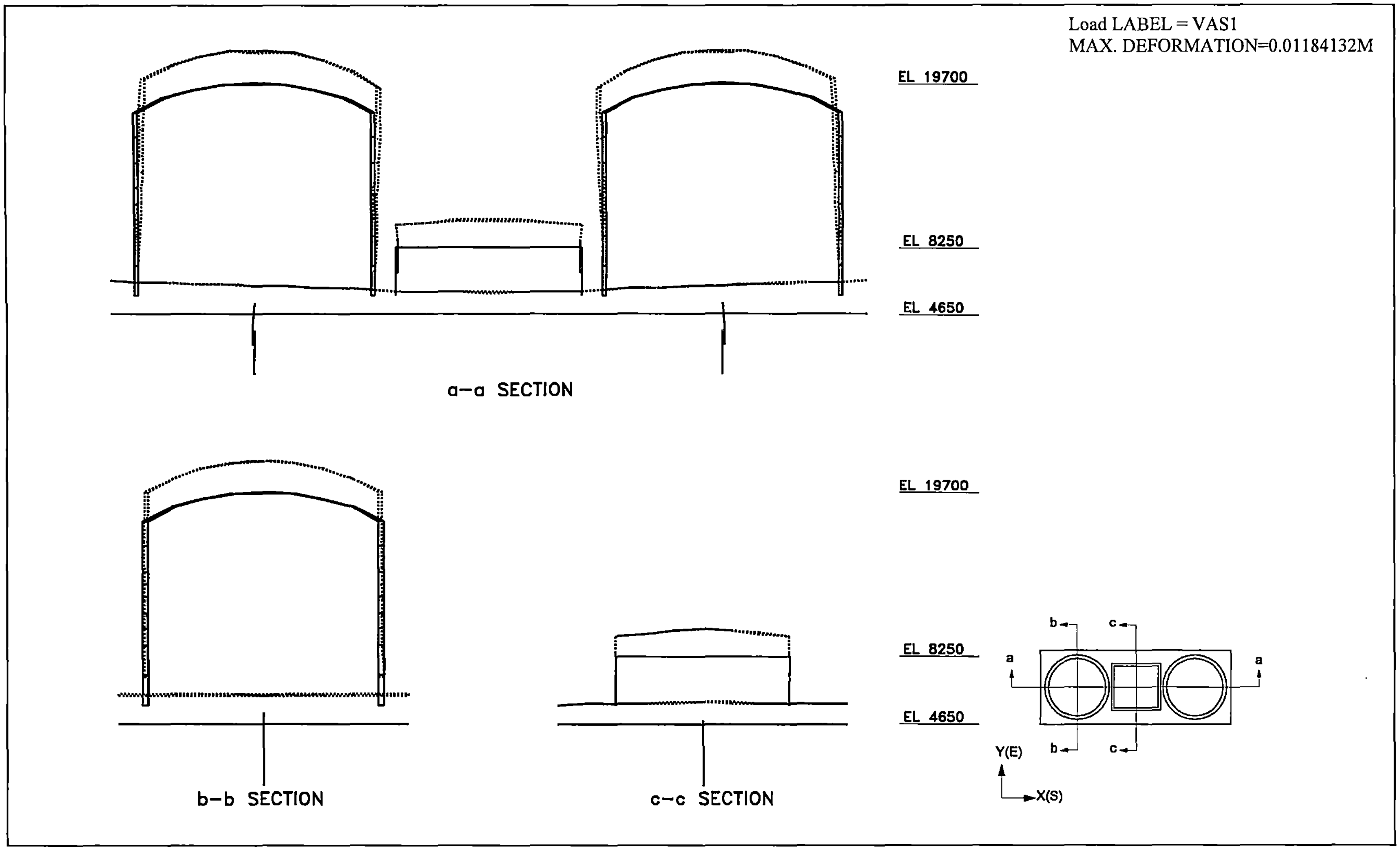


Figure 6.2-35 Deformation due to Structure Load, VAS1

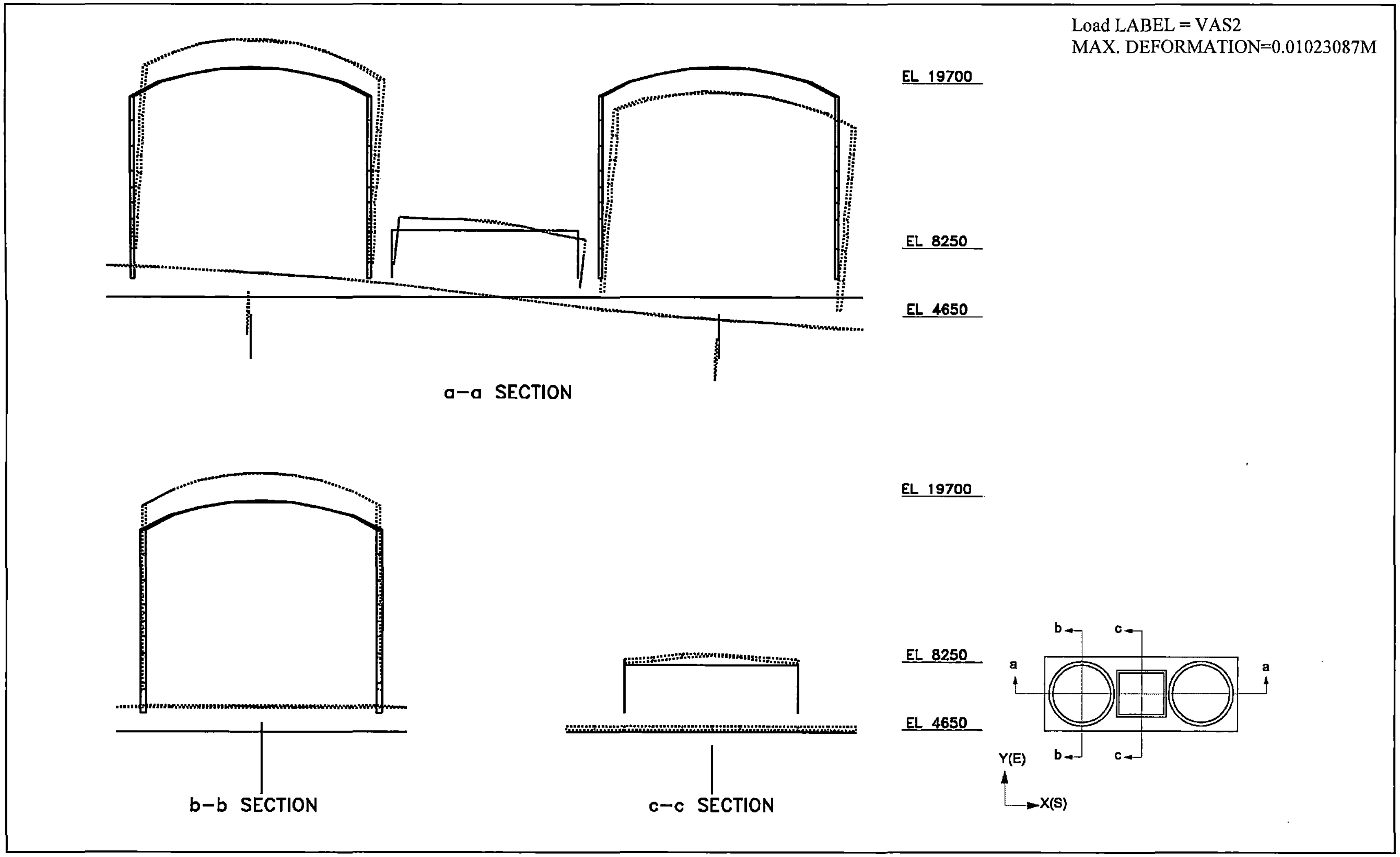


Figure 6.2-36 Deformation due to Structure Load, VAS2

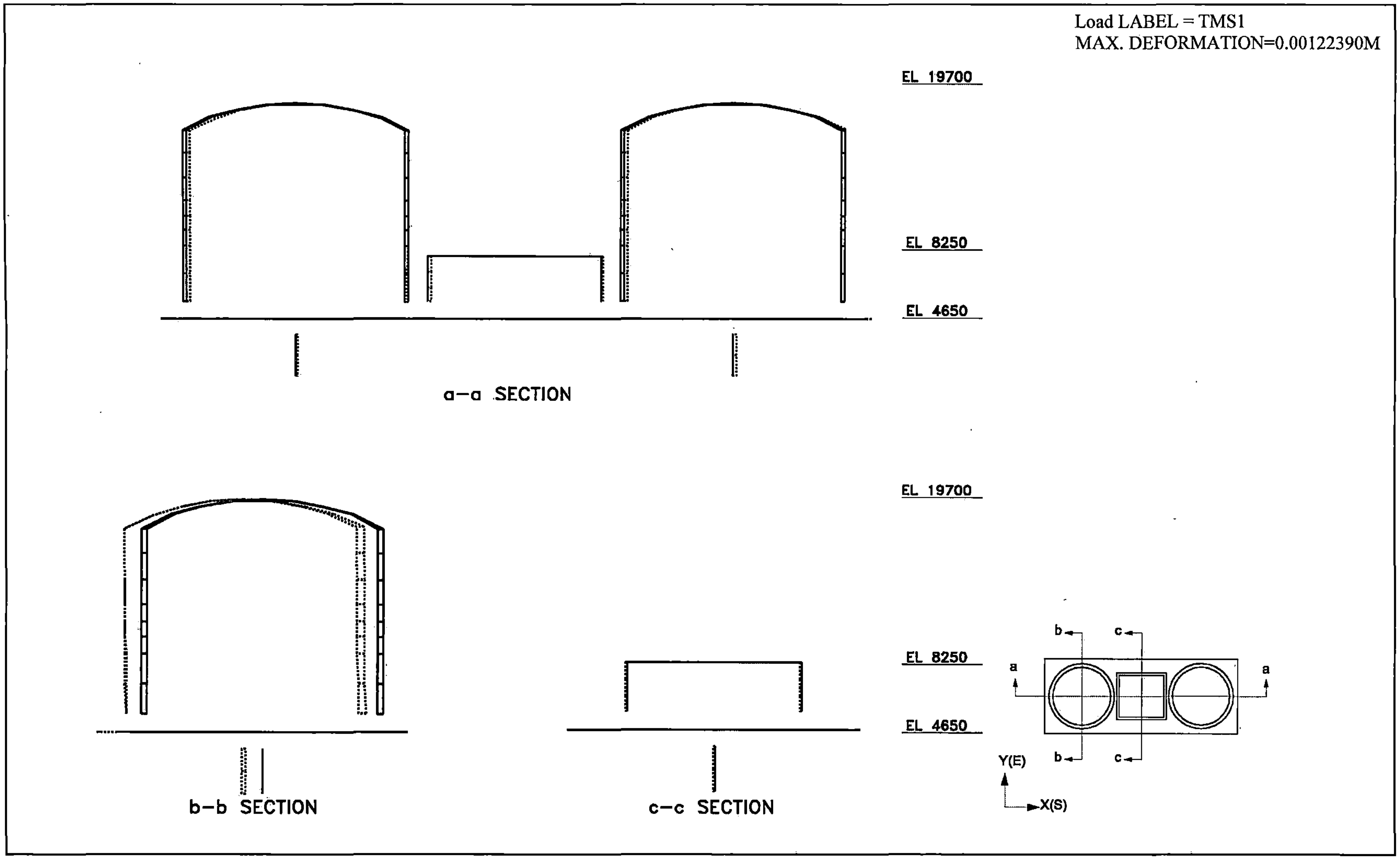


Figure 6.2-37 Deformation due to Structure Load, TMS1

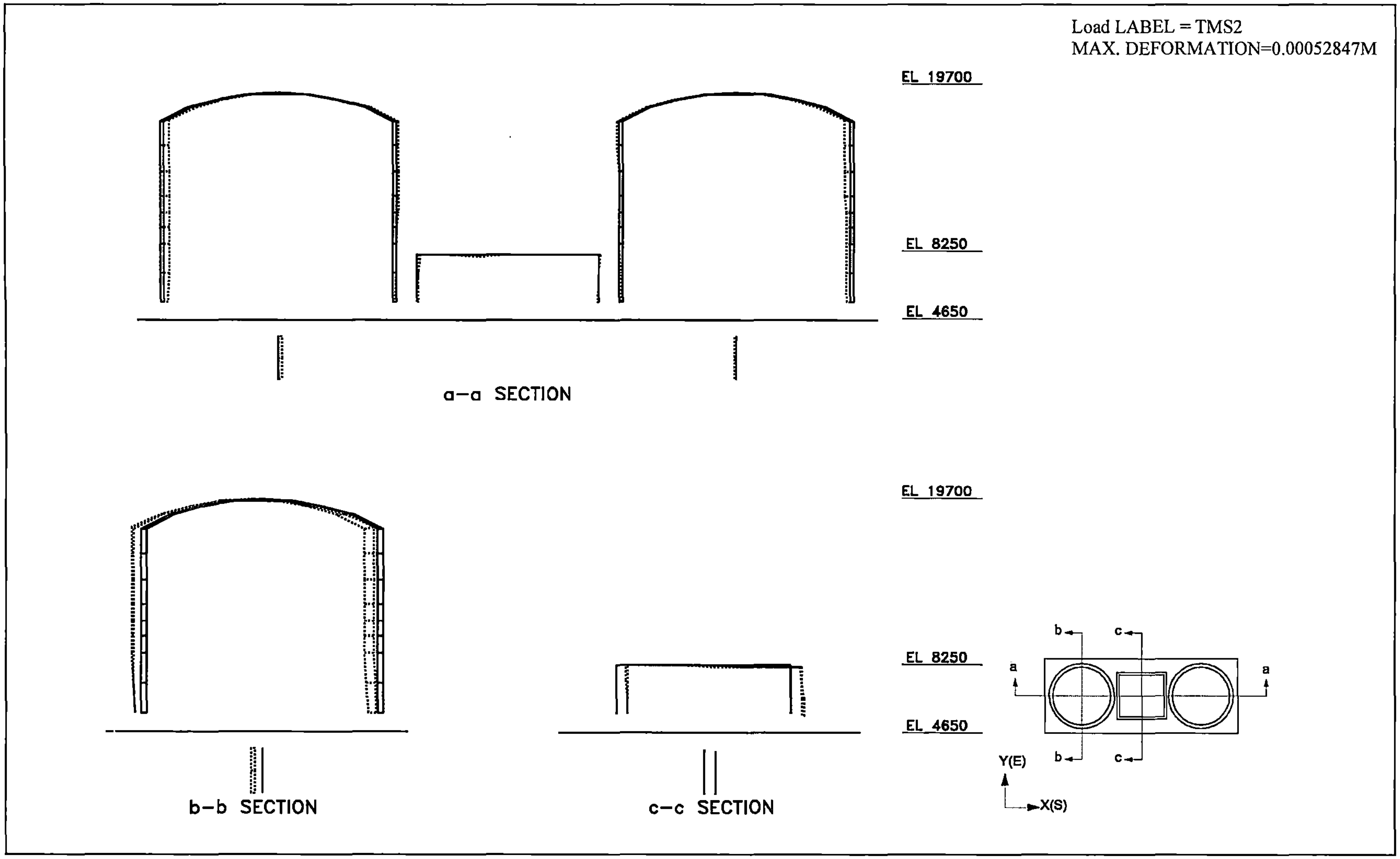
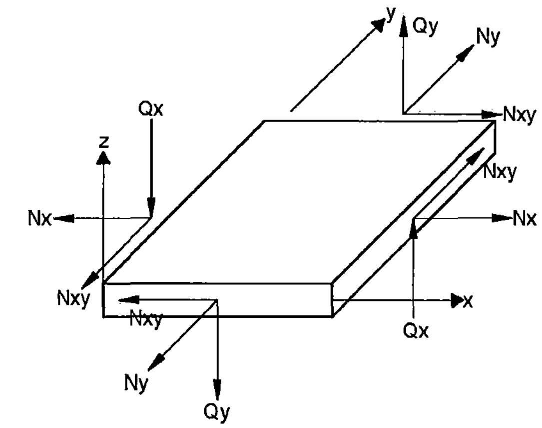
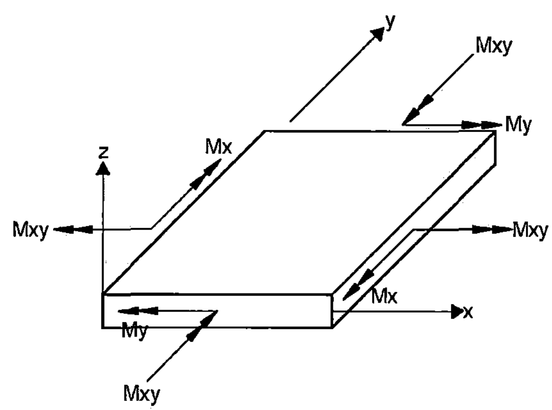


Figure 6.2-38 Deformation due to Structure Load, TMS2



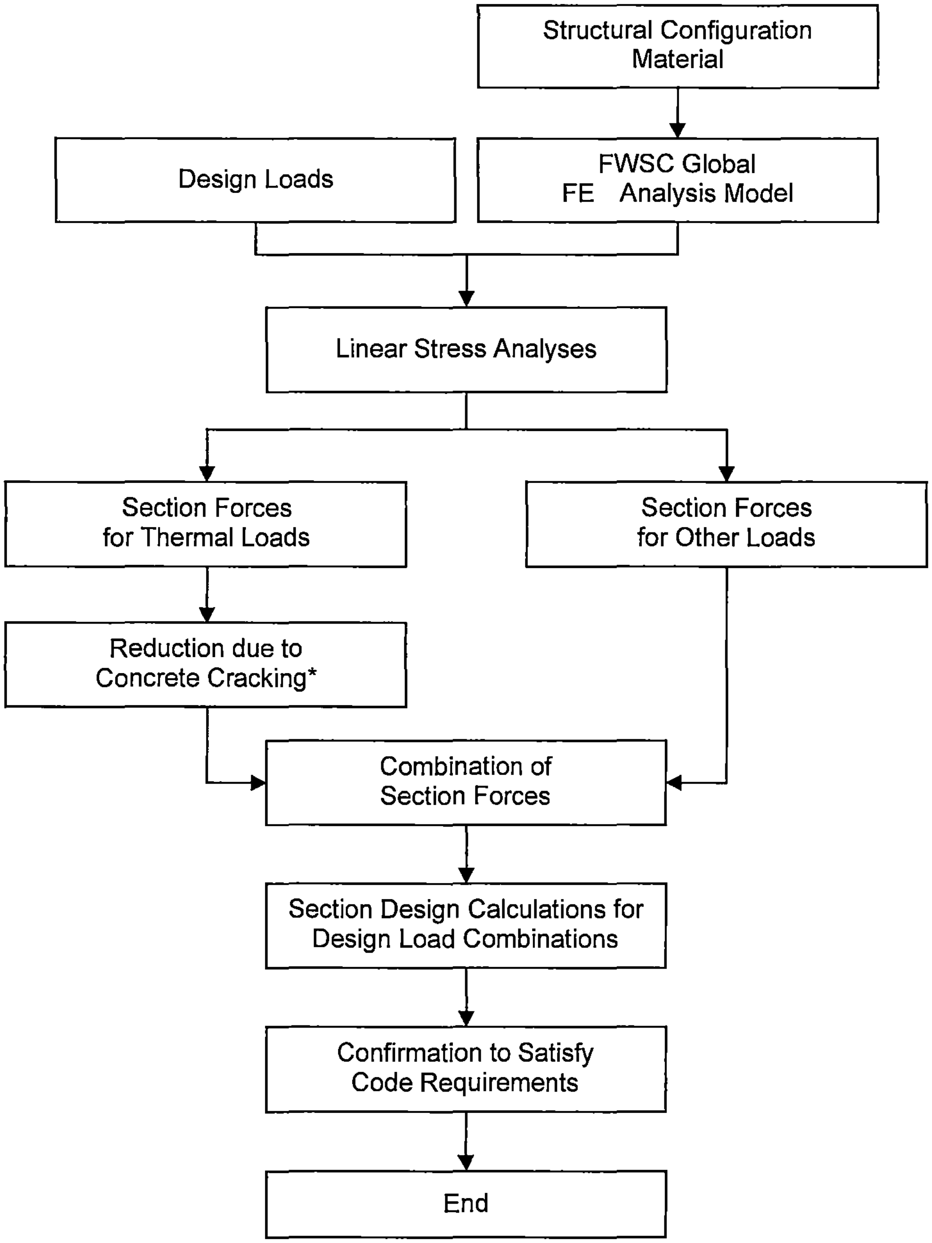
Membrane and Shear Forces



Moments

Structure	x	y	z
Wall in N-S direction	toward South	upward	toward West
Wall in E-W direction	toward East	upward	toward South
Tank Wall	horizontal	upward	outward
Foundation Mat & Roof	toward South	toward East	upward
Shear key in N-S direction	toward South	upward	toward West
Shear key in E-W direction	toward East	upward	toward South

Figure 6.2-39 Forces and Moments in Shell Element



*: Thermal section forces are reduced using the section design calculation program, SSDP-2D.

Figure 6.4-1 Design Flow Chart of Reinforced Concrete Structures

axial load N_u

$N_u = 0$

$$v_c = \min(v_{c1}, v_{c2})$$

$$v_{c1} = 1.9\sqrt{f'_c} + 2500\rho_w \frac{V_u d}{M_u}$$

$$v_{c2} = 3.5\sqrt{f'_c}$$

where,

$\left(\frac{V_u d}{M_u}\right)$ shall not exceed 1.0.

$N_u > 0$ (compression)

$$v_c = \min(v_{c1}, v_{c2})$$

$$v_{c1} = 1.9\sqrt{f'_c} + 2500\rho_w \frac{V_u d}{M_m}$$

$$v_{c2} = 3.5\sqrt{f'_c}\sqrt{1 + \frac{N_u}{500A_g}}$$

$$M_m = M_u - N_u \frac{(4h - d)}{8}$$

if $M_m \leq 0$

$$v_c = v_{c2}$$

$N_u < 0$ (tension)

$$v_{c2} = 2\left(1 + \frac{N_u}{500A_g}\right)\sqrt{f'_c}$$

$$V_c = v_c d$$

where,

v_c: allowable shear stress carried by concrete, psi

V_c: shear strength provided by concrete, lb / in

d: distance from extreme compression fiber to centroid of tension reinforcement, in

f'_c: specified compressive strength of concrete, psi

ρ_w: ratio of tension reinforcement $(= A_s / b_w d)$

V_u: shear force at section, lb

M_u: moment at section, lb - in

N_u: axial load at section, compression positive, lb

h: overall thickness of section, in

A_g: gross area of section, in^2

Figure 6.4-2 Calculation of Shear Strength Provided by Concrete

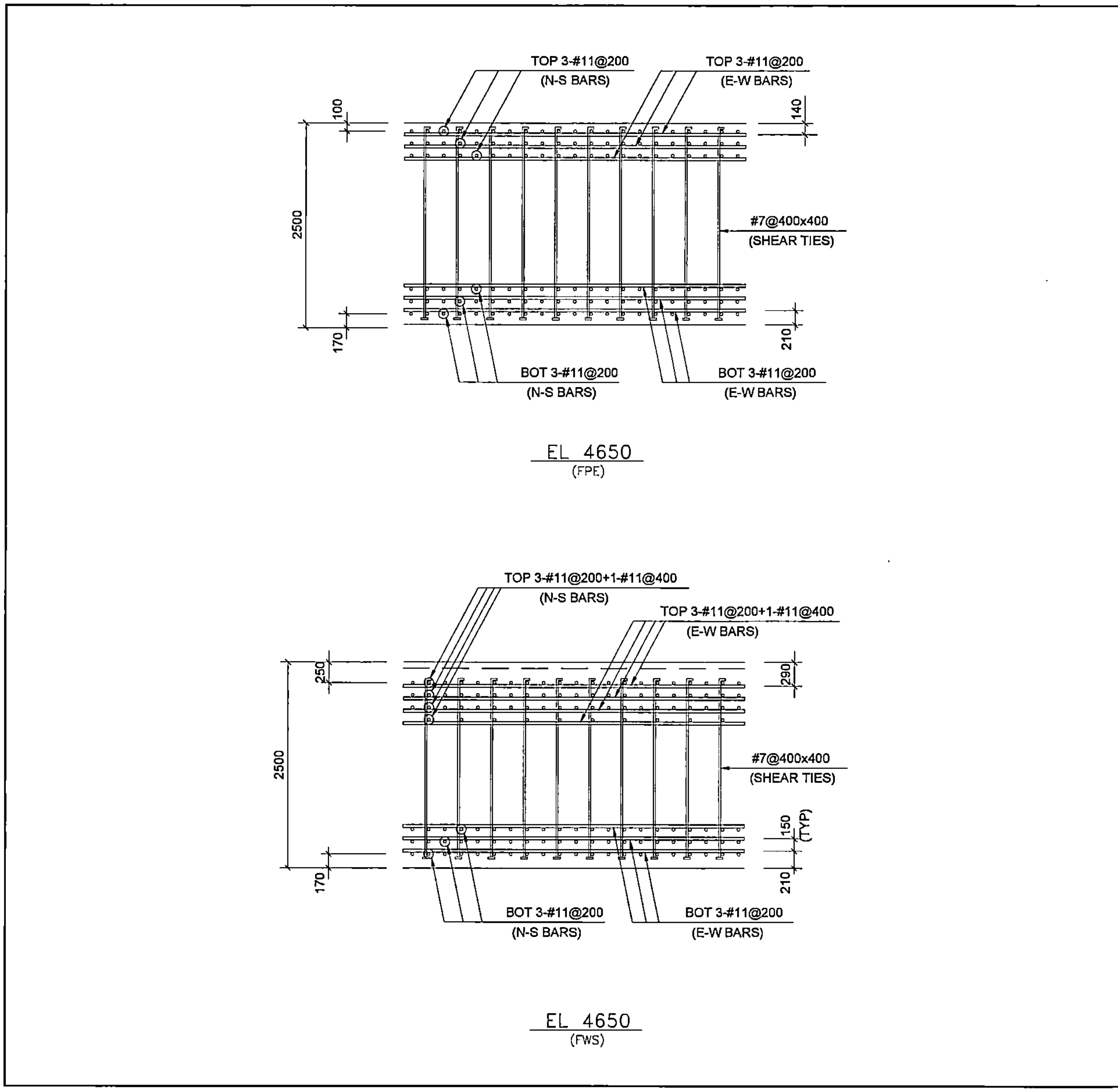


Figure 7.1-1 Typical Basemat Rebar Arrangement (unit: mm)

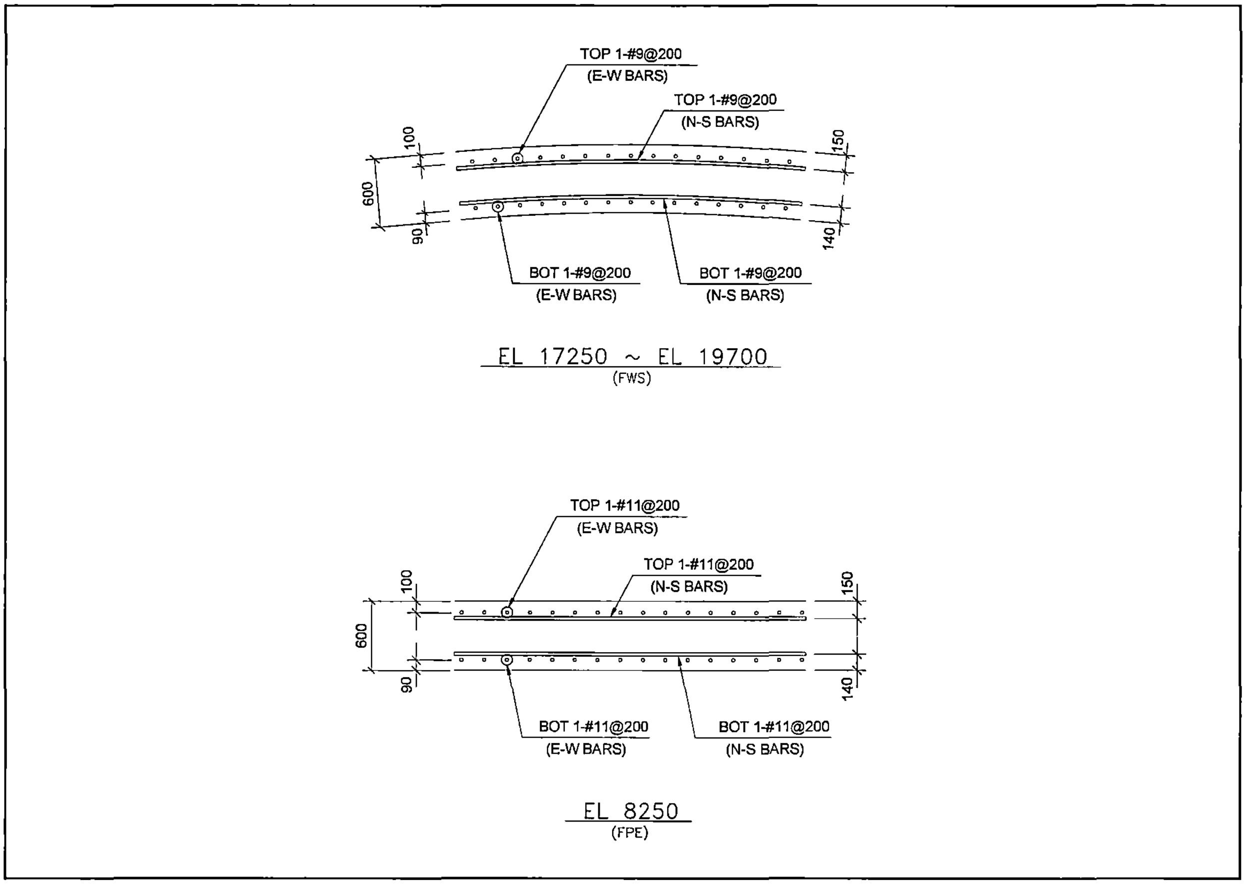


Figure 7.1-2 Typical Roofs Rebar Arrangement (unit: mm)

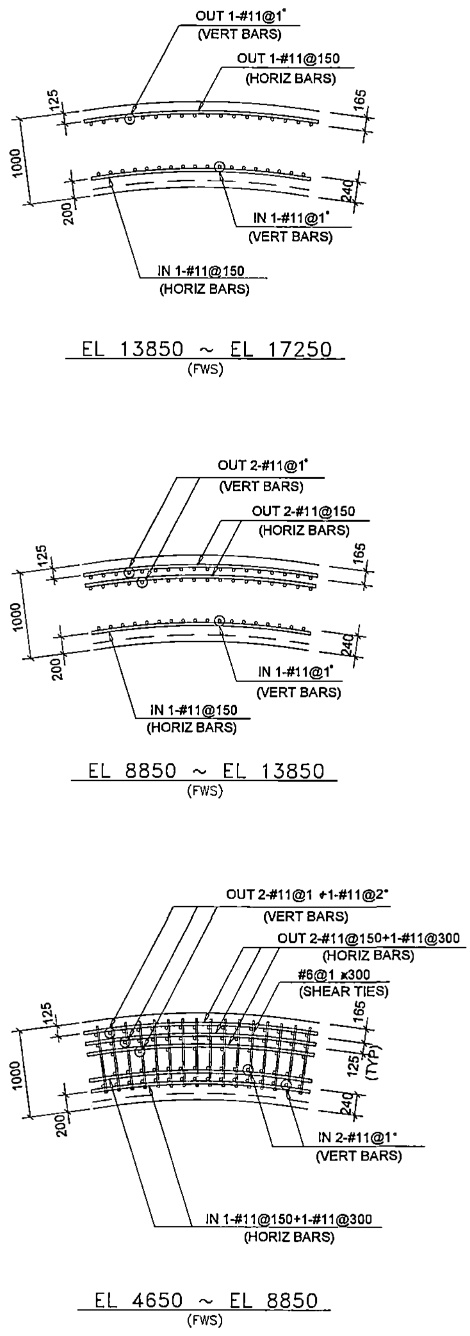


Figure 7.1-3 Typical Walls Rebar Arrangement of FWS (unit: mm)

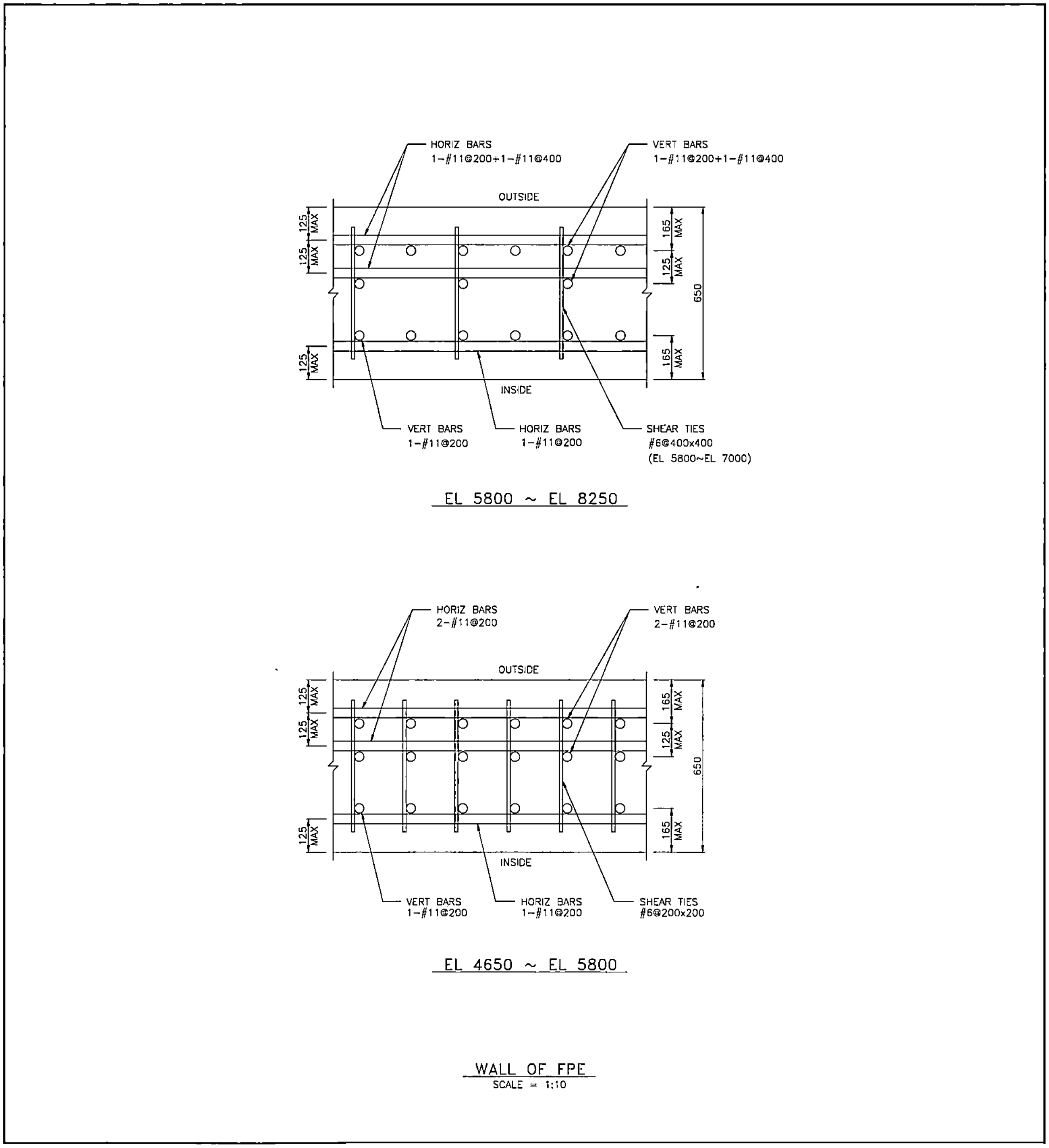
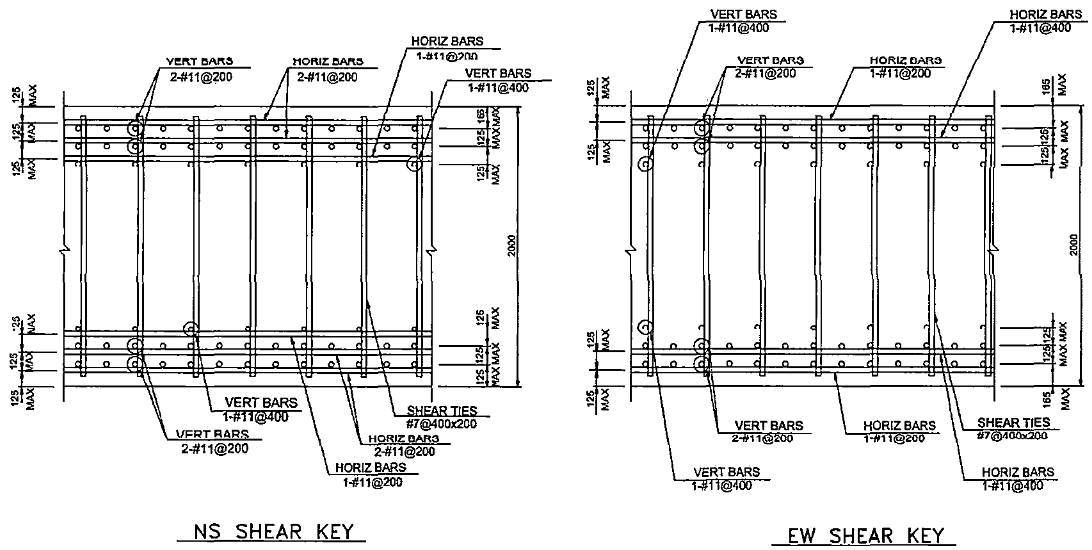


Figure 7.1-4 Typical Walls Rebar Arrangement of FPE (unit: mm)



Note: The effect of the shear height change from 3000mm to 3600mm is evaluated in Appendix D.

Figure 7.1-5 Typical Walls Rebar Arrangement of Shear Key (unit: mm)

APPENDIX A
NOT USED

APPENDIX B
NOT USED

APPENDIX C
NOT USED

APPENDIX D
EVALUATION FOR CHANGE OF SHEAR KEY SIZE

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D.1 SCOPE

This appendix describes the design methodology and evaluation for impact of the change of shear key height from 3.0 m of standard design to 3.6 m.

D.2 DESIGN METHODOLOGY

The shear keys were originally modeled as three (3) meters height elements in the FEM analysis to evaluate the design stresses. It is requested to re-evaluate these stresses because the height of shear key is changed to 3.6 m to maintain the sliding resistance capability of the FWSC. The methodology of this re-evaluation is based on the following procedure:

(1) The required rebar arrangement ratio of shear key is calculated using the updated lateral resistance pressure along shear key normal to the direction of seismic motion described in Reference 2.1.2-l.
The shear key is assumed as a cantilever beam fixed at the bottom of basemat.
The updated lateral resistance pressure is applied as inverted triangular distributed load to the shear key. Based on the calculated element forces, bending moment and shear force, the required rebar arrangement ratio is estimated.

(2) The bending moment (M_{max}) and shear force (V_{max}) are estimated by the following formula:

$$M_{\max} = \frac{1}{3} \times W \times H^2$$

$$V_{\max} = \frac{1}{2} \times W \times H$$

where,

W : *pressure load*

H : *Height of Shear key*

(3) The rebar arrangement ratio for main rebars and shear ties are calculated using the following procedure:

$$\rho_{REQ} = \frac{1}{m}\left(1 - \sqrt{1 - \frac{2m\,R_u}{f_y}}\right)$$

where,

$$R_u = \frac{M_u}{\phi b d^2}$$

$$m = \frac{f_y}{0.85 f_c'}$$

Mu : design bending moment, 1b-in

ϕ : strength reduction factor (0.9 for flexure)

b : width, in

d : distance from extreme compression fiber to centroid of tension reinforcement, in

The minimum rebar ratio is checked by the following equation:

$$\rho \geq \rho_{MIN} = \frac{200}{f_y}$$

Shear ties are required when the shear force exceeds a fraction of the nominal shear strength provided by concrete. That is, shear ties should be provided when

$$\phi V_c \leq V_u$$

where,

ϕ : strength reduction factor (0.85 for shear)

V_c : nominal shear strength provided by concrete, lb

V_u : design shear force, lb

The nominal shear strength provided by concrete is computed by the following equation:

$$V_c = 2\sqrt{f_c'}\ bd$$

The shear strength to be provided by the shear tie is

$$V_s = V_n - V_c \geq \frac{V_u}{\phi} - V_c$$

The nominal shear strength provided by the shear tie is computed by the following equation:

$$V_s = \frac{A_v f_y d}{s}$$

where A_v is shear tie area within the spacing distance s.

Therefore, the required tie bar ratio is calculated by the following equation:

$$\rho_{wREQ} = \frac{V_s}{bd} \cdot \frac{1}{f_y}$$

(4) The rebar arrangement for vertical direction and shear tie are determined to satisfy this required rebar arrangement ratio.

D.3 SECTION DESIGN

D.3.1 Design Load for Shear Key

The lateral resistance pressure along shear key normal to the direction of seismic motion (F_r') is reported in Reference 2.1.2-l.

$$NS : F_r' = 82MN$$

$$EW : F_r' = 71MN$$

These pressures are changed to the inverted triangular load applied to the shear key as unit load as follows. Here, three (3) shear key are provided for the FWSC, one is located at the center of the FWSC structure in N-S direction (Center shear key), the other two are located at the centers of South and North Tanks in E-W direction (North and South shear keys). The length of these shear keys are the same as the width of basemat in each direction, N-S and E-W. The height of these entire shear keys is 3.6m and the thickness of the shear keys is 2.0m. Therefore, the effective lengths of shear keys are 48.0m for Center shear key and 18.0m for North and South shear keys.

$$NS : F_{unit} = \frac{82MN}{18m \times 2} = 2.28\ MN/m$$

$$W_{unit} = \frac{2 \times 2.28\ MN/m}{3.6m} = 1.27\ MN/m/m$$

$$EW : F_{unit} = \frac{71MN}{48m} = 1.48\ MN/m$$

$$W_{unit} = \frac{2 \times 1.48\ MN/m}{3.6m} = 0.82\ MN/m/m$$

The design forces, bending moment and shear force, are calculated as follows:

$$NS : M_{max} = \frac{1}{3} \times W_{unit} \times H^2 = \frac{1}{3} \times 1.27 \times 3.6^2 = 5.5\ MN \cdot m/m$$

$$V_{max} = \frac{1}{2} \times W_{unit} \times H = \frac{1}{2} \times 1.27 \times 3.6 = 2.3\ MN/m$$

$$EW : M_{max} = \frac{1}{3} \times W_{unit} \times H^2 = \frac{1}{3} \times 0.82 \times 3.6^2 = 3.5\ MN \cdot m/m$$

$$V_{\max} = \frac{1}{2} \times W_{unit} \times H = \frac{1}{2} \times 0.82 \times 3.6 = 1.5\ MN/m$$

D.3.2 Section Design for Vertical Main Bar

(a) North and South shear keys

$f_y = 60000\ psi$

$f_c' = 4000\ psi$

$b = 1.0\ m \Rightarrow 39.37\ inch$

$D = 2.0\ m \Rightarrow 78.74\ inch$

$d = 2.0 - 0.165 - 0.125 = 1.71\ m \Rightarrow 67.32\ inch$

$M = 5.5\ MN \cdot m \Rightarrow 48.68 \times 10^6\ lb \cdot in$

$\phi = 0.9$

$$R_u = \frac{M}{\phi \cdot b \cdot d^2} = 303.14$$

$$m = \frac{f_y}{0.85 \cdot f_c'} = 17.65$$

$$\rho_{REQ} = \frac{1}{m} \cdot \left(1 - \sqrt{1 - \frac{2 \cdot m \cdot R_u}{f_y}}\right) = 0.530\ \%$$

$$\rho_{MIN} \geq \frac{200}{f_y} = 0.333\ \%$$

$\rho_{DGN} = 0.629\ \%\ (2\text{–}\#11@200 + 1\text{–}\#11@400) > \rho_{REQ} = 0.530\ \% \Rightarrow OK$

$\rho_{DGN} = 0.629\ \%\ (2\text{–}\#11@200 + 1\text{–}\#11@400) > \rho_{MIN} = 0.333\ \% \Rightarrow OK$

$\rho_{REQ} / \rho_{DGN} = 0.530\% / 0.629\% = 0.843$

where,

- f_y : specified yield strength of nonprestressed reinforcement
- f_c' : specified compressive strength of concrete
- b : unit width of shear key
- D : thickness of shear key
- d : distance from extreme compression fiber to centroid of tension reinforcement
- M : design bending moment
- ϕ : strength reduction factor (0.9 for flexure)

R_u : see Section D.2
m : see Section D.2
ρ_{REQ} : see Section D.2
ρ_{MIN} : see Section D.2
ρ_{DGN} : design rebar ratio for vertical main bar

(b) Center shear key

$f_y = 60000\ psi$

$f_c' = 4000\,psi$

$b = 1.0\ m \quad \Rightarrow \quad 39.37\ inch$

$D = 2.0\ m \quad \Rightarrow \quad 78.74\ inch$

$d = 2.0 - 0.165 - 0.125 = 1.71\ m \quad \Rightarrow \quad 67.32\ inch$

$M = 3.5\ MN \cdot m \quad \Rightarrow \quad 30.98 \times 10^6\ lb \cdot in$

$\phi = 0.9$

$$R_u = \frac{M}{\phi \cdot b \cdot d^2} = 192.91$$

$$m = \frac{f_y}{0.85 \cdot f_c'} = 17.65$$

$$\rho_{REQ} = \frac{1}{m} \cdot \left(1 - \sqrt{1 - \frac{2 \cdot m \cdot R_u}{f_y}} \right) = 0.331\,\%$$

$$\rho_{MIN} \geq \frac{200}{f_y} = 0.333\ \%$$

$\rho_{DGN} = 0.629\ \% \left(2\text{–}\#11@200 + 1\text{–}\#11@400\right) > \rho_{REQ} = 0.331\,\% \quad \Rightarrow \quad OK$
$\rho_{DGN} = 0.629\ \% \left(2\text{–}\#11@200 + 1\text{–}\#11@400\right) > \rho_{MIN} = 0.333\,\% \quad \Rightarrow \quad OK$
$\rho_{REQ} / \rho_{DGN} = 0.331\% / 0.629\% = 0.526$

where,
f_y : specified yield strength of nonprestressed reinforcement
f_c' : specified compressive strength of concrete
b : unit width of shear key
D : thickness of shear key

d : distance from extreme compression fiber to centroid of tension reinforcement
M : design bending moment
ϕ : strength reduction factor (0.9 for flexure)
R_u : see Section D.2
m : see Section D.2
ρ_{REQ} : see Section D.2
ρ_{MIN} : see Section D.2
ρ_{DGN} : design rebar ratio for vertical main bar

D.3.3 Section Design for Shear Tie

(a) North and South shear keys

$f_y = 60000\ psi$

$f_c' = 4000 psi$

$b = 1.0\ m \Rightarrow 39.37\ inch$

$D = 2.0\ m \Rightarrow 78.74\ inch$

$d = 2.0 - 0.165 - 0.125 = 1.71\ m \Rightarrow 67.32\ inch$

$V_u = 2.3\ MN \Rightarrow 517.1 \times 10^3\ lb$

$\phi = 0.85$

$V_c = 2 \cdot \sqrt{f_c'} \cdot b \cdot d = 335.3 \times 10^3\ lb \Rightarrow 1.491\ MN$

$V_s \geq \frac{V_u}{\phi} - V_c = 273.0 \times 10^3\ lb \Rightarrow 1.215\ MN$

$\rho_{WREQ} = \frac{V_s}{b \cdot d} \cdot \frac{1}{f_y} = 0.172\ \%$

$\rho_{WDGN} = 0.484\ \%\ (\#7 @ 400 \times 200) > \rho_{WREQ} = 0.172\% \Rightarrow OK$

$\rho_{WREQ} / \rho_{WDGN} = 0.172\% / 0.484\% = 0.355$

where,

f_y : specified yield strength of nonprestressed reinforcement
f_c' : specified compressive strength of concrete
b : unit width of shear key

D : thickness of shear key
d : distance from extreme compression fiber to centroid of tension reinforcement
V_u : design shear force
ϕ : strength reduction factor (0.85 for shear)
V_c : see section D.2
V_s : see section D.2
ρ_{WREQ} : see section D.2
ρ_{WDGN} : design rebar ratio for shear tie

(b) Center shear key

$f_y = 60000\ psi$

$f_c' = 4000\,psi$

$b = 1.0\ m \Rightarrow 39.37\ inch$

$D = 2.0\ m \Rightarrow 78.74\ inch$

$d = 2.0 - 0.165 - 0.125 = 1.71\ m \Rightarrow 67.32\ inch$

$V_u = 1.5\ MN \Rightarrow 337.2 \times 10^3\ lb$

$\phi = 0.85$

$V_c = 2 \cdot \sqrt{f_c'} \cdot b \cdot d = 335.3 \times 10^3\ lb \Rightarrow 1.491\ MN$

$V_s \geq \frac{V_u}{\phi} - V_c = 61.5 \times 10^3\ lb \Rightarrow 0.273\ MN$

$\rho_{WREQ} = \frac{V_s}{b \cdot d} \cdot \frac{1}{f_y} = 0.039\ \%$

$\rho_{WDGN} = 0.484\ \% \left(\#7@400 \times 200\right) > \rho_{WREQ} = 0.039\ \% \Rightarrow OK$

$\rho_{WREQ} / \rho_{WDGN} = 0.039\% / 0.484\% = 0.081$

where,

f_y : specified yield strength of nonprestressed reinforcement
f_c' : specified compressive strength of concrete
b : unit width of shear key
D : thickness of shear key
d : distance from extreme compression fiber to centroid of tension reinforcement

V_u : design shear force
ϕ : strength reduction factor (0.85 for shear)
V_c : see section D.2
V_s : see section D.2
ρ_{WREQ} : see section D.2
ρ_{WDGN} : design rebar ratio for shear tie

D.4 Impact Evaluation on Basemat Design

The shear keys have been designed to withstand the lateral resistance pressure that occurred during a seismic event. The impact of the change of shear key height on the shear key design has been evaluated as shown above. This section shows the evaluation of the impact on the basemat design due to the change.

D.4.1 Design Methodology

The impact evaluation of basemat design is performed according to the following procedure:

(1) Obtain coefficient which expresses the basemat stress increase due to the change of shear keys height.

(2) Confirm the maximum rebar stress of the basemat element near shear key position in case of load combination including seismic forces.

(3) Update the maximum rebar stress multiplying the above coefficient.

(4) Evaluate the maximum stress ratio for flexure and membrane forces of basemat reflecting the updated rebar stress.

D.4.2 Evaluation of Basemat Stress Ratio

The following coefficient is utilized conservatively to show effects of the design condition change:

$$K1 = \left(\frac{3.6}{3.0}\right)^2 = 1.44$$

where,
$K1$: factor of the shear key height change impact
(shear key height =3.0m and 3.6m, See Figure D-1.)

(a) North and South shear keys

The maximum stress ratio for flexure and membrane forces of basemat, $\{\sigma/\sigma_a\}_{\max}$, is re-estimated including the factor of the shear key height change impact ratio, $K1$. The basemat

elements, 205, 206, 251, and 252 are selected. Table D-1 gives a summary of the maximum stress ratios.

$$K1 \times \{\sigma/\sigma_a\}_{max} = 1.44 \times 0.545 = 0.785 < 1.0 \quad \text{OK}$$

where,

σ : original maximum basemat rebar stress

σ_a : allowable rebar stress

It is confirmed from this calculation that the basemat design is still adequate considering North and South shear keys design condition change.

(b) Center shear key

The maximum stress ratio for flexure and membrane forces of basemat, $\{\sigma/\sigma_a\}_{max}$, is re-estimated adding the factor of the shear key height change impact ratio, $K1$. The basemat elements, 227 and 16085 are selected.

$$K1 \times \{\sigma/\sigma_a\}_{max} = 1.44 \times 0.594 = 0.855 < 1.0 \quad \text{OK}$$

where,

σ : original maximum basemat rebar stress

σ_a : allowable rebar stress

It is confirmed from this calculation that the basemat design is still adequate considering Center shear key design condition change.

D.5 CONCLUSION

It is concluded that shear keys of the FWSC structures are adequately designed to resist the request of the sliding capacity increment with the change of shear key height.

Table D-1 Maximum Stress Ratios (Basemat) for Flexure and Membrane Forces

Location	Element	Concrete		Primary Reinforcement							
				NS direction				EW direction			
				Top		Bottom		Top		Bottom	
	ID	σ/σ$_a$	Load ID	σ/σ$_a$	Load ID	σ/σ$_a$	Load ID	σ/σ$_a$	Load ID	σ/σ$_a$	Load ID
Basemat EL 4.65	205	0.312	6025	0.518	6042	0.453	6002	0.139	6530	0.190	6014
	206	0.254	6022	0.534	6042	0.372	6002	0.168	6011	0.087	6024
	251	0.312	6025	0.545	6042	0.450	6002	0.139	6534	0.189	6014
	252	0.253	6022	0.532	6042	0.371	6002	0.167	6011	0.088	6024

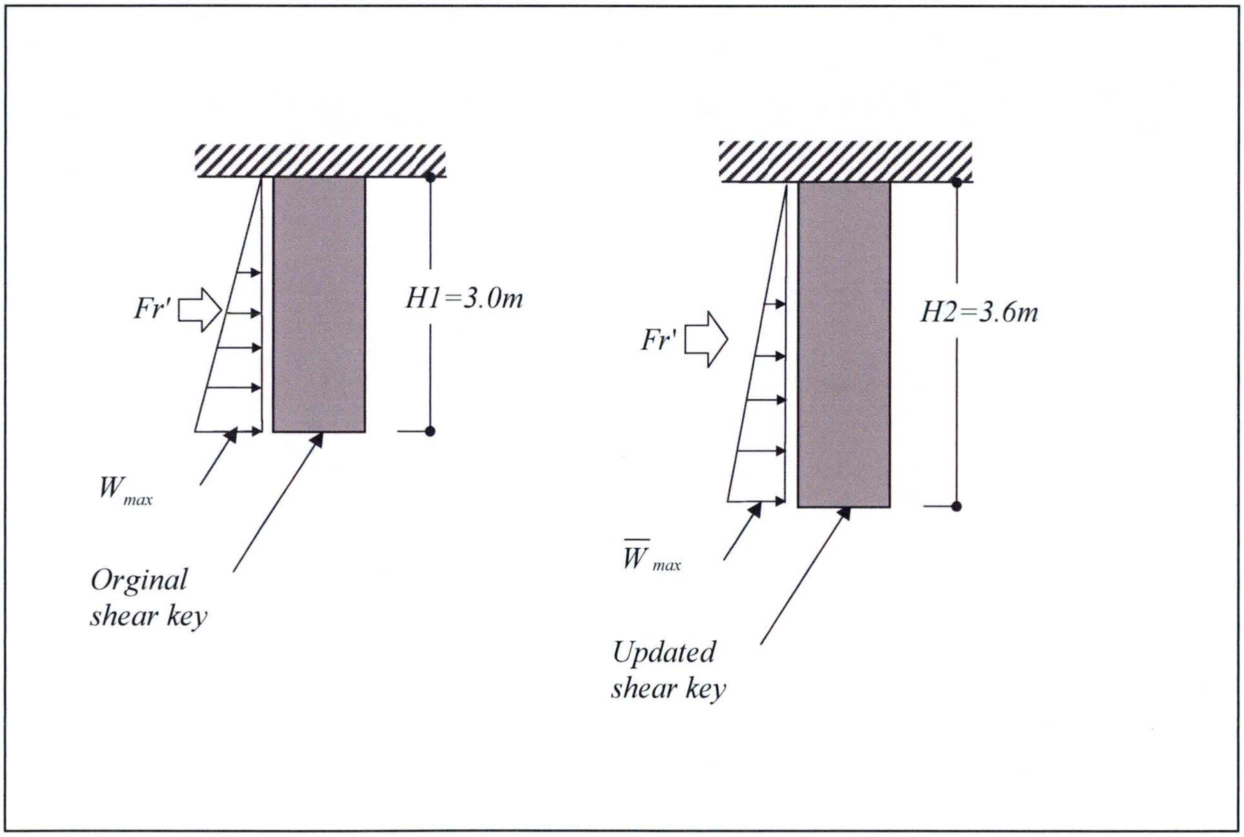

Figure D-1 Schematic View of Shear Key Configuration

APPENDIX E
COMPARISON WITH DCD DATA

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Table E-1 Design Seismic Shear Loads for Horizontal

Elevation (m)	Node No.	NS-direction			EW-direction		
		NA3 (MN)	DCD (MN)	Ratio (NA3/DCD)	NA3 (MN)	DCD (MN)	Ratio (NA3/DCD)
FWS							
19.70	10	4.96	4.58	1.08	5.24	5.11	1.03
17.25	9	4.96	4.58	1.08	5.24	5.11	1.03
17.25	9	12.13	11.10	1.09	12.89	12.08	1.07
15.53	8	12.13	11.10	1.09	12.89	12.08	1.07
15.53	8	16.84	15.48	1.09	17.92	16.50	1.09
13.81	7	16.84	15.48	1.09	17.92	16.50	1.09
13.81	7	20.86	19.34	1.08	22.29	20.12	1.11
12.10	6	20.86	19.34	1.08	22.29	20.12	1.11
12.10	6	23.73	22.82	1.04	25.30	23.76	1.06
11.00	5	23.73	22.82	1.04	25.30	23.76	1.06
11.00	5	25.67	24.62	1.04	27.34	25.31	1.08
9.90	4	25.67	24.62	1.04	27.34	25.31	1.08
9.90	4	27.33	26.15	1.05	29.06	26.56	1.09
8.81	3	27.33	26.15	1.05	29.06	26.56	1.09
8.81	3	42.95	43.28	0.99	44.49	45.46	0.98
6.73	2	42.95	43.28	0.99	44.49	45.46	0.98
6.73	2	44.27	45.32	0.98	46.08	47.98	0.96
4.65	1	44.27	45.32	0.98	46.08	47.98	0.96
FPE							
8.25	405	4.93	8.12	0.61	8.09	7.38	1.10
4.65	404	4.93	8.12	0.61	8.09	7.38	1.10

Note: NA3 is obtained from Reference 2.1.2-l based on site-specific seismic response analysis in References 2.1.2-k, 2.1.2-m and 2.1.2-n.

Table E-2 Design Seismic Moment Loads for Horizontal

Elevation (m)	Node No.	NS-direction NA3 (MN-m)	NS-direction DCD (MN-m)	NS-direction Ratio (NA3/DCD)	EW-direction NA3 (MN-m)	EW-direction DCD (MN-m)	EW-direction Ratio (NA3/DCD)
FWS							
19.70	10	4.83	4.28	1.13	5.22	7.04	0.74
17.25	9	16.13	14.15	1.14	17.27	19.32	0.89
17.25	9	25.86	22.15	1.17	26.46	26.66	0.99
15.53	8	44.75	39.03	1.15	47.75	46.89	1.02
15.53	8	54.30	45.36	1.20	57.49	57.19	1.01
13.81	7	79.96	70.71	1.13	84.36	84.37	1.00
13.81	7	88.93	76.08	1.17	95.05	92.34	1.03
12.10	6	120.57	107.47	1.12	124.95	124.50	1.00
12.10	6	126.39	111.34	1.14	132.69	128.42	1.03
11.00	5	151.72	133.85	1.13	157.13	152.91	1.03
11.00	5	155.06	136.36	1.14	160.28	157.01	1.02
9.90	4	183.63	163.37	1.12	190.39	184.15	1.03
9.90	4	186.58	165.62	1.13	193.32	187.46	1.03
8.81	3	216.50	194.22	1.11	225.10	216.46	1.04
8.81	3	221.20	197.00	1.12	228.81	220.56	1.04
6.73	2	306.02	278.95	1.10	320.47	294.96	1.09
6.73	2	309.86	280.93	1.10	323.87	298.67	1.08
4.65	1	400.55	366.19	1.09	418.66	375.33	1.12
FPE							
8.25	405	2.32	2.17	1.07	7.71	9.67	0.80
4.65	404	18.05	27.70	0.65	30.63	26.97	1.14

Note: NA3 is obtained from Reference 2.1.2-l based on site-specific seismic response analysis in References 2.1.2-k, 2.1.2-m and 2.1.2-n.

Table E-3 Design Seismic Torsion Loads

Elevation (m)	Node No.	Calculated Torsion NA3 (MN-m)	Calculated Torsion DCD (MN-m)	Calculated Torsion Ratio (NA3/DCD)	Accidental Torsion NA3 (MN-m)	Accidental Torsion DCD (MN-m)	Accidental Torsion Ratio (NA3/DCD)	Design Torsion NA3 (MN-m)	Design Torsion DCD (MN-m)	Design Torsion Ratio (NA3/DCD)
FWS										
19.70	10	4.50	0.72	6.22	4.58	4.47	1.03	9.09	5.19	1.75
17.25	9	4.50	0.72	6.22	4.58	4.47	1.03	9.09	5.19	1.75
17.25	9	13.64	2.19	6.23	11.28	10.57	1.07	24.92	12.76	1.95
15.53	8	13.64	2.19	6.23	11.28	10.57	1.07	24.92	12.76	1.95
15.53	8	22.34	3.59	6.22	15.68	14.43	1.09	38.03	18.03	2.11
13.81	7	22.34	3.59	6.22	15.68	14.43	1.09	38.03	18.03	2.11
13.81	7	30.08	4.86	6.19	19.50	17.61	1.11	49.58	22.47	2.21
12.10	6	30.08	4.86	6.19	19.50	17.61	1.11	49.58	22.47	2.21
12.10	6	35.42	5.76	6.15	22.13	20.79	1.06	57.55	26.55	2.17
11.00	5	35.42	5.76	6.15	22.13	20.79	1.06	57.55	26.55	2.17
11.00	5	39.03	6.37	6.12	23.92	22.15	1.08	62.95	28.52	2.21
9.90	4	39.03	6.37	6.12	23.92	22.15	1.08	62.95	28.52	2.21
9.90	4	41.89	6.89	6.08	25.43	23.24	1.09	67.32	30.13	2.23
8.81	3	41.89	6.89	6.08	25.43	23.24	1.09	67.32	30.13	2.23
8.81	3	45.14	7.50	6.02	38.93	39.78	0.98	84.07	47.28	1.78
6.73	2	45.14	7.50	6.02	38.93	39.78	0.98	84.07	47.28	1.78
6.73	2	47.70	8.13	5.87	40.32	41.98	0.96	88.01	50.11	1.76
4.65	1	47.70	8.13	5.87	40.32	41.98	0.96	88.01	50.11	1.76
FPE										
8.25	405	9.58	15.05	0.64	5.38	5.40	1.00	14.95	20.45	0.73
4.65	404	9.58	15.05	0.64	5.38	5.40	1.00	14.95	20.45	0.73

Note: NA3 is obtained from Reference 2.1.2-l based on site-specific seismic response analysis in References 2.1.2-k, 2.1.2-m and 2.1.2-n.

Table E-4 Maximum Response Force of Water for Horizontal SSE

Elevation (m)	NS-direction			EW-direction			Remark
	NA3 (MN)	DCD (MN)	Ratio (NA3/DCD)	NA3 (MN)	DCD (MN)	Ratio (NA3/DCD)	
12.10	1.11	2.18	0.51	0.69	2.18	0.32	Convective
8.81	14.25	15.94	0.89	15.83	19.18	0.83	Impulsive

Note: NA3 is obtained from Reference 2.1.2-l based on site-specific seismic response analysis in References 2.1.2-k, 2.1.2-m and 2.1.2-n.

Table E-5 Vertical Acceleration

FWS					
Elevation (m)	Node No.	Stick Model	NA3 (g)	DCD (g)	Ratio (NA3/DCD)
19.70	10	FWS	1.43	1.69	0.85
17.25	9	FWS	1.43	1.64	0.87
15.53	8	FWS	1.40	1.58	0.89
13.81	7	FWS	1.35	1.58	0.85
12.10	6	FWS	1.27	1.43	0.89
11.00	5	FWS	1.21	1.23	0.99
9.90	4	FWS	1.15	1.13	1.02
8.81	3	FWS	1.07	1.05	1.02
6.73	2	FWS	0.92	1.00	0.91
4.65	8002	FWSC	0.95	0.78	1.22
2.15	8001	FWSC	1.00	0.78	1.27
19.70	11	Oscillator	3.98	3.26	1.22
19.70	12	Oscillator	2.78	–	–
FPE					
Elevation (m)	Node No.	Stick Model	NA3 (g)	DCD (g)	Ratio (NA3/DCD)
8.25	405	FPE	0.78	1.12	0.70
6.45	402	FPE	0.72	1.09	0.66
8.25	13	Oscillator	1.88	–	–

Note: NA3 is obtained from Reference 2.1.2-l based on site-specific seismic response analysis in References 2.1.2-k, 2.1.2-m and 2.1.2-n.

Table E-6 Lateral Resistance Force at Shear Key

Lateral Resistance Force at Shear Key (Fr')					
NA3		DCD		Ratio (NA3/DCD)	
NS-direction (MN)	EW-direction (MN)	NS-direction (MN)	EW-direction (MN)	NS-direction	EW-direction
82	71	58	58	1.41	1.23

Note: NA3 is obtained from Reference 2.1.2-l based on site-specific seismic response analysis in References 2.1.2-j and 2.1.2-n.

Table E-7 Maximum Stress Ratios (Basemat and Slabs) for Flexure and Membrane Forces

Location	Element	Concrete				
		NA3		DCD		Ratio (NA3/DCD)
	ID	σ/σ_a	Load ID	σ/σ_a	Load ID	
Basemat EL 4.65	18	0.384	6045	0.487	6047	0.79
	227	0.604	6047	0.650	6027	0.93
	237	0.619	6027	0.657	6047	0.94
	16085	0.342	6028	0.371	6027	0.92
Roof of FPE EL 8.25	51556	0.308	6005	0.416	6051	0.74
	51558	0.197	6046	0.219	6014	0.90
	51576	0.532	6045	0.556	6045	0.96
	51578	0.366	6053	0.374	6053	0.98
Roof of Tank	26007	0.113	4011	0.113	4011	1.00
	26079	0.306	6029	0.294	6024	1.04
	26082	0.215	4013	0.215	4013	1.00
	26085	0.177	2002	0.177	2002	1.00

Note: σ_a is shown in Table 6.4-2.

Table E-7 Maximum Stress Ratios (Basemat and Slabs) for Flexure and Membrane Forces (Continued)

Location	Element	Primary Reinforcement																			
		NS direction										EW direction									
		Top					Bottom					Top					Bottom				
		NA3		DCD		Ratio (NA3/DCD)	NA3		DCD		Ratio (NA3/DCD)	NA3		DCD		Ratio (NA3/DCD)	NA3		DCD		Ratio (NA3/DCD)
	ID	σ/σ_a	Load ID	σ/σ_a	Load ID		σ/σ_a	Load ID	σ/σ_a	Load ID		σ/σ_a	Load ID	σ/σ_a	Load ID		σ/σ_a	Load ID	σ/σ_a	Load ID	
Basemat EL 4.65	18	0.736	6050	0.762	6050	0.97	0.190	6536	0.248	6047	0.77	0.187	6016	0.218	6047	0.86	0.337	6056	0.425	6056	0.79
	227	0.531	6016	0.626	6016	0.85	0.553	6027	0.565	6027	0.98	0.389	6041	0.302	6049	1.29	0.594	6013	0.729	6013	0.81
	237	0.866	6056	0.949	6056	0.91	0.697	6016	0.776	6015	0.90	0.552	6054	0.619	6054	0.89	0.526	6014	0.598	6014	0.88
	16085	0.394	6015	0.478	6015	0.82	0.508	6034	0.576	6036	0.88	0.084	6551	0.103	6508	0.82	0.399	6010	0.452	6016	0.88
Roof of FPE EL 8.25	51556	0.524	6055	0.477	6055	1.10	0.452	6027	0.499	6027	0.91	0.530	6053	0.363	6513	1.46	0.529	6005	0.576	6005	0.92
	51558	0.485	6055	0.541	6055	0.90	0.442	6535	0.502	6535	0.88	0.479	6526	0.521	6525	0.92	0.395	6526	0.441	6527	0.90
	51576	0.744	6053	0.786	6053	0.95	0.470	6025	0.510	6033	0.92	0.838	6045	0.907	6045	0.92	0.318	6525	0.371	6525	0.86
	51578	0.580	6053	0.636	6053	0.91	0.263	6507	0.321	6507	0.82	0.503	6055	0.555	6055	0.91	0.329	6533	0.378	6533	0.87
Roof of Tank	26007	0.237	6547	0.200	6547	1.18	0.142	6527	0.114	6527	1.25	0.209	6545	0.177	6545	1.18	0.130	6525	0.108	6525	1.21
	26079	0.403	6045	0.398	6045	1.01	0.254	6025	0.240	6025	1.06	0.226	6053	0.234	6053	0.96	0.161	6505	0.158	6025	1.02
	26082	0.542	6047	0.531	6047	1.02	0.331	6025	0.294	6025	1.13	0.564	6047	0.549	6047	1.03	0.292	6027	0.282	6027	1.04
	26085	0.541	6047	0.516	6047	1.05	0.223	6527	0.180	6527	1.24	0.536	6047	0.518	6047	1.03	0.362	6027	0.338	6027	1.07

Note: σ_a is shown in Table 6.4-3.

Table E-8 Maximum Stress Ratios (Walls) for Flexure and Membrane Forces

Location	Element ID	Concrete				
		NA3		DCD		Ratio (NA3/DCD)
		σ/σ_a	Load ID	σ/σ_a	Load ID	
South Wall of FPE	66004	0.573	6053	0.663	6045	0.86
	66006	0.479	6050	0.491	6050	0.98
	66024	0.363	6007	0.383	6015	0.95
East Wall of FPE	67004	0.437	6052	0.468	6051	0.93
	67006	0.574	6056	0.534	6010	1.07
	67024	0.597	6054	0.605	6045	0.99
Wall of South Tank	35007	0.435	6055	0.390	6047	1.11
	35010	0.394	6047	0.404	6047	0.97
	36507	0.246	6052	0.237	6047	1.04
	36510	0.294	6043	0.234	7025	1.26
	38507	0.128	4012	0.128	4012	1.00
	38510	0.145	6045	0.138	4012	1.05
	45001	0.421	6047	0.405	6041	1.04
	46501	0.260	6051	0.217	4013	1.20
	48501	0.142	4014	0.142	4014	1.00
Shear Key	72008	0.250	6023	0.054	6047	4.62
	73017	0.293	6042	0.274	6046	1.07

Note: σ_a is shown in Table 6.4-2.

Table E-8 Maximum Stress Ratios (Walls) for Flexure and Membrane Forces (Continued)

Location	Element	Primary Reinforcement																			
		Horizontal direction										Vertical direction									
		Inside					Outside					Inside					Outside				
		NA3		DCD		Ratio (NA3/DCD)	NA3		DCD		Ratio (NA3/DCD)	NA3		DCD		Ratio (NA3/DCD)	NA3		DCD		Ratio (NA3/DCD)
	ID	σ/σ_a	Load ID	σ/σ_a	Load ID		σ/σ_a	Load ID	σ/σ_a	Load ID		σ/σ_a	Load ID	σ/σ_a	Load ID		σ/σ_a	Load ID	σ/σ_a	Load ID	
South Wall of FPE	66004	0.451	6513	0.536	6513	0.84	0.417	6053	0.454	6053	0.92	0.596	6513	0.677	6513	0.88	0.541	6053	0.594	6053	0.91
	66006	0.323	6529	0.308	6529	1.05	0.431	6049	0.456	6053	0.94	0.287	6022	0.267	6022	1.08	0.739	6053	0.802	6053	0.92
	66024	0.498	6533	0.547	6525	0.91	0.471	6545	0.512	6545	0.92	0.417	6536	0.483	6536	0.86	0.455	6055	0.502	6055	0.91
East Wall of FPE	67004	0.365	6014	0.405	6014	0.90	0.340	6054	0.361	6054	0.94	0.312	6016	0.365	6016	0.85	0.226	6522	0.241	6522	0.94
	67006	0.668	6014	0.735	6014	0.91	0.657	6054	0.693	6054	0.95	0.601	6010	0.631	6002	0.95	0.534	6042	0.541	6042	0.99
	67024	0.528	6022	0.540	6030	0.98	0.639	6054	0.642	6042	1.00	0.298	6526	0.354	6525	0.84	0.590	6046	0.643	6046	0.92
Wall of South Tank	35007	0.272	6010	0.266	6014	1.02	0.346	6054	0.344	6054	1.01	0.139	6016	0.106	6510	1.31	0.285	6032	0.315	6029	0.90
	35010	0.392	6001	0.371	6001	1.06	0.392	6041	0.379	6041	1.03	0.672	6528	0.749	6528	0.90	0.474	6508	0.531	6507	0.89
	36507	0.430	6029	0.394	6029	1.09	0.396	6051	0.384	6055	1.03	0.351	6501	0.410	6506	0.86	0.237	6056	0.248	6542	0.95
	36510	0.587	6025	0.568	6025	1.03	0.419	6045	0.408	6045	1.03	0.512	6507	0.551	6507	0.93	0.314	6545	0.342	6545	0.92
	38507	0.296	6033	0.283	6026	1.04	0.390	6045	0.380	6045	1.03	0.126	6036	0.120	6028	1.05	0.137	6056	0.146	6554	0.94
	38510	0.366	6027	0.352	6027	1.04	0.438	6047	0.428	6047	1.03	0.166	6027	0.152	6507	1.09	0.161	6547	0.181	6547	0.89
	45001	0.410	6007	0.413	6007	0.99	0.393	6047	0.396	6047	0.99	0.740	6547	0.800	6547	0.93	0.599	6507	0.641	6507	0.93
	46501	0.555	6014	0.521	6035	1.06	0.437	6055	0.422	6047	1.04	0.573	6507	0.619	6515	0.93	0.370	6547	0.383	6547	0.97
	48501	0.364	6027	0.349	6027	1.04	0.452	6047	0.440	6047	1.03	0.120	6507	0.136	6507	0.88	0.172	6547	0.195	6547	0.89
Shear Key	72008	0.350	6023	0.301	6023	1.16	0.245	6051	0.228	6032	1.07	0.431	6023	0.304	6023	1.42	0.322	6003	0.204	6003	1.58
	73017	0.546	6022	0.478	6021	1.14	0.559	6025	0.532	6021	1.05	0.383	6501	0.338	6005	1.13	0.481	6522	0.344	6525	1.40

Note: σ_a is shown in Table 6.4-3.

Table E-9 Maximum Stress Ratios for Membrane Compressive Forces

Location	Element ID	Thickness h (m)	NA3 Load ID	NA3 Calculated Concrete Stress σ_x (MPa)	NA3 σ_y (MPa)	NA3 τ_{xy} (MPa)	NA3 σ_c (MPa)	DCD Load ID	DCD Calculated Concrete Stress σ_x (MPa)	DCD σ_y (MPa)	DCD τ_{xy} (MPa)	DCD σ_c (MPa)	Ratio (NA3/DCD) σ_x	Ratio σ_y	Ratio τ_{xy}	Ratio σ_c
Basemat EL 4.65	18	2.50	6030	2.9	-0.1	-0.7	3.1	6030	2.9	0.0	-0.7	3.1	1.02	10.85	0.98	1.01
	227	2.50	6056	2.6	-4.6	0.5	2.6	6056	2.7	-4.6	0.6	2.8	0.96	1.00	0.98	0.96
	237	2.50	6034	2.0	0.3	0.3	2.0	6034	1.9	0.3	0.3	2.0	1.01	1.01	0.95	1.01
	16085	2.50	6053	2.7	0.9	0.5	2.8	6051	2.8	0.7	0.6	2.9	0.97	1.24	0.91	0.97
Roof of FPE EL 8.25	51556	0.60	6007	0.2	0.0	1.5	1.6	6007	0.2	0.0	1.8	1.9	0.96	1.49	0.84	0.84
	51558	0.60	6005	0.1	1.1	2.1	2.8	6005	0.2	1.2	2.4	3.1	0.91	0.95	0.87	0.89
	51576	0.60	6005	0.3	0.1	1.7	1.9	6005	0.2	0.1	2.1	2.2	1.38	1.08	0.82	0.85
	51578	0.60	6013	0.0	0.6	1.8	2.1	6013	0.0	0.6	2.1	2.4	-0.03	0.92	0.87	0.87
Roof of Tank	26007	0.60	6008	1.2	0.9	-0.1	1.2	6008	1.0	0.8	-0.1	1.0	1.18	1.22	0.96	1.18
	26079	0.60	6006	-0.5	0.7	0.0	0.7	6005	-0.4	0.6	0.0	0.6	1.21	1.15	-26.29	1.15
	26082	0.60	6006	-0.1	0.1	0.7	0.7	6007	0.2	0.4	-0.4	0.7	-0.28	0.24	-1.94	1.10
	26085	0.60	6007	0.2	-0.5	-0.8	0.8	6007	0.2	0.4	0.4	0.7	1.36	-1.19	-2.32	1.14
South Wall of FPE	66004	0.65	6025	1.6	0.8	2.6	3.9	6005	0.1	0.5	3.1	3.5	11.27	1.62	0.84	1.12
	66006	0.65	6013	0.9	2.6	2.0	3.9	6013	0.9	3.1	2.2	4.5	0.91	0.83	0.94	0.88
	66024	0.65	6005	1.4	0.2	-2.3	3.2	6005	1.5	0.2	-2.7	3.6	0.95	1.01	0.87	0.89
East Wall of FPE	67004	0.65	6034	3.6	-0.4	1.0	3.8	6034	3.2	-0.5	1.8	3.9	1.13	0.90	0.55	0.98
	67006	0.65	6034	4.4	2.5	3.6	7.2	6034	4.6	2.8	4.0	7.8	0.96	0.86	0.92	0.93
	67024	0.65	6030	2.9	-0.2	0.5	3.0	6022	3.0	-0.2	0.7	3.2	0.96	0.90	0.72	0.94
Wall of South Tank	35007	1.00	6010	1.0	0.5	1.5	2.3	6010	1.3	1.9	0.7	2.4	0.80	0.28	2.12	0.96
	35010	1.00	6013	0.5	4.1	-0.7	4.2	6013	0.6	4.8	-0.5	4.9	0.77	0.84	1.31	0.86
	36507	1.00	6004	-0.3	0.9	-1.2	1.6	6002	-0.9	1.1	-1.1	1.6	0.28	0.77	1.06	1.00
	36510	1.00	6005	-1.2	1.4	-1.5	2.1	6013	-1.6	2.3	-0.6	2.4	0.72	0.63	2.68	0.89
	38507	1.00	6014	0.5	-0.1	-0.3	0.7	6014	0.5	-0.2	-0.3	0.6	1.12	0.38	0.98	1.10
	38510	1.00	6008	0.7	-0.2	-0.4	0.8	6008	0.7	-0.3	-0.3	0.8	1.04	0.61	1.14	1.09
	45001	1.00	6007	1.1	3.8	-1.6	4.5	6007	1.1	5.0	0.3	5.0	1.01	0.76	-5.39	0.91
	46501	1.00	6007	-1.2	1.5	1.6	2.3	6007	-1.2	1.6	1.6	2.3	1.01	0.93	1.01	0.96
	48501	1.00	6007	0.9	-0.3	-0.1	0.9	6007	0.8	-0.4	-0.1	0.8	1.08	0.76	1.03	1.08
Shear Key	72008	2.00	6048	-0.2	0.2	0.5	0.5	6044	-0.2	0.2	0.5	0.5	1.25	0.94	1.01	0.97
	73017	2.00	6044	5.6	-0.6	0.4	5.6	6044	5.4	-0.7	0.3	5.4	1.04	0.87	1.21	1.04

Note: Compressive forces are positive.

Table E-9 Maximum Stress Ratios for Membrane Compressive Forces (Continued)

Location	Element ID	NA3			DCD			σ_c/σ_a		
		Load ID	σ_c (MPa)	σ_a (MPa)	Load ID	σ_c (MPa)	σ_a (MPa)	NA3	DCD	Ratio (NA3/DCD)
Basemat EL 4.65	18	6030	3.1	20.7	6030	3.1	20.7	0.15	0.15	1.01
	227	6056	2.6	20.7	6056	2.8	20.7	0.13	0.13	0.96
	237	6034	2.0	20.7	6034	2.0	20.7	0.10	0.10	1.01
	16085	6053	2.8	20.7	6051	2.9	20.7	0.14	0.14	0.97
Roof of FPE EL 8.25	51556	6007	1.6	20.7	6007	1.9	20.7	0.08	0.09	0.84
	51558	6005	2.8	20.7	6005	3.1	20.7	0.13	0.15	0.89
	51576	6005	1.9	20.7	6005	2.2	20.7	0.09	0.11	0.85
	51578	6013	2.1	20.7	6013	2.4	20.7	0.10	0.12	0.87
Roof of Tank	26007	6008	1.2	20.7	6008	1.0	20.7	0.06	0.05	1.18
	26079	6006	0.7	20.7	6005	0.6	20.7	0.03	0.03	1.15
	26082	6006	0.7	20.7	6007	0.7	20.7	0.03	0.03	1.10
	26085	6007	0.8	20.7	6007	0.7	20.7	0.04	0.03	1.14
South Wall of FPE	66004	6025	3.9	25.9	6005	3.5	20.7	0.15	0.17	0.90
	66006	6013	3.9	20.7	6013	4.5	20.7	0.19	0.22	0.88
	66024	6005	3.2	20.7	6005	3.6	20.7	0.15	0.17	0.89
East Wall of FPE	67004	6034	3.8	25.9	6034	3.9	25.9	0.15	0.15	0.98
	67006	6034	7.2	25.9	6034	7.8	25.9	0.28	0.30	0.93
	67024	6030	3.0	25.9	6022	3.2	25.9	0.12	0.12	0.94
Wall of South Tank	35007	6010	2.3	20.7	6010	2.4	20.7	0.11	0.11	0.96
	35010	6013	4.2	20.7	6013	4.9	20.7	0.20	0.24	0.86
	36507	6004	1.6	20.7	6002	1.6	20.7	0.08	0.08	1.00
	36510	6005	2.1	20.7	6013	2.4	20.7	0.10	0.11	0.89
	38507	6014	0.7	20.7	6014	0.6	20.7	0.03	0.03	1.10
	38510	6008	0.8	20.7	6008	0.8	20.7	0.04	0.04	1.09
	45001	6007	4.5	20.7	6007	5.0	20.7	0.22	0.24	0.91
	46501	6007	2.3	20.7	6007	2.3	20.7	0.11	0.11	0.96
	48501	6007	0.9	20.7	6007	0.8	20.7	0.04	0.04	1.08
Shear Key	72008	6048	0.5	20.7	6044	0.5	20.7	0.02	0.02	0.97
	73017	6044	5.6	20.7	6044	5.4	20.7	0.27	0.26	1.04

Note: Compressive forces are positive.

Table E-10 Calculation Results for Maximum Transverse Shear

Location	Element ID	NA3 Load ID	NA3 d (m)	NA3 ρ_w (%)	NA3 ρ_v (%)	DCD Load ID	DCD d (m)	DCD ρ_w (%)	DCD ρ_v (%)
Basemat EL 4.65	18	6041	2.240	0.674	0.242	6041	2.243	0.673	0.242
	227	6001	2.053	0.859	0.484	6001	2.055	0.858	0.484
	237	6041	2.044	0.862	0.484	6041	2.045	0.862	0.484
	16085	6001	2.039	0.865	0.242	6001	2.044	0.862	0.242
Roof of FPE EL 8.25	51556	6041	0.453	1.111	0.000	6041	0.465	1.082	0.000
	51558	6041	0.499	1.008	0.000	6041	0.499	1.008	0.000
	51576	6041	0.450	1.118	0.000	6041	0.450	1.118	0.000
	51578	6041	0.457	1.102	0.000	6021	0.462	1.090	0.000
Roof of Tank	26007	6541	0.475	0.679	0.000	6541	0.473	0.682	0.000
	26079	6041	0.451	0.716	0.000	6041	0.451	0.716	0.000
	26082	6041	0.476	0.678	0.000	6041	0.476	0.678	0.000
	26085	6041	0.486	0.664	0.000	6041	0.486	0.664	0.000
South Wall of FPE	66004	4014	0.422	2.387	0.000	4014	0.422	2.387	0.000
	66006	6041	0.436	2.872	0.710	6041	0.436	2.873	0.710
	66024	4011	0.443	1.701	0.000	4011	0.443	1.701	0.000
East Wall of FPE	67004	6021	0.485	1.037	0.000	6021	0.485	1.037	0.000
	67006	6041	0.436	2.864	0.710	6041	0.436	2.862	0.710
	67024	6001	0.443	1.702	0.000	6001	0.443	1.702	0.000
Wall of South Tank	35007	6021	0.735	2.285	0.631	6021	0.735	2.285	0.631
	35010	6541	0.698	1.919	0.631	6541	0.698	1.919	0.631
	36507	6021	0.764	0.878	0.000	6541	0.779	1.721	0.000
	36510	4011	0.772	1.735	0.000	4011	0.772	1.735	0.000
	38507	6041	0.835	0.804	0.000	6041	0.835	0.804	0.000
	38510	4011	0.835	0.804	0.000	4011	0.835	0.804	0.000
	45001	6541	0.698	1.918	0.631	6541	0.698	1.918	0.631
	46501	6541	0.775	1.730	0.000	6541	0.780	1.718	0.000
	48501	6041	0.835	0.804	0.000	7028	0.835	0.804	0.000
Shear Key	72008	6021	1.738	0.711	0.484	6021	1.798	0.419	0.000
	73017	6001	1.735	0.725	0.484	6001	1.737	0.741	0.177

Note: The shear Key of element ID 72008 does not have shear reinforcement in standard design in Reference 2.1.2-i.
The shear reinforcement is added for NA3 as shown in Table 7.1-1.

Table E-10 Calculation Results for Maximum Transverse Shear (Continued)

Location	Element	NA3						DCD						Ratio				
		Load	Shear Forces (MN/m)					Load	Shear Forces (MN/m)					(NA3/DCD)				
	ID	ID	V_u	V_c	V_s	ϕV_n	$V_u/\phi V_n$	ID	V_u	V_c	V_s	ϕV_n	$V_u/\phi V_n$	V_u	V_c	V_s	ϕV_n	$V_u/\phi V_n$
Basemat EL 4.65	18	6041	1.001	1.391	2.244	3.090	0.324	6041	1.036	1.362	2.247	3.067	0.338	0.97	1.02	1.00	1.01	0.96
	227	6001	2.710	1.172	4.114	4.493	0.603	6001	2.674	1.120	4.118	4.452	0.601	1.01	1.05	1.00	1.01	1.00
	237	6041	2.195	1.275	4.096	4.565	0.481	6041	2.432	1.217	4.098	4.517	0.538	0.90	1.05	1.00	1.01	0.89
	16085	6001	1.199	1.672	2.043	3.158	0.380	6001	1.228	1.609	2.048	3.108	0.395	0.98	1.04	1.00	1.02	0.96
Roof of FPE EL 8.25	51556	6041	0.040	0.395	0.000	0.336	0.120	6041	0.039	0.406	0.000	0.345	0.113	1.03	0.97	-	0.97	1.06
	51558	6041	0.127	0.455	0.000	0.386	0.329	6041	0.132	0.453	0.000	0.385	0.343	0.96	1.00	-	1.00	0.96
	51576	6041	0.237	0.427	0.000	0.363	0.653	6041	0.237	0.428	0.000	0.364	0.651	1.00	1.00	-	1.00	1.00
	51578	6041	0.121	0.667	0.000	0.567	0.213	6021	0.078	0.442	0.000	0.375	0.208	1.55	1.51	-	1.51	1.02
Roof of Tank	26007	6541	0.005	0.407	0.000	0.346	0.014	6541	0.005	0.427	0.000	0.363	0.013	1.00	0.95	-	0.95	1.05
	26079	6041	0.109	0.458	0.000	0.389	0.279	6041	0.094	0.454	0.000	0.386	0.243	1.16	1.01	-	1.01	1.15
	26082	6041	0.117	0.459	0.000	0.390	0.299	6041	0.102	0.457	0.000	0.389	0.263	1.14	1.00	-	1.00	1.13
	26085	6041	0.118	0.471	0.000	0.400	0.294	6041	0.103	0.469	0.000	0.399	0.258	1.14	1.00	-	1.00	1.14
South Wall of FPE	66004	4014	0.215	0.459	0.000	0.390	0.551	4014	0.215	0.459	0.000	0.390	0.551	1.00	1.00	-	1.00	1.00
	66006	6041	0.730	0.278	1.282	1.325	0.551	6041	0.730	0.263	1.282	1.313	0.556	1.00	1.05	1.00	1.01	0.99
	66024	4011	0.192	0.491	0.000	0.418	0.460	4011	0.192	0.491	0.000	0.418	0.460	1.00	1.00	-	1.00	1.00
East Wall of FPE	67004	6021	0.230	0.647	0.000	0.550	0.418	6021	0.226	0.826	0.000	0.702	0.322	1.02	0.78	-	0.78	1.30
	67006	6041	0.223	0.290	1.282	1.335	0.167	6041	0.206	0.257	1.282	1.308	0.158	1.08	1.13	1.00	1.02	1.06
	67024	6001	0.247	0.496	0.000	0.421	0.587	6001	0.243	0.494	0.000	0.420	0.579	1.02	1.00	-	1.00	1.01
Wall of South Tank	35007	6021	0.542	0.343	1.920	1.923	0.282	6021	0.553	0.282	1.920	1.871	0.295	0.98	1.22	1.00	1.03	0.95
	35010	6541	0.450	0.283	1.823	1.791	0.251	6541	0.452	0.155	1.823	1.682	0.269	0.99	1.83	1.00	1.06	0.93
	36507	6021	0.112	0.740	0.000	0.629	0.177	6541	0.049	0.499	0.000	0.424	0.116	2.27	1.48	-	1.48	1.53
	36510	4011	0.084	0.753	0.000	0.640	0.132	4011	0.084	0.753	0.000	0.640	0.132	1.00	1.00	-	1.00	1.00
	38507	6041	0.136	0.950	0.000	0.808	0.169	6041	0.122	1.075	0.000	0.914	0.133	1.12	0.88	-	0.88	1.26
	38510	4011	0.228	0.896	0.000	0.762	0.299	4011	0.228	0.896	0.000	0.762	0.299	1.00	1.00	-	1.00	1.00
	45001	6541	0.551	0.066	1.823	1.606	0.343	6541	0.563	0.000	1.823	1.550	0.363	0.98	-	1.00	1.04	0.95
	46501	6541	0.040	0.316	0.000	0.269	0.150	6541	0.039	0.270	0.000	0.229	0.170	1.03	1.17	-	1.17	0.88
	48501	6041	0.147	1.161	0.000	0.987	0.149	7028	0.089	0.810	0.000	0.688	0.130	1.64	1.43	-	1.43	1.15
Shear Key	72008	6021	1.582	1.415	3.483	4.163	0.380	6021	0.376	1.474	0.000	1.253	0.300	4.21	0.96	-	3.32	1.27
	73017	6001	1.131	1.159	3.477	3.940	0.287	6001	0.259	0.966	1.273	1.903	0.136	4.37	1.20	2.73	2.07	2.11

APPENDIX F
IN-PLANE SHEAR CHECK FOR FWSC ACCORDING TO ACI 349-01

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F.1 SCOPE

This appendix describes in-plane shear check for the FWSC according to ACI 349-01.

F.2 IN-PLANE SHEAR CHECK

According to Section 21.6.5.6 of ACI 349-01, the maximum shear strength of a horizontal wall segment per unit length is calculated as follows:

$$Vn_{\max} = 8\sqrt{f_c^{'}}h \quad \text{(For all wall piers)}$$

$$Vn_{\max} = 10\sqrt{f_c^{'}}h \quad \text{(For individual wall piers)}$$

where,

h is wall thickness.

When f_c'=5000 psi and h=25.59 and 39.37 in (=0.65m and 1.00 m) are substituted above the equation for the typical FWSC walls,

1) For all wall piers
   - h=0.65m: $Vn_{\max} = 14476 lb/in = 2.533 MN/m$
   - h=1.00m: $Vn_{\max} = 22271 lb/in = 3.898 MN/m$
2) For individual wall piers
   - h=0.65m: $Vn_{\max} = 18095 lb/in = 3.167 MN/m$
   - h=1.00m: $Vn_{\max} = 27839 lb/in = 4.872 MN/m$

The above values are less than the shear strength defined in Section 21.6.5.2 of ACI 349-01, since Section 21.6.5.2 of ACI 349-01 governs the in-plane shear capacity if the rebar ratio is less than 0.94%, as shown below.

The limiting rebar ratio is obtained by calculating the rebar ratio when the equations in Section 21.6.5.6 and Section 21.6.5.2 of ACI 349-01 are equal as shown below:

$$8\sqrt{f_c^{'}}h = \left(2\sqrt{f_c^{'}} + \rho_n f_y\right)h \quad \text{(For all wall piers)}$$

$$10\sqrt{f_c^{'}}h = \left(2\sqrt{f_c^{'}} + \rho_n f_y\right)h \quad \text{(For individual wall piers)}$$

When f_y=60000 psi and f_c'=5000 psi, the limiting rebar ratio is evaluated as follows:

$$\rho_n = 8\sqrt{f_c^{'}} / f_y = 0.009428$$

The allowable shear force is evaluated by multiplying strength reduction factor ϕ (=0.85) according to Section 9.3.2.3 of ACI 349-01.

1) For all wall piers

   h=0.65m: $Vn_{max} = 12305 lb/in = 2.155 MN/m$

   h=1.00m: $Vn_{max} = 18930 lb/in = 3.315 MN/m$

2) For individual wall piers

   h=0.65m: $Vn_{max} = 15381 lb/in = 2.693 MN/m$

   h=1.00m: $Vn_{max} = 23663 lb/in = 4.143 MN/m$

F.3 CONCLUSIONS

The results of in-plane shear check for selected elements are shown in Table F-1. The allowable shear strength for all wall piers is used conservatively. It is confirmed that the in-plane shear of all elements except for Element 67006 are lower than the allowable shear strength. The in-plane shear check according to Section 21.6.5.6 of ACI 349-01 for the entire East wall of FPE including Element 67006, and the entire West wall are shown in Tables F-2 and F-3 respectively. Conservatively, the thermal reduction due to cracking is not considered except for Tables F-2 and F-3. It is confirmed that the in-plane shear for all walls except for the west wall of the FPE are less than the allowable shear forces evaluated above.

In Table F-3, total in-plane shear (N_{xy_All}) slightly exceeds the allowable shear strength by 0.2%. The actual wall (end to end) is about 10% longer than the wall length used to calculate the wall strength (which is computed using the length used in the model). Therefore, the wall strength based on actual wall length will be greater than the wall strength in Table F-3 and this will cover the 0.2% exceedance.

Table F-1 Maximum Stress Ratios for In-Plane Shear Check

Location	Element ID	Load ID	Total In-Plane Shear N_{xy} (MN/m)*	Thickness h (m)	Primary Reinforce-ment Ratio	Allowable Shear Strength $\phi V_n = \phi 8hf'^{0.5}_c$ (MN/m)**	$N_{xy}/\phi V_n$
South Wall of FPE	66004	6053	1.682	0.65	2.322%	2.155	0.78
	66006	6010	1.246	0.65	2.322%	2.155	0.58
	66024	6033	1.525	0.65	1.935%	2.099	0.73
East Wall of FPE	67004	6046	1.192	0.65	2.322%	2.155	0.55
	67006	6054	3.806	0.65	2.322%	2.155	1.77
	67024	6046	1.288	0.65	1.935%	2.155	0.60
Wall of South Tank	35007	6054	1.454	1.00	2.683%	3.315	0.44
	35010	6044	1.862	1.00	2.683%	3.315	0.56
	36507	6054	1.179	1.00	2.013%	3.315	0.36
	36510	6043	1.712	1.00	2.013%	3.315	0.52
	38507	6054	0.307	1.00	1.342%	3.315	0.09
	38510	6047	0.593	1.00	1.342%	3.315	0.18
	45001	6027	2.094	1.00	2.683%	3.198	0.66
	46501	6047	1.753	1.00	2.013%	3.315	0.53
	48501	6047	0.525	1.00	1.342%	3.315	0.16

Note: Exceedance is highlighted.
* The reduction of thermal stress due to cracking is NOT considered conservatively.
** The reduction of concrete strength due to high temperature described in Section 6.4.1 is considered.

Table F-2 Maximum Stress Ratios for In-Plane Shear Check for East Wall of FPE

Location	**Element ID**	Load ID	Total In-Plane Shear N_{xy} (MN/m)*	Thickness h (m)	Primary Reinforce-ment Ratio	Allowable Shear Strength for individual wall $\phi V_n = \phi 10hf'_c{}^{0.5}$ (MN/m)**	$N_{xy}/\phi V_n$	Total In-Plane Shear N_{xy_All} (MN/m)*	Allowable Shear Strength for all wall $\phi V_n = \phi 8hf'_c{}^{0.5}$ (MN/m)**	$N_{xy\_All}/\phi V_n$
East Wall of FPE	67001	6046	2.276	0.65	2.322%	2.693	0.85	1.608	2.155	0.75
	67002	6045	1.470	0.65	2.322%		0.55			
	67003	6045	0.999	0.65	2.322%		0.37			
	67004	6046	1.028	0.65	2.322%		0.38			
	67005	6046	1.539	0.65	2.322%		0.57			
	67006	6054	2.352	0.65	2.322%		0.87			

Note: *The reduction of thermal stress due to cracking is considered.

** The reduction of concrete strength due to high temperature described in Section 6.4.1 is considered.

Table F-3 Maximum Stress Ratios for In-Plane Shear Check for West Wall of FPE

Location	Element ID	Load ID	Total In-Plane Shear N_{xy} (MN/m)*	Thickness h (m)	Primary Reinforce-ment Ratio	Allowable Shear Strength for individual wall $\phi V_n = \phi 10 h f'_c{}^{0.5}$ ** (MN/m)	$N_{xy}/\phi V_n$	Total In-Plane Shear N_{xy_All} (MN/m)*	Allowable Shear Strength for all wall $\phi V_n = \phi 8 h f'_c{}^{0.5}$ (MN/m) **	$N_{xy\_All}/\phi V_n$
West Wall of FPE	68001	6046	2.184	0.65	2.322%	2.693	0.811	2.160	2.155	1.00 ***
	68003	6046	1.793	0.65	2.322%		0.666			
	68005	6046	2.508	0.65	2.322%		0.931			

Note:* The reduction of thermal stress due to cracking is considered.

** The reduction of concrete strength due to high temperature described in Section 6.4.1 is considered.

*** See Section F.3 for the justification of this minor exceedance.

APPENDIX G
COMPRESSION LIMIT CHECK FOR FWSC ACCORDING TO ACI 349-01

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G.1 SCOPE

Although the FWSC is not structurally integrated with the containment structure, its section design is conservatively taken to be the more limiting of ACI 349-01 (Reference 2.2-a) and 2004 ASME Section III, Division 2, Subsection CC (Reference 2.2-e) requirements and utilizes the existing code conformance check algorithm of the SSDP-2D computer code. A discussion of the SSDP-2D computer program is provided in Section 6.4.1.

The membrane compression check that is described in Section 6.4.2 is based on provisions outlined in Subsection CC-3420 of ASME-2004 (Reference 2.2-e). Table 7.2-7 summarizes the results of this ASME membrane compression check. In order to demonstrate that the FWSC design also satisfies the requirements of ACI 349-01 (Reference 2.2-a), this appendix describes the compression limit check for the FWSC according to ACI 349-01 provisions.

G.2 COMPRESSION LIMIT PER ACI 349-01

According to Section 10.3.5.2 of ACI 394-01 (Reference 2.2-a), the design axial load strength, ϕP_n, of nonprestressed compression members with tie reinforcement shall not be taken greater than the following:

$$\phi P_{n(\max)} = 0.80\phi\left[0.85 f_c' \left(A_g - A_{st}\right) + f_y A_{st}\right] \quad \text{(G-1)}$$

In the Equation G-1, A_g is defined as the gross area of section and A_{st} as the total area of longitudinal reinforcement. Section 10.0 of ACI 349-01 (Reference 2.2-a) defines the ratio of nonprestressed tension reinforcement, ρ, as follows:

$$\rho = \frac{A_s}{bd} \quad \text{(G-2)}$$

Where:

A_s = area of nonprestressed tension reinforcement

b = width of compression face of member

d = distance from extreme compression fiber to centroid of tension reinforcement

Assuming that Ag ≈ bd and As = Ast, Equation G-2 can be re-written as follows:

$$A_{st} = \rho A_g \quad \text{(G-3)}$$

Since ACI 349-01 (Reference 2.2-a) provides allowable design strengths and not stresses, an equivalent allowable stress for compression, σ_a, is defined as follows:

$$\sigma_a = \frac{\phi P_{n(\max)}}{A_g} \quad \text{(G-4)}$$

Combining Equations G-1, G-3, and G-4 results in the following equation for the allowable stress for compression, σ_a, used in the checks performed in this appendix:

$$\sigma_a = 0.80\phi\left[0.85 f_c'(1-\rho)+\rho f_y\right] \quad \text{(G-5)}$$

Where:

ϕ = 0.7 (strength reduction factor for axial compression and axial compression with flexure per Section 9.3.2.2(b) of Reference 2.2-a)

f_c' = specified compressive strength of concrete from Table 6.4-1

ρ = sum of the primary reinforcement ratio at each face (top/inside and bottom/outside) for each Element ID in Table 7.1-1

f_y = specified yield strength of nonprestressed reinforcement from Table 6.4-1

G.3 CONCLUSIONS

The results of the ACI 349-01 compression limit check are shown in Table G-1. The results confirm that the calculated compressive stresses are less than the equivalent allowable stress calculated using Equation G-5. Therefore, the FWSC design meets the compression limit requirements of ACI 349-01 (Reference 2.2-a), as shown by the results of this appendix, as well as the membrane compression limit requirements of ASME-2004 (Reference 2.2-e), as shown by the results in Table 7.2-7.

Table G-1 Membrane Compressive Stress Check According to ACI 349-01

Location	Element ID	Load ID	Calculated Concrete Stress[*1] σ_x (MPa)	σ_y (MPa)	τ_{xy} (MPa)	σ_c (MPa)	Total Primary Reinforcement Ratio[*2] ρ (%)	Allowable Stress[*3,*4] σ_a (MPa)	σ_c/σ_a
Basemat EL 4.65m	18	6030	2.9	-0.1	-0.7	3.1	1.208	15.8	0.20
	227	6056	2.6	-4.6	0.5	2.6	1.309	16.0	0.16
	237	6034	2.0	0.3	0.3	2.0	1.309	16.0	0.13
	16085	6053	2.7	0.9	0.5	2.8	1.309	16.0	0.18
Roof of FPE EL 8.25m	51556	6007	0.2	0.0	1.5	1.6	1.678	18.6	0.09
	51558	6005	0.1	1.1	2.1	2.8	1.678	18.6	0.15
	51576	6025	0.3	0.1	1.7	1.9	1.678	18.6	0.10
	51578	6013	0.0	0.6	1.8	2.1	1.678	18.6	0.11
Roof of Tank	26007	6008	1.2	0.9	-0.1	1.2	1.076	18.6	0.07
	26079	6006	-0.5	0.7	0.0	0.7	1.076	18.6	0.04
	26082	6006	-0.1	0.1	0.7	0.7	1.076	18.6	0.04
	26085	6007	0.2	-0.5	-0.8	0.8	1.076	18.6	0.04
South Wall of FPE	66004	6025	1.6	0.8	2.6	3.9	2.322	18.6	0.21
	66006	6013	0.9	2.6	2.0	3.9	2.322	21.4	0.18
	66024	6005	1.4	0.2	-2.3	3.2	1.935	18.6	0.17
East Wall of FPE	67004	6034	3.6	-0.4	1.0	3.8	2.322	18.6	0.20
	67006	6034	4.4	2.5	3.6	7.2	2.322	21.4	0.34
	67024	6030	2.9	-0.2	0.5	3.0	1.935	18.6	0.16
Wall of South Tank	35007	6010	1.0	0.5	1.5	2.3	2.683	22.2	0.10
	35010	6013	0.5	4.1	-0.7	4.2	2.683	22.2	0.19
	36507	6004	-0.3	0.9	-1.2	1.6	2.013	18.6	0.09
	36510	6005	-1.2	1.4	-1.5	2.1	2.013	18.6	0.11
	38507	6014	0.5	-0.1	-0.3	0.7	1.342	18.6	0.04
	38510	6008	0.7	-0.2	-0.4	0.8	1.342	18.6	0.05
	45001	6007	1.1	3.8	-1.6	4.5	2.683	22.2	0.20
	46501	6007	-1.2	1.5	1.6	2.3	2.013	18.6	0.12
	48501	6007	0.9	-0.3	-0.1	0.9	1.342	18.6	0.05
Shear Key	72008	6048	-0.2	0.2	0.5	0.5	0.754	18.0	0.03
	73017	6044	5.6	-0.6	0.4	5.6	1.258	19.1	0.29

Notes:

*1: Calculated concrete stress values are obtained from Table 7.2-7.

*2: Total primary reinforcement ratio is obtained by summing the primary reinforcement ratio at each face (top/inside and bottom/outside) for each Element ID in Table 7.1-1. If the ratios for Direction 1 and Direction 2 differ, then the minimum value is used for each Element ID.

*3: The allowable stress is calculated according to Equation G-5 of this appendix.

*4: For the section without shear tie, the reinforcement limit of 1% is applied according to Section 14.3.6 of ACI 349-01.