
RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

APR1400 Design Certification

Korea Electric Power Corporation / Korea Hydro & Nuclear Power Co., LTD

Docket No. 52-046

RAI No.: 252-8299
SRP Section: 03.07.02 – Seismic Subsystem Analysis
Application Section: 3.7.2
Date of RAI Issue: 10/19/2015

Question No. 03.07.02-8

10 CFR 50 Appendix S requires that the safety functions of structures, systems, and components (SSCs) must be assured during and after the vibratory ground motion associated with the safe shutdown earthquake (SSE) ground motion through design, testing, or qualification methods. In accordance with 10 CFR 50 Appendix S, the staff reviews the adequacy of the seismic analysis methods used to demonstrate that SSCs can withstand seismic loads and remain functional. SRP Section 3.7.2.II.11 states that to account for accidental torsion, an additional eccentricity of $\pm 5\%$ of the maximum building dimension shall be assumed for both horizontal directions.

Regarding the consideration of accidental torsion, DCD Section 3.7.2.10 states that additional eccentricity of 5 % of the maximum building dimension, perpendicular to load direction that results in an accidental torque, is applied to the static finite element structural model to calculate element forces due to accidental torsion. To assist the staff in evaluating the adequacy of the consideration of accidental torsion, the staff requests the applicant to clarify how the accidental torsion effects are combined with the computed seismic response, including a numerical example that shows the process.

Response

The accidental torsional moments are calculated by multiplying the maximum seismic story shear forces (DCD Tier 2, Table 3.7-22 & 25) of each floor by 5 percent of the maximum building dimension at that floor elevation. The accidental torsional moments are applied in the direction perpendicular to the direction of the shear force considered.

These accidental torsional moments (in the clockwise and counter-clockwise directions), as calculated, are applied at the mass center of each floor with the SSE loads in the static finite element structural model (DCD Tier 2, Section 3.8.4.3.4).

Accidental Torsional moment is defined as:

$$T = F_x \times e_y + F_y \times e_x$$

Here, T : Torsional moment at each level

F_x : E-W directional story shear force at each level

e_y : 5% of the maximum N-S directional building dimensions at each Level

F_y : N-S directional story shear force at each level

e_x : 5% of the maximum E-W directional building dimensions at each Level

For example, the accidental torsional moment at EL. 213.5 ft in the auxiliary building, is calculated as follows:

$$\begin{aligned} T &= 5,425 \text{ kips} \times 7.125 \text{ ft} + 7,174 \text{ kips} \times 7.825 \text{ ft} \\ &= 94,789 \text{ kips-ft} \end{aligned}$$

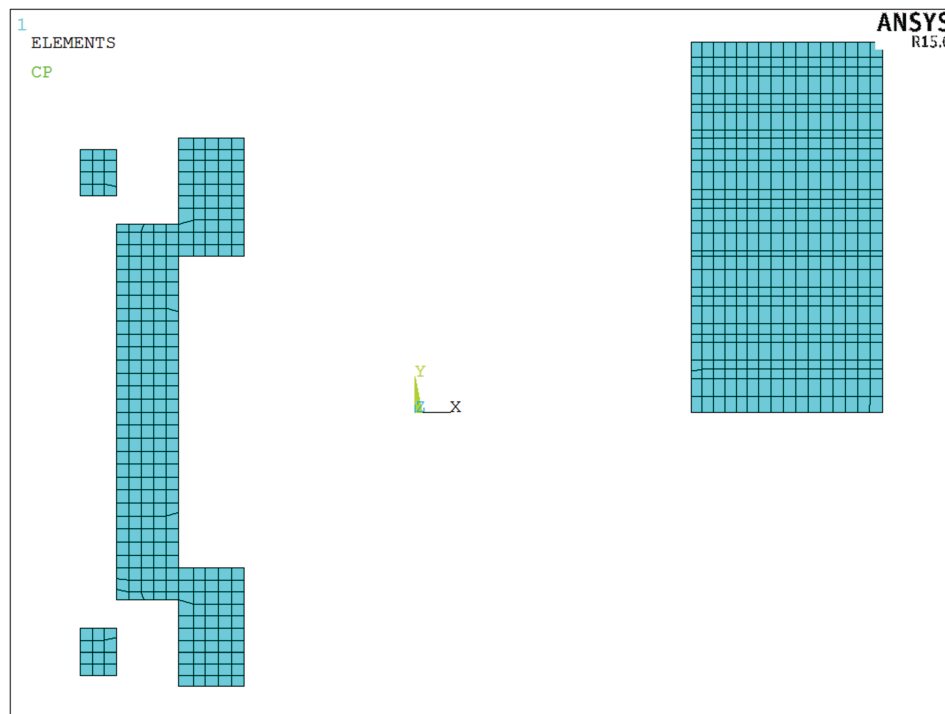
Here, 5,425 kips (In Table 3.7-22)

7.125 ft (5% of 142.5 ft)

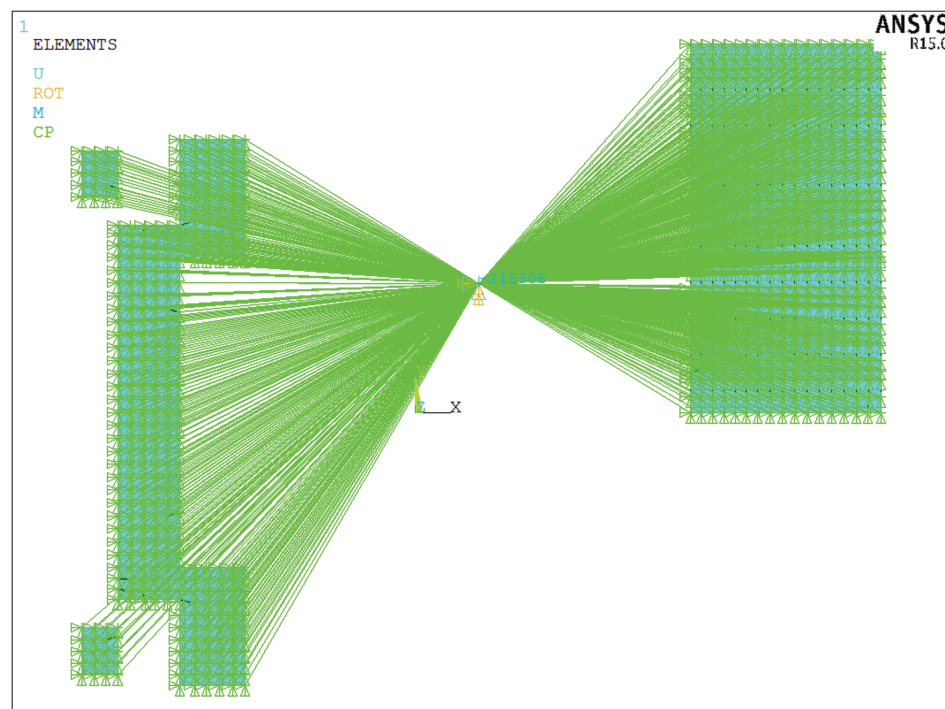
7,174 kips (In Table 3.7-22)

7.825 ft (5% of 156.5 ft)

For developing load combinations with SSE and accidental torsion loading cases, the additional structural ANSYS model is developed, as shown in Figure 1.B. The additional structural model has the same properties as the structural analysis model (Figure 1.A), but all floor nodes are constrained to the mass center, where the accidental torsional moment is applied.



A. Structural Analysis Model at EL. 213.5 ft Floor Level of AB



B. Accidental Torsion Structural Analysis Model at EL. 213.5 ft Floor Level of AB Using Constraint

Figure 1. Accidental Torsion Analysis Model

The analysis results of the SSE and the accidental torsion loading cases for the shear wall element are combined, as shown in the following table. The selected element is shown in Figure 2.

Element No. 139281 (wall)	In-plane Forces			Out-of-plane Moments		
	(kips/ft)			(kips-ft/ft)		
Load Case	N11	N22	N12	M11	M22	M12
1: Load Combination with Seismic (+) ⁽¹⁾	0.63	3.26	26.42	3.06	3.86	0.37
2: Load Combination with Seismic (-) ⁽²⁾	-2.39	-5.52	-20.62	-3.88	-0.38	-2.05
Torsion (Absolute)	1.16	0.15	1.19	0.22	0.06	2.06
Combinations of LC #1	1.79	3.41	27.61	3.28	3.92	2.43
Combinations of LC #2	-3.55	-5.67	-21.81	-4.10	-0.44	-4.11

Note (1): 1.0D + 1.0L + 1.0Lh + 1.0Lg_s + 1.0Lg_d + 1.0Es

Note (2): 1.0D + 1.0L + 1.0Lh + 1.0Lg_s + 1.0Lg_d - 1.0Es

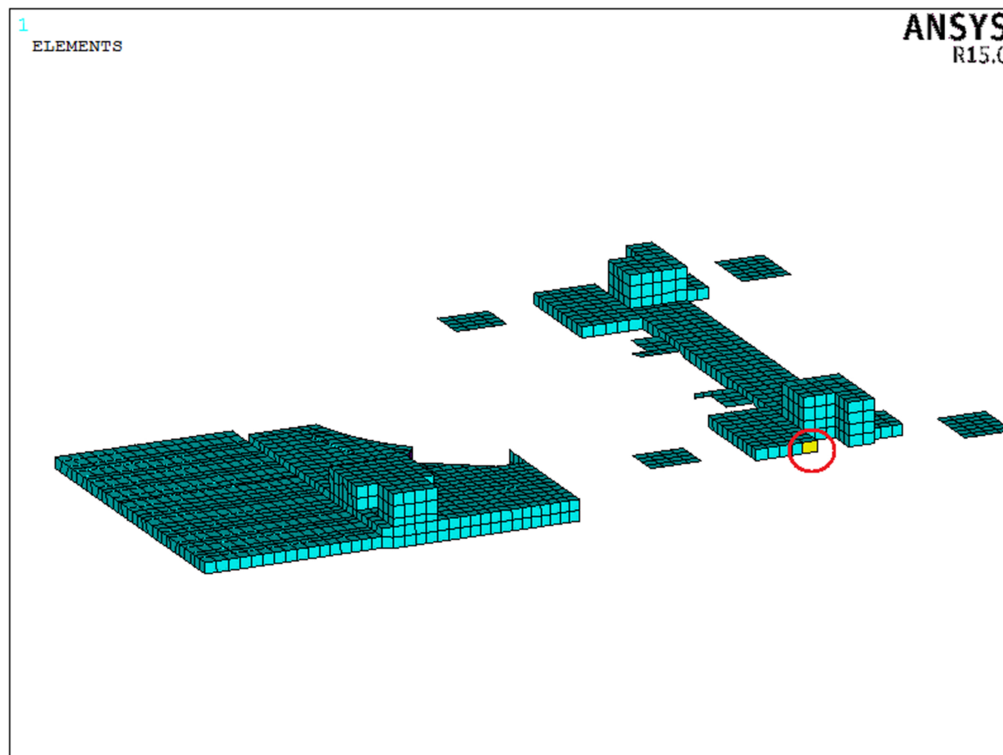


Figure 2. The Selected Element in the Auxiliary Building

The same method is applied to the emergency diesel generator building (EDGB), the diesel fuel oil tank (DFOT) room, and the internal structure (IS).

The accidental torsional moment at EL. 135 ft in the EDGB is calculated as follows:

$$T = 2,860 \times 6.55 \text{ ft} + 2847 \text{ kips} \times 3 \text{ ft}$$

$$= 27,273 \text{ kips-ft}$$

Here, 2,860 kips (In Table 3.7-25)
 6.55 ft (5% of 131 ft)
 2847 kips (In Table 3.7-25)
 3 ft (5% of 60 ft)

The analysis results of the SSE and the accidental torsion loading cases for the shear wall element are combined, as shown in the following table. The selected element is shown in Figure 3.

Element No. 13330005	In-plane Forces			Out-of-plane Moments		
	(kips/ft)			(kips-ft/ft)		
Load Case	N11	N22	N12	M11	M22	M12
1: Load Combination with Seismic (+) ⁽¹⁾	-2.23	6.44	4.54	-1.00	-0.56	0.84
2: Load Combination with Seismic (-) ⁽²⁾	-30.44	-10.92	-10.12	-10.60	-1.83	-1.22
Torsion (Absolute)	0.06	0.01	0.01	0.06	0.03	0.42
Combinations of LC #1	-2.29	6.45	4.55	-1.06	-0.59	1.26
Combinations of LC #2	-30.50	-10.93	-10.13	-10.66	-1.86	-1.64

Note (1): 1.0D + 1.0L + 1.0Es

Note (2): 1.0D + 1.0L - 1.0Es

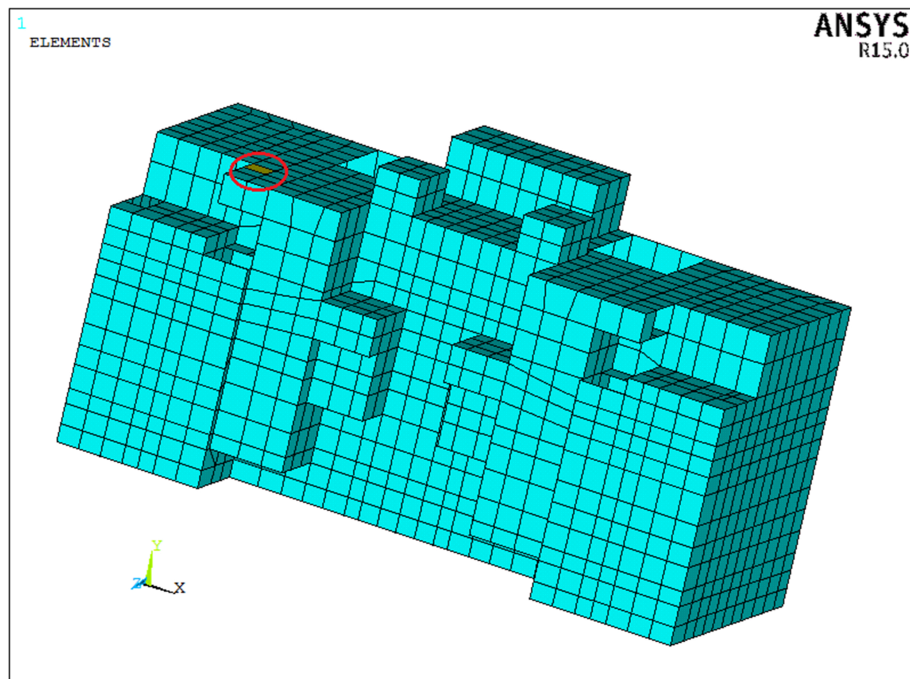


Figure 3. Selected Element in the Emergency Diesel Generator Building

The accidental torsion at EL. 135ft in the DFOT room is calculated as follows:

$$T = 1,051 \text{ kips} \times 6.55 \text{ ft} + 1,170 \text{ kips} \times 3 \text{ ft}$$

$$= 7,005 \text{ kips-ft}$$

Here, 1,051 kips (In Table 3.7-25)
 6.55 ft (5% of 66.5ft)
 1,170 kips (In Table 3.7-25)
 3 ft (5% of 60ft)

The analysis results of the SSE and the accidental torsion loading cases for the shear wall element are combined in the following table. The selected element is shown in Figure 4.

Element No. 11070015	In-plane forces			Out-of-plane moments		
	(kips/ft)			(kips-ft/ft)		
Load Case	N11	N22	N12	M11	M22	M12
1: Load Combination with Seismic (+) ⁽¹⁾	2.96	10.25	6.59	3.62	7.07	32.38
2: Load Combination with Seismic (-) ⁽²⁾	-26.09	-15.50	-30.58	-32.00	-66.52	-16.67
Torsion (Absolute)	0.87	1.00	1.88	2.51	1.29	7.91
Combinations of LC #1	3.84	11.25	8.47	6.12	8.36	40.29
Combinations of LC #2	-26.97	-16.50	-28.70	-34.50	-67.81	-24.57

Note (1): 1.0D + 1.0L + 1.0Lh + 1.0Lg_s + 1.0Lg_d + 1.0Es

Note (2): 1.0D + 1.0L + 1.0Lh + 1.0Lg_s + 1.0Lg_d - 1.0Es

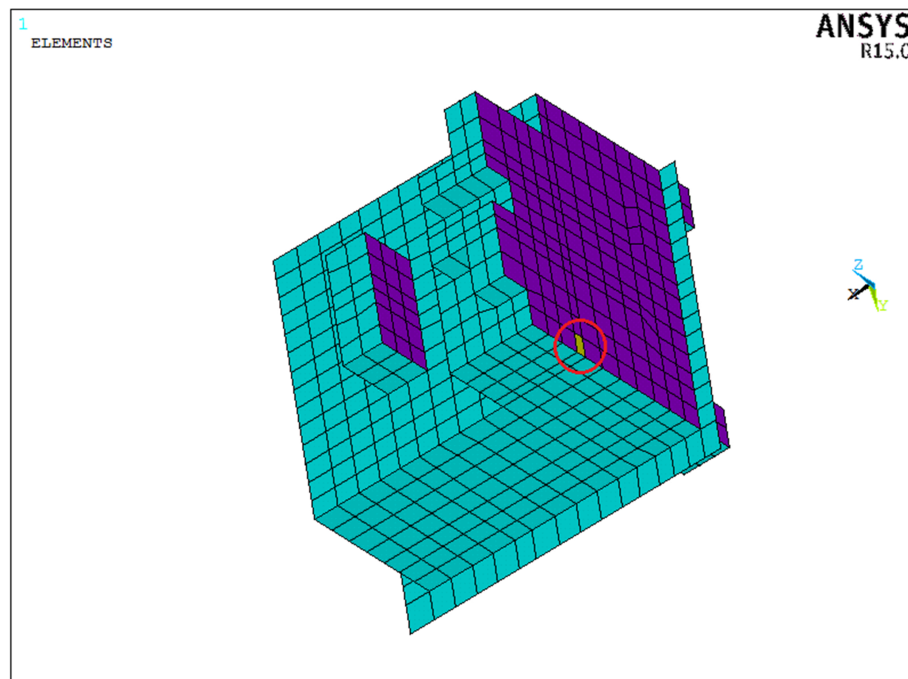


Figure 4. Selected Element in the Diesel Fuel Oil Tank Room

The calculation of the accidental torsion at EL.156 ft in the internal structure is as follows:

The torsion moment of the internal structure (primary shield, secondary shield) is applied as 499,387 kip-ft at EL. 156 ft.

The analysis results of the SSE and the accidental torsion loading cases for the primary shield wall element are combined as shown in following table. The selected element is shown in Figure 5.

Element Node No. 10013	Normal Stress			Shear Stress		
	(kips/ft ²)			(kips/ft ²)		
Load Case	SX	SY	SZ	SXY	SYZ	SXZ
Load Combination without Seismic Load	-0.64	-1.08	-5.40	-0.04	0.59	0.66
Seismic Load without Accidental Torsion	1.44	1.48	3.66	1.87	0.88	3.88
Accidental Torsion (absolute)	0.03	0.04	0.24	0.04	0.34	0.01
Seismic Load Considering Accidental Torsion	1.47	1.52	3.90	1.91	1.22	3.89
Load Combinations of LC #1 ⁽¹⁾	0.82	0.45	-1.50	1.87	1.81	4.55
Load Combinations of LC #2 ⁽²⁾	-2.11	-2.60	-9.29	-1.95	-0.63	-3.23

Note (1): 1.0D + 1.0L + 1.0Lh + 2.8Pa + 1.0Ta + 1.0Yr + 1.0Es (accidental torsion included)

Note (2): 1.0D + 1.0L + 1.0Lh + 2.8Pa + 1.0Ta + 1.0Yr - 1.0Es (accidental torsion included)

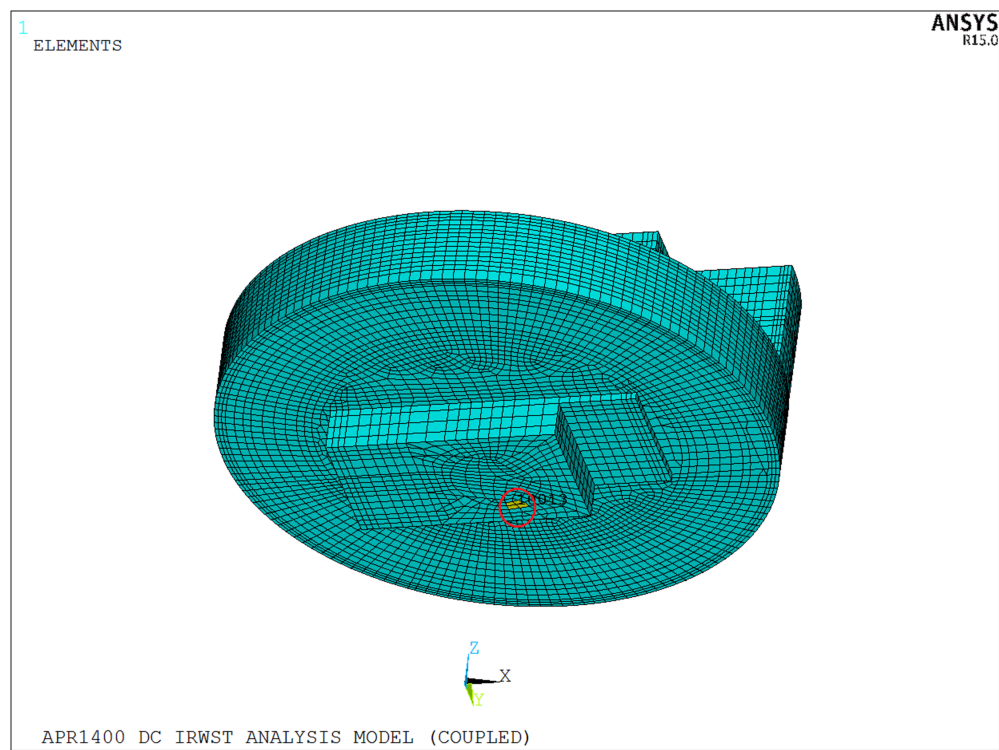


Figure 5. Selected Element in the Primary Shield Wall

The analysis results of the SSE and the accidental torsion loading case for the secondary shield wall element are combined as shown in the following table.

Element No. 10279	In-plane Force			Out-of-plane Moment		
	(kips/ft)			(kips-ft/ft)		
Load Case	N11	N22	N12	M11	M22	M12
Load Combination without Seismic Load	-5.68	-102.99	29.66	2.49	-6.16	17.06
Seismic Load without Accidental Torsion	37.53	138.87	84.93	5.19	6.93	10.49
Accidental Torsion (absolute)	2.17	0.95	20.25	0.59	0.07	0.76
Seismic Load Considering Accidental Torsion	39.70	139.82	105.18	5.78	7.00	11.24
Load Combinations of LC #1 ⁽¹⁾	34.02	36.83	134.85	8.26	0.83	28.30
Load Combinations of LC #2 ⁽²⁾	-45.38	-242.80	-75.52	-3.29	-13.16	5.82

Note (1): 1.0D + 1.0L + 1.0Lh + 2.8Pa + 1.0Yr + 1.0Es (accidental torsion included)

Note (2): 1.0D + 1.0L + 1.0Lh + 2.8Pa + 1.0Yr - 1.0Es (accidental torsion included)

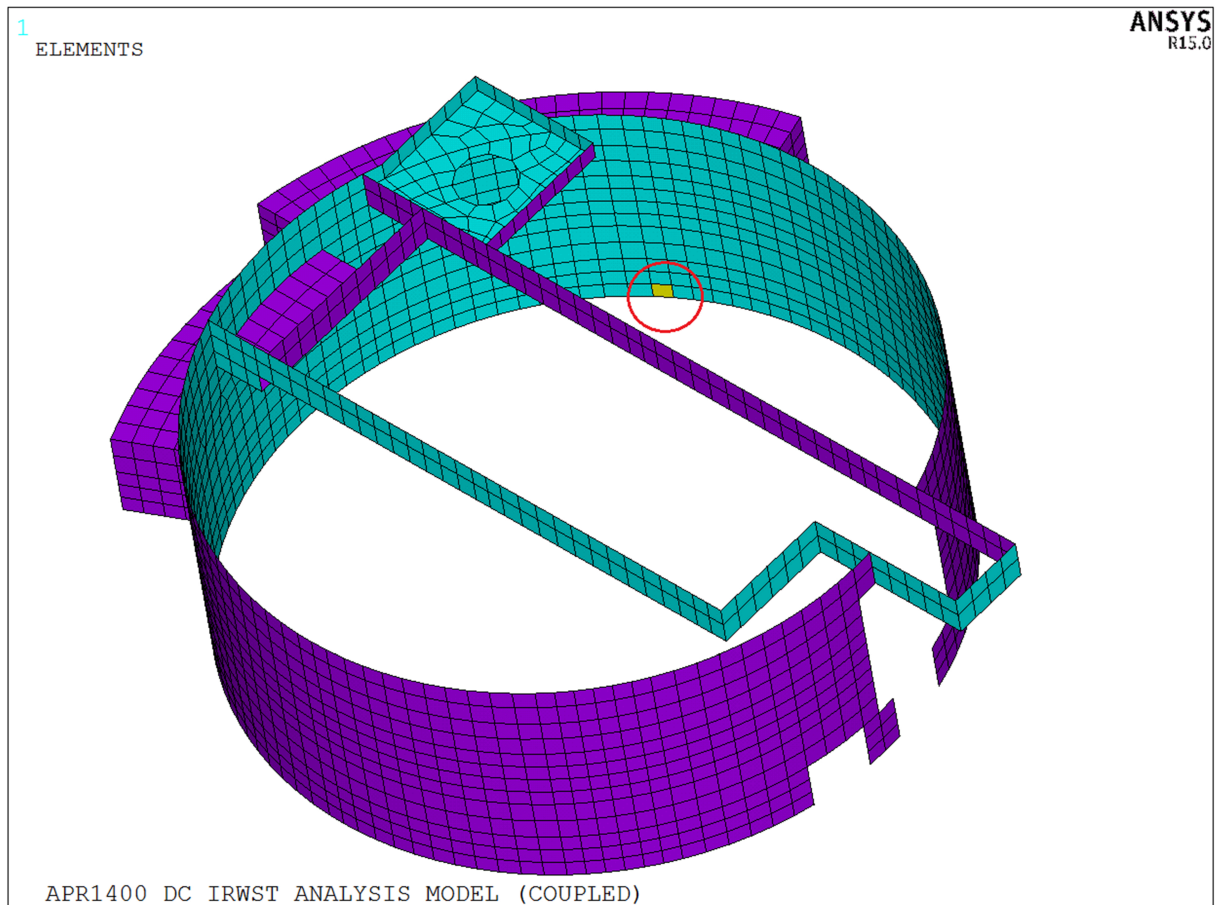


Figure 6. Selected Element in the Secondary Shield Wall

Impact on DCD

There is no impact on the DCD.

Impact on PRA

There is no impact on the PRA.

Impact on Technical Specifications

There is no impact on the Technical Specifications.

Impact on Technical/Topical/Environmental Reports

There is no impact on any Technical, Topical, or Environmental Report.