Table 15.7-3 Minimum Required Freeboard

Value of S_{DS}	Risk Category		
	I or II	III	IV
$S_{DS} < 0.167g$	*a*	*a*	δ_s[c]
$0.167g \le S_{DS} < 0.33g$	*a*	*a*	δ_s[c]
$0.33g \le S_{DS} < 0.50g$	*a*	$0.7\delta_s$[b]	δ_s[c]
$S_{DS} \ge 0.50g$	*a*	$0.7\delta_s$[b]	δ_s[c]

[a]NOTE: No minimum freeboard is required.
[c]Freeboard equal to the calculated wave height, δ_s, is required unless one of the following alternatives is provided: (1) Secondary containment is provided to control the product spill. (2) The roof and supporting structure are designed to contain the sloshing liquid.
[b]A freeboard equal to $0.7\delta_s$ is required unless one of the following alternatives is provided: (1) Secondary containment is provided to control the product spill. (2) The roof and supporting structure are designed to contain the sloshing liquid.

c. If the sloshing is restricted because the freeboard is less than the computed sloshing height, then the roof and supporting structure shall be designed for an equivalent hydrostatic head equal to the computed sloshing height less the freeboard. In addition, the design of the tank shall use the confined portion of the convective (sloshing) mass as an additional impulsive mass.

15.7.6.1.3 Equipment and Attached Piping Equipment, piping, and walkways or other appurtenances attached to the structure shall be designed to accommodate the displacements imposed by seismic forces. For piping attachments, see Section 15.7.4.

15.7.6.1.4 Internal Elements The attachments of internal equipment and accessories that are attached to the primary liquid or pressure retaining shell or bottom or that provide structural support for major elements (e.g., a column supporting the roof rafters) shall be designed for the lateral loads due to the sloshing liquid in addition to the inertial forces by a substantiated analysis method.

15.7.6.1.5 Sliding Resistance The transfer of the total lateral shear force between the tank or vessel and the subgrade shall be considered:

a. For unanchored flat bottom steel tanks, the overall horizontal seismic shear force is permitted to be resisted by friction between the tank bottom and the foundation or subgrade. Unanchored storage tanks shall be designed such that sliding will not occur where the tank is full of stored product. The maximum calculated seismic base shear, *V*, shall not exceed

$$V < W \tan 30° \qquad (15.7\text{-}14)$$

W shall be determined using the effective seismic weight of the tank, roof, and contents after reduction for coincident vertical earthquake. Lower values of the friction factor shall be used if the design of the tank bottom to supporting foundation does not justify the friction value above (e.g., leak detection membrane beneath the bottom with a lower friction factor, smooth bottoms, etc.). Alternatively, the friction factor is permitted to be determined by testing in accordance with Section 11.1.4.
b. No additional lateral anchorage is required for anchored steel tanks designed in accordance with reference documents.
c. The lateral shear transfer behavior for special tank configurations (e.g., shovel bottoms, highly crowned tank bottoms, tanks on grillage) can be unique and are beyond the scope of this standard.

15.7.6.1.6 Local Shear Transfer Local transfer of the shear from the roof to the wall and the wall of the tank into the base shall be considered. For cylindrical tanks and vessels, the peak local tangential shear per unit length shall be calculated by

$$v_{max} = \frac{2V}{\pi D} \qquad (15.7\text{-}15)$$

a. Tangential shear in flat bottom steel tanks shall be transferred through the welded connection to the steel bottom. This transfer mechanism is deemed acceptable for steel tanks designed in accordance with the reference documents where $S_{DS} < 1.0g$.
b. For concrete tanks with a sliding base where the lateral shear is resisted by friction between the tank wall and the base, the friction coefficient value used for design shall not exceed tan 30°.
c. Fixed-base or hinged-base concrete tanks transfer the horizontal seismic base shear shared by membrane (tangential) shear and radial shear into the foundation. For anchored flexible-base concrete tanks, the majority of the base shear is resisted by membrane (tangential) shear through the anchoring system with only insignificant vertical bending in the wall. The connection between the wall and floor shall be designed to resist the maximum tangential shear.