Document: ACI 350.3: Code Requirements for Seismic Analysis and Design of Liquid-Containing Concrete Structures (ACI 350.3) and Commentary
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No.	Public Commenter Name	Pg #	Line #	Public Comment	Committee Response
1.	Rommel Amante			Please maintain the Alternative Procedure that utilizes UBC 1997 for derivation of seismic loads	Disagree. The Committee deleted Appendix B for the following reasons: The IBC and ASCE 7 are now the codes most used for seismic design throughout the world. It is currently unknown if any jurisdictions worldwide are still using the 1997 UBC by legal adoption. The 1997 UBC is 20 years old and is no longer the recommended code for seismic design. It is unlikely that deletion of this Appendix will significantly affect worldwide seismic design methods. If a jurisdiction does want to use the 1997 UBC for seismic design of liquid containing structures, Appendix B in the historical ACI 350.3-06 standard could still be used as a reference. Deletion of Appendix B will simplify the code and will reduce the potential for inconsistencies in code requirements. No change required.
2.	David Mauser	3	10	Should the code references be D110-2013 and D115-2017?	(Preface and Chapt 10, Refs for circ prestressed tanks) Code Change Proposal 350-F-19-01 will update to ANSI/AWWA D110-13 and ANSI/AWWA D115-17 (350-F-19-01).
3.	Eric Wilkins	7	5	The newest ACI 350 has not been released. Based on my knowledge it will be based on ACI 318-11 in which Chapter 13 is for two-way slabs.	ACI 350.3 will be issued at the same time as the next edition of ACI 350

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				Should this be Chapter 21 for Earthquake-Resistant Structures similar to the original ACI 350-06?	which is currently being finalized. The Chapters have been reorganized in the draft version of ACI 350-XX, with Chapter 13 applying to seismic design. No change required.
4.	Eric Wilkins	18	8	Have considerations been made to reduce the Importance Factor for redundant Risk Category IV structures?	(Table 4.1.1a) Adopted ASCE 7-16 Importance Factors for consistency. There is no definition or reduction in Importance Factor for “redundant” Risk Category IV structures. No change required.
5.	Daniel Morgan	18	8	Risk category and importance factors appear to be a repetition of ASCE 7-10 Chapter 1 info. Can ASCE 7-10 be referenced instead of repeated? ASCE 7-10 Section 15.7.7.3 specifically requires the designer to ignore importance factors from ACI 350.3	See response to Soules, Comment 48.
6.	Hamid Lotfi	19	2	Replace r with R (r is used for radius, R is used for response modification factor).	Agree - editorial (Table 4.1.1b)
7.	Eric Wilkins	19	2	The response modification factors and structure types given in Table 4.1.1b do not match up with the values given in ASCE 7 for ground-supported tanks as referenced in the International Building Code. On average it appears that the ACI factors are higher than the ASCE factors resulting in a lower seismic force. Is there a reason why an effort hasn’t been made to make these tables align?	See response to Soules, Comment 48.
8.	Eric Wilkins	19	2	The title for Table 4.1.1b should have a capital R for the response modification factor.	Agree – editorial.
9.	Daniel Morgan	19	2	ASCE 7-10 Chapter 15 provide Response modification factors for tanks, which are different than what is shown here. ASCE 7-10 Section 15.7.7.3 specifically requires the designer to ignore R values from ACI 350.3. Please clarify which standard governs. Each is copying information from the other and each is referencing the other with modifications.	See response to Soules, Comment 48.
10.	Hamid Lotfi	20	1	Dynamic earth pressure is included in Eq. 4.1.2. To be consistent, include dynamic earth pressure in Eq. 4.1.3e.	(Eq 4.1.3e; Note text below eqn) Equation 4.1.3e will be modified to include M_{eg}. Response by K. Monroe.

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11.	Hamid Lotfi	20	6	Dynamic earth pressure is included in Eq. 4.1.2. To be consistent, include dynamic earth pressure in Eq. 4.1.3h.	(4.1.3h; Note text below eqn) Equation 4.1.3h will be modified to include M_{eg}. Response by K. Monroe.
12.	David Mauser	22	17	It appears that ACI 350.3 Ch. 5.3 and ACI 350 load combos 9-5 and 9-7 require the effects of dynamic earth pressure and fluid to be directly added to the factored static earth and fluid effects (without any reduction in the factored static effect from load combo 9-2), such that even in a low seismic region, seismic loads combos will always control the wall design. The only provision to offset the addition of the seismic load is ACI 21.2.1.8 which allows Sd to be omitted with seismic loads, but when Sd is already 1.0 based on bar spacing, etc, this provision doesn't provide any reduction in the overall demand. This is more of an ACI 350 question, but shouldn't the static loads have a smaller load factor in the seismic load combos, such that the seismic load combos would only control in higher seismic regions? Related to ACI 350.3, suggest that there be some discussion added to the commentary on how to apply the dynamic loads in ACI 350 load combos, for the basic tank design cases (i.e. leak tested and full without backfill, backfilled and empty, and backfilled and full).	(5.3.1) – two parts to the response. **Part 1:** Dynamic earth pressure is included in E in the load combinations. The 1.6 load factor in load combinations 9-5 & 9-7 is for static soil pressure. Where 350.3 Chapter 5.3 calls for combining dynamic soil pressure it is to be combined the same way the liquid convective and impulsive forces combine using SRSS to determine the E for load combinations. See Eq. 4.1.2. Seismic forces are applied to the tank's normal operating condition. Short term conditions such as tank overflow occur over so short a period as to be extremely unlikely to have the design seismic event occur. It is prudent to design for seismic considering a tank or one cell of a tank to be empty for an extended time. This should be evaluated on a case by case basis by the licensed design professional. No change required. **Part 2:** Proposed addition to commentary at the end of R1.1: The operational conditions used to calculate the seismic forces

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					determined by ACI 350.3 need to be evaluated by the designer. Considerations such as normal operational liquid levels, potential for a tank or cells within a tank to be empty during a seismic event should be included. It is common to consider several loading conditions when designing for seismic loading, such as with the liquid at normal operating levels and with the tank or individual tank cells empty.
13.	Eric Wilkins	23	6	It is pretty straightforward to combine the dynamic forces on a rectangular tank as the forces all act perpendicular to the wall. For a circular tank the distribution varies and therefore combining the forces will not work. I believe the intent is that because the impulsive and convective forces are out of phase we are allowed to combine them using SRSS. Because with circular tanks the loading varies and can't be combined. Some note either in the body of the code or in the commentary should be added clarifying that the individual design loads (out-of-plane shear, in-plane shear etc) can be combined using SRSS from the various dynamic forces. The code section 6.2 does reference this for hoop stresses.	(5.3.2) The horizontal "pressure" distribution across the diameter of a cylindrical tank at any height is defined by the equations at end of R5.3.3 (pg. 60, lines 6 and 7). Note that: • Only vertical acceleration of the constrained fluid is a pressure acting in all directions. Impulsive and convective fluid "pressures" act only in the direction of the earthquake and can be treated as added mass attached to the wall. • Equations 6.2a and 6.2b use the SRSS horizontal "pressure" distribution for calculation of peak hydrodynamic membrane (hoop) force in the cylindrical tank at a given height, and is only applicable at sections away from boundaries at the

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					base or roof connections (at a distance greater than $1.0\sqrt{r\,t_w}$ *to* $1.7\sqrt{r\,t_w}$ from the boundary). In non-boundary regions impulsive and convective forces are resisted by tangential shear with negligible through-thickness flexure and radial shear • In boundary regions the base restraint prevents the free deformation of the cylinder under load. This results in through-thickness flexure and shear, and results in changes in magnitude of hoop stress and tangential shear. Indeterminate structure analysis using FEA or solutions from shell theory are used for calculating design forces. SRSS is the generally accepted means to account for the effects of out-of-phase dynamic forces (inertia, impulsive, convective, and vertical acceleration) of the container and constrained fluid. Whether used as a means to determine the combined load acting on an element or as a means to combine the effects of component loads, the results are the same because of superposition.
14.	Hamid Lotfi	23	8	Dynamic earth pressure is included in Eq. 4.1.2. To be consistent, include dynamic earth pressure in Eq. 5.3.2.	(Eq 5.3.2) The sentence that follows Equation 5.3.2 states that the dynamic earth

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					pressure shall be included in Eq 5.3.2 where applicable. Equation 4.1.2 indicates how it should be included. The shape of the soil pressure will vary depending on the geotechnical report, and the Design Professional needs to determine the equation for the dynamic earth pressure at any height along the wall. Response prepared by K. Monroe. Add "R5.3.2 - The shape of the dynamic soil pressure will vary depending on the soil conditions, the geotechnical professional should determine the distribution of the dynamic earth pressure at any height on the wall. Also see R8.1."
15.	Eric Wilkins	25	11	Can you explain how this equation was derived? It doesn't appear to match up directly with equation F.78b in TID-7024.	(Eq 7.1b) Eqn 7.1b is correct with lower case "l" replaced with "L/2"and Θ_h replaced with C_c in TID 7024 eqn F.78b. This was confirmed by correspondence with Dr. Housner in the 1990's. No change required.
16.	Eric Wilkins	25	15	Can you explain how this equation was derived? It doesn't appear to match up directly with equation F.115 in TID-7024.	(Eq 7.1d) Eqn 7.1d is correct with R replaced by "D/2"and Θ_h replaced with C_c in TID 7024 eqn F.115. This was confirmed by correspondence with Dr. Housner in the 1990's. No change required.
17.	David Mauser	26	7	There needs to be more guidance on how to calculate dynamic earth pressure. Code discussion on dynamic earth pressure suggests Seed & Whitman (1970) procedure by reference to resultant at 0.6H from base, but does not provide enough information to actually calculate	(8.1) Commentary R8.1 provides the guidance requested. No change required.

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				the seismic component of earth pressure. Suggest including approximate method & formulas (otherwise, many engineers will simply ignore, or significantly under or over-estimate the dynamic earth pressure loading).	
18.	David Mauser	38	11	ASCE 7-10 Section 15.7.7.3 specifically requires the designer to use Tc <= TL, instead of Tc <= 1.6/Ts. Please clarify which standard governs.	See response to Soules, Comment 49.
19.	Daniel Morgan	38	13	ASCE 7-10 Section 15.7.7.3 specifically requires the designer to use Tc > TL, instead of Tc > 1.6/Ts. Please clarify which standard governs.	See response to Soules, Comment 50.
20.	Daniel Morgan	38	14	ASCE 7-10 Equation 15.7-11 is required to be used in lieu of ACI 350.3 equation 9.4.2b. Please clarify which standard governs.	See response to Soules, Comment 51.
21.	Daniel Morgan	38	15	ASCE 7-10 Section 15.7.7.3 requires the designer to refer to section 15.7.2(c) for determination of Ct, instead of using this section from ACI 350.3. However, section 15.7.2 states that “Tanks and vessels…shall be designed in accordance with [ASCE 7] and shall be designed to meet the requirements of [ACI 350.3].” Please clarify which standard governs.	This is a question on the ASCE 7 Standard, no response required.
22.	Eric Wilkins	38	11 thru 14	ASCE 7-10 and 7-16 both have modifications to the equations used to determine the convective acceleration, Cc. These modifications cause the accelerations (and consequently the wave heights) to be significantly higher than the ACI 350.3 equations. The International Building Code references ASCE 7 therefore new concrete tanks need to be designed using the ASCE 7 modifications. Is there a reason why the committee hasn’t adopted the ASCE 7 equations? For various large diameter tanks, I’ve noticed the ASCE modifications to result in the convective acceleration and wave depth to be on the order of 2x the ACI equations.	See responses to Soules, Comments 47, 49, 50, 51.
23.	Hamid Lotfi	47	14	Replace Eq. (4.1e) with Eq. (4.1.2)	(R4.1, 2nd para.) Agree, editorial.
24.	Hamid Lotfi	49	5 to 18	Remove. This paragraph is identical to Lines 12 to 22 of Page 48 and Lines 1 to 4 of Page 49.	Agree, editorial. (R4.1, last 2 paragraphs match paragraphs above – delete last 2 para.)
25.	Eric Wilkins	49	5 thru 18	This is a copy of lines 12-22 on page 48 and 1-4 on page 49.	Agree, editorial. (R4.1, last 2 para.)
26.	Hamid Lotfi	50	13	Variable I is used for importance factor. Use a different notation for moment of inertia.	Agree (R4.1.3) In R4.1.3, revise “$\boldsymbol{I}$” to be “$\boldsymbol{I_b}$” (2 places in the text and one place on the Figure).

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					Add the following to 1.2 Notation: "I_b = moment of inertia at the base of tank"
27.	Eric Wilkins	50	13	Equation (Mo-Mb)/(I/y) should be (Mo-Mb)/(I/x) as shown in Figure R4.1.3.	Agree, editorial. (R4.1.3; Note: Figure R4.1.3 was recently modified to replace y with x.) Figure updated.
28.	Hamid Lotfi	54	13	The distribution of tangential shear in Fig. R5.2.2.b is not illustrated correctly. The direction of tangential shear does not change, however, the figure shows that the direction of shear changes at the location of maximum shear.	Agree. (Fig R5.2.2b) Figure updated.
29.	Hamid Lotfi	55	7	Replace Fig. R5.2.1 with Fig. R5.2.2.a	Agree, editorial.
30.	Hamid Lotfi	56	2	Replace Fig. R5.2.2 with Fig. R5.2.2.b	Agree, editorial.
31.	Eric Wilkins	56	2	Clarify if the reference to Fig. R5.2.2 should be R5.2.2(a).	Editorial, reference should be to Fig. R5.2.2.b.
32.	Hamid Lotfi	56	9	Replace Fig. R5.2.1 with Fig. R5.2.2.a	Agree, editorial.
33.	Eric Wilkins	56	16	It appears the linear approximation lines were removed from Fig. R5.3.1(a). Is there a reason why? It seems linear approximation as an acceptable way to do a quick hand-calc.	Agree (Fig R5.3.1) Figure updated.
34.	Mark W Cunningham	57	1	Changes to R5.3.1 included with LB350-11-02 appear to be missing. Unfortunately, I can't cut and paste from that ballot document because it is not available on ACI website. It includes the following: "Based on the exact distribution, the impulsive and convective pressure distributions are:" and then there should be two new equations for Piy and Pcy (p's should be capital letters here). This should be followed by: "Alternatively, the assumed linear distributions can be used as follows:"	(R5.3.1) LB350-11-02 text added. Linear approximation lines for Fig R5.3.1(a) – see comment 33 above.

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				Note that the Fig R5.3.1(a) no longer shows the linear approximations for impulsive and convective pressures, but the equations correspond to linear distributions.	
35.	Hamid Lotfi	57	4	Remove *	Agree, editorial.
36.	Hamid Lotfi	57	6	Remove *	Agree, editorial.
37.	Mark W Cunningham	58	Fig R5.3.1(b)	The equation numbers referenced in Fig R5.3.1(b) need to be updated: 4-1a should be 4.1b 4-3 should be 4.1d 4-4 should be 4.1e	Agree, editorial. Figure updated
38.	Eric Wilkins	59	2	It appears the linear approximation lines were removed from Fig. R5.3.3. Is there a reason why? It seems linear approximation as an acceptable way to do a quick hand-calc.	Agree. (Fig R5.3.3) Figure updated
39.	Mark W Cunningham	59	5	Changes to R5.3.3 included with LB350-11-02 appear to be missing. Unfortunately, I can't cut and paste from that ballot document because it is not available on ACI website. It includes the following: "Based on the exact distribution, the impulsive and convective pressure distributions are:" and then there should be two new equations for Piy and Pcy (p's should be capital letters here). This should be followed by: "Alternatively, the assumed linear distributions can be used as follows:" Note that the Fig R5.3.3 no longer shows the linear approximations for impulsive and convective pressures, but the equations correspond to linear distributions.	(R5.3.3) LB350-11-02 text added. Linear approximation lines for Fig R5.3.3 – see comment 38 above.
40.	Hamid Lotfi	60	3	Replace Fig. R5.2.1 with Fig. R5.2.2.a	Agree, editorial.
41.	Eric Wilkins	64	8 thru 19	There numerous graphical errors in Fig. R7.1.	Agree, editorial, figure will be fixed.
42.	Eric Wilkins	65	2 thru 12	There numerous graphical errors in Fig. R7.1.	Agree, editorial, figure will be fixed.
43.	Eric Wilkins	66	19	It appears that Θ_o should be q_o.	Agree, editorial. (R5.3.3 For circular tanks…)
44.	Hamid Lotfi	68	11	Replace Eq. (4.1e) with Eq. (4.1.2)	Agree, editorial.

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45.	Eric Wilkins	73	15	The equation includes a units multiplier of 12 to convert tw from inches in feet. I see this unit conversion multiplier in numerous equations throughout the code. With the advent of calculation tools such as MathCAD which account for units I believe equations should not include unit multiplier conversions unless necessary (for instance sqrt(f'c) in ACI 350). It is up to the Engineer to verify they follow thru with their units.	(R9.2.4) Under notations, Section 1.2, the units applicable to each symbol are defined. The equations presented are correct and the variables are defined in accordance with the units commonly used for these calculations. No change required.
46.	J. G. (Greg) Soules, P.E., S.E.	Multiple	Multiple	Update all references from ASCE 7-10 to ASCE 7-16.	Agree, references updated.
47.	J. G. (Greg) Soules, P.E., S.E.	12	17	Add T_L to Section 1.2 – Notation with the following definition "T_L = long-period transition period(s) shown in Figs. 22-14 through 22-17 of ASCE 7-16". T_L is required to determine Cc according to the procedures in ASCE 7-16 and all other tank standards referenced in ASCE 7-16.	T_L definition added to Section 1.2.
48.	J. G. (Greg) Soules, P.E., S.E.	19	2	Revise Table 4.1.1.1b entry (a) Anchored, flexible-base tanks. Revise entry for Ri for "On or above grade" from 3.5 to 3.25 to match comparable entry in ASCE 7-16 Table 15.4-2. Maximum R values used in ASCE 7 /IBC / NEHRP Provisions are determined by the BSSC PUC committee. All tank standards referenced in ASCE 7 use R values determined by the BSSC PUC.	R_i revised to 3.25.
49.	J. G. (Greg) Soules, P.E., S.E.	38	11	Revise For $Tc \leq 1.6/Ts$ s to For $Tc \leq T_L$ s This revision is required to match the method for calculating the convective acceleration from ASCE 7-16 and all other tank standards referenced in ASCE 7-16. 1.6/Ts significantly underestimates the long-period transition period thereby resulting in a significant underestimation of convective forces and seismic freeboard, especially in large diameter tanks. This is a significant life safety issue.	Revised limit on Eq. 9.4.2a per comment.
50.	J. G. (Greg) Soules, P.E., S.E.	38	13	Revise For $Tc > 1.6/Ts$ s to $Tc > T_L$ s This revision is required to match the method for calculating the convective acceleration from ASCE 7-16 and all other tank standards referenced in ASCE 7-16. 1.6/Ts significantly underestimates the long-period transition period thereby resulting in a significant underestimation of convective forces and seismic freeboard, especially in large diameter tanks. This is a significant life safety issue.	Revised limit on Eq. 9.4.2b per comment.

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51.	J. G. (Greg) Soules, P.E., S.E.	38	14	Delete Equation 9.2.4b for Cc and replace with new Equation 9.2.4b Cc = (S_{D1} T_L / T_c^2). This change will match Equation 11.4-7 of ASCE 7-16. The current Equation 9.2.4b significantly underestimates the convective forces and seismic freeboard, especially in large diameter tanks. This is a significant life safety issue. Calculations showing the extreme underestimation of convective forces were sent to ACI staff.	Revised Eq. 9.4.2b to read (match ASCE 7-16, Eq. 15.7-11) $\boldsymbol{C_c} = \frac{(1.5\boldsymbol{S_{D1}}\boldsymbol{T_L})}{(\boldsymbol{T_c})^2}$