SB-0020: CR-2011-03346 evaluation: The response section in the CR states, with reference to study calculation C-CSS-099.20-054 that "This analysis conservatively ignores the embedded vertical reinforcement steel (rebar) at each of the 16 architectural shoulders, Ref. Dwg. C-110. This analysis evaluated the structure for the design basis seismic event (controlling load case for this analysis) using a sectional model for the walls. This is a very conservative modeling technique since all of the main shield building rebar is expected to remain effective. Even with the conservative model, this analysis concluded that the Shield Building is structurally adequate for this controlling load case." FSAR Section 3.8.2.2.6 states that the smallest safety margin provided on the shield building based on ultimate strength design was for vertical reinforcement under load combination DL + LL + E' + TA, which was the controlling load combination. From brief review of study calculation C-CSS-099.20-054, it is the staff's understanding that the vertical reinforcement (outer face only) was removed for evaluating the SB structural integrity only under the DL + E' load combination (which is not the controlling case), and that no rebar is removed for evaluating the thermal loading. Thus, it appears that the controlling load case was not evaluated using the conservative model and the conclusion stated above (in CR 2011-03346) with regard to the conservative model does not appear to be accurate. Please characterize the evaluation in study calculation C-CSS-099.20-054 stating the elevations between which the outer vertical rebar was removed and the load combination considered in the evaluation.

Response

Note: Calculation C-CSS-099.20-054 is an engineering study that was performed as a lower bounding analysis by removing the vertical reinforcing steel in the affected area to show the amount of conservatism in the original analysis. The original design basis calculations continue to represent the current condition of the shield building and are not being superseded by this study analysis.

Question SB-0020 involves four parts and each will be addressed separately. These four parts are:

1) Discussion of controlling load case reported in USAR Section 3.8.2.2.6

2) Controlling load combination used in Calculation C-CSS-099.20-054

3) Removal of rebar for evaluating thermal loading effects

4) Elevations between which the outer vertical rebar was removed

Response Part A (Discussion of controlling load case reported in USAR Section 3.8.2.2.6): The original calculations reported in USAR Section 3.8.2.2.6 follow a very conservative approach to obtain the vertical reinforcement demand for ultimate strength design (refer to calculations VC03-B001-003 and VC03-B001-004). Such approach can be summarized as follows:

P/6

1. Calculate vertical membrane force per unit length (N_y) due to vertical loads (e.g., DL, LL, E_y) per Eq. 1; where *P* is the vertical force acting at the location/elevation of interest, and R is radius of the cylinder centerline (70.75 ft):

$$N_y = \frac{P}{2\pi R} \qquad \text{Eq. 1}$$

2. Calculate vertical membrane force per unit length (N_y) for bending moments (M) due to lateral loads (e.g., W', E') per Eq. 2; where *I* is the moment of inertia of the cylinder (2782305.1 ft^4), *c* is the distance from the Neutral Axis (N.A.) to the extreme fiber in tension or compression (72 ft), and *t* is the cylinder thickness (2.5 ft)

$$N_y = \frac{Mc}{I}t \qquad \text{Eq. 2}$$

3. Calculate thermal moments in the vertical direction (M_y), accounting for concrete cracking, per the methodology presented in ACI 307-69.
4. Design the cylinder shell for the combined effect of the demands calculated in steps 1, 2 and 3 accounting for moment and axial force interaction and concrete cracking.

Vertical demands calculated per the aforementioned procedure are summarized in calculation VC03-B001-004. This approach results in unrealistically large demands for the vertical reinforcement the reason being that Eq. 2 assumes that concrete does not crack under bending moments due to lateral loads, which is inconsistent with the design philosophy of ACI 318-63, ACI 307-69 and modern reinforced concrete design codes (e.g., ACI 349). Note that concrete cracking shifts the Neutral Axis location; which increases the internal moment arm of the vertical reinforcement, and results in lower demands for the vertical reinforcement. Therefore the demand to capacity ratios reported in USAR Section 3.8.2.2.6 for DL + LL + E' + T_A are very conservative and unrealistically large.

Response Part B (Controlling load combination used in Calculation C-CSS-099.20-054**):** Calculation C-CSS-099.20-054 accounts for dead load, seismic and accident temperature demands, in particular the following load combination is considered DL +LL+ E' +T_A., where LL is conservatively ignored since it reduces the demand on the vertical reinforcement. The approach used to calculate the combined demand due to DL+E'+T_A is consistent with ACI 307-69 (Refer to ACI 307-69 supplement) and can be summarized as follows:

(a) Determine the mechanical/external axial and moment demand at the section of interest according to the applicable design load combination (i.e., in the case of interest for D+E').

(b) Calculate the maximum compressive (ε_c) and tensile (ε_{smax}) strains due to mechanical loads (i.e., in the case of interest for D+E') per the procedures presented in Calculation C-CSS-099.20-054 Section 3.2, as shown in Figure 1. Note that similar procedures are presented in ACI 307-69 supplement figure 18 and accompanying equations.

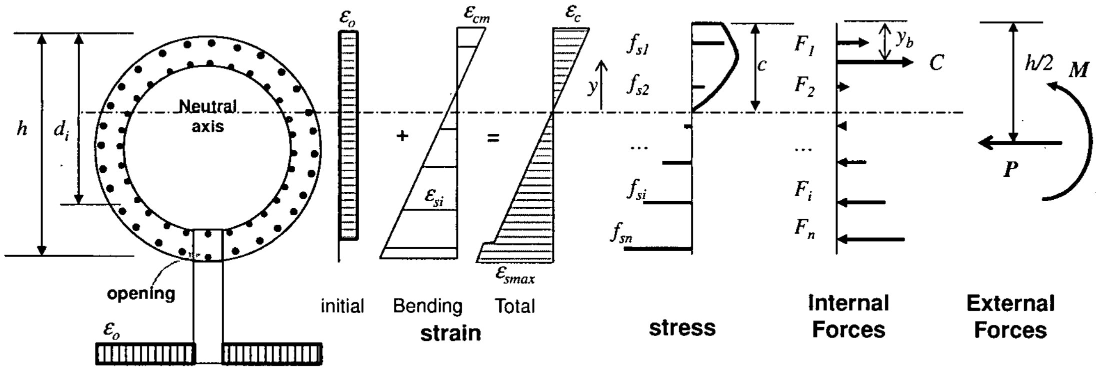

Figure 1: Shield building section showing strain, stress, and force distribution under axial and bending demands

(c) Calculate the maximum compression force (P_c) and tension force (P_t) due to mechanical loads (i.e., in the case of interest for D+E') using the equations shown below, where the maximum stress is conservatively uniformly distributed through the thickness. The forces P_c and P_t are shown in figure 2. Note that similar procedures are presented in ACI 307-69 supplement figure 22.

$P_c = f_c(\varepsilon_c)t$ Maximum compressive force Eq. 3

$P_t = [\![(A]\!]_s + A_s')E_s\varepsilon_{smax}$ Maximum tensile force Eq. 4

(d) Calculate the thermal gradient for the load combination of interest.

(e) Calculate the total demand for (D + E' + T_A) per the procedures presented in sections 3.3.1 and 3.3.2, which are consistent with ACI 307-69 Supplement Section ***EQUATIONS FOR COMBINING STRESSES DUE TO WIND AND DEAD LOAD WITH VERTICAL STRESSES DUE TO TEMPERATURE.***

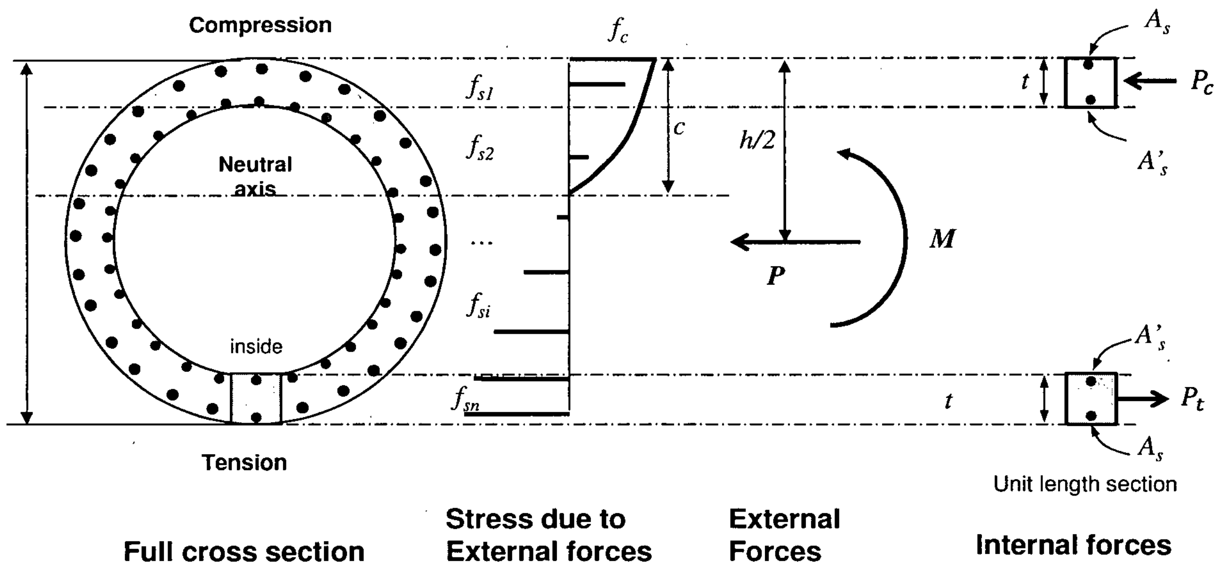

Figure 2: Maximum compression (Pc) and tension (Pt) forces per unit length.

Response Part C: (Removal of rebar for evaluating thermal loading effects) Thermal stresses are produced by the effect of internal or external restraint; temperature changes do not result in thermal stresses for statically determined structures. For reinforced concrete structures, once concrete cracks due to a temperature gradient, thermal moments are only due to the restraint induced by the tensile reinforcement. In the case of the SB cylinder, the O.F. reinforcement provides such restraint. Therefore, the thermal moment is equal to zero if the SB O.F. reinforcement is ignored in the calculation of thermal stresses. Thus Calculation C-CSS-099.20-054, Rev 0 follows the following conservative procedure to calculate the demand due to D+E'+TA:

1. Conservatively ignore the O.F reinforcement to calculate the maximum concrete and steel strains required in Eqs. 3 and 4 to calculate P_t and P_c for the mechanical loads (i.e., in the case of interest for D+E').
2. Conservatively used P_t and P_c from step 1 to calculate the thermal stresses. In this step, conservatively, the O.F reinforcement is not ignored, otherwise the thermal moment will be equal to zero.

Response Part D (elevations between which the outer vertical rebar was removed): the area of O.F. reinforcement at each flute shoulder (~10ft) is ignored from elevation 565' to 806' (i.e., over the complete cylinder high), as shown in the following sketch by red circles.

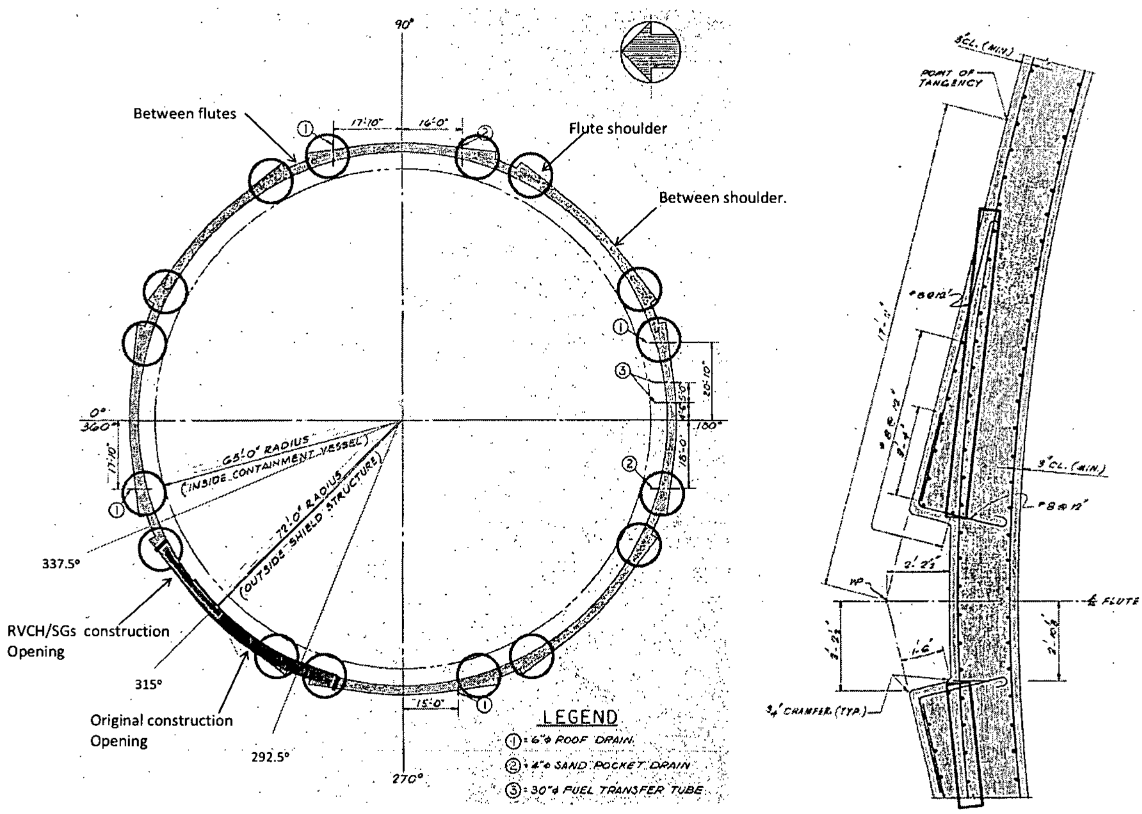

Figure 3: Locations, where O.F reinforcement is conservatively ignored.