Attachment
Director of NRR
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ATTACHMENT E

CRITERIA FOR THE RE-EVALUATION OF CONCRETE MASONRY WALLS

For

Monticello Nuclear Generating Plant

8105210197

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CRITERIA FOR THE RE-EVALUATION

OF CONCRETE MASONRY WALLS

FOR THE

MONTICELLO NUCLEAR POWER PLANT

1.0 GENERAL

1.1 Purpose

This specification is provided to establish design requirements and criteria for use in re-evaluating the structural adequacy of concrete block walls as required by NRC IE Bulletin 80-11, Masonry Wall Design, dated May 8, 1980.

1.2 Scope

The re-evaluation shall determine whether the concrete masonry walls will perform their intended function under loads and load combinations specified herein. Concrete masonry walls not supporting safety systems but whose collapse could result in the loss of required function of safety related equipment or systems shall be evaluated to demonstrate that an SSE or postulated accident will not cause failure to the extent that functions of safety related items is impaired. Verification of wall adequacy shall take into account support condition, global response of wall, and local transfer of load. Evaluation of anchor bolts and embedments are not considered to be within the scope of IE Bulletin 80-11.

2.0 GOVERNING CODES

For the purposes of re-evaluation, the American Concrete Institute "Building Code Requirements for Concrete Masonry Structures" (ACI 531-79) will be used except as noted herein.

3.0 LOADS AND LOAD COMBINATIONS

The walls shall be evaluated for the following loads.

3.1 Service Load Conditions

$D + R + T' + E$

$D + T + W$

3.2 Factored Load Conditions

D + R + T + E' + Px

D + T + W'

3.3 Definition of Terms

D - Dead loads or there related internal moments and forces including any permanent equipment loads.

R - Pipe reactions during normal operating or shutdown conditions, based on the most critical transient or steady-state conditions.

T - Thermal effects and loads during normal operating or shutdown conditions, based on the most critical transient or steady-state conditions.

E - Loads generated by the operating basis earthquake.

W - Loads generated by the design wind specified for the plant.

E'- Loads generated by the safe shutdown earthquake.

W'- Loads generated by the tornado specified for the plant.

Px- Jet impingement load due to postulated pipe break.

NOTE: All walls studied were interior walls. Thermal effects were considered to be negligible. Wind loads do not affect interior walls. Loads T, W and W' were considered to be zero in this evaluation.

4.0 MATERIALS

The project specifications indicate that materials used for the performance of the work were originally specified to meet the following requirements.

4.1 Concrete Masonry Units

Hollow Concrete Blocks: ASTM C-90-66T Grade U-1 with a minimum net compressive strength of 2500 psi.

Solid Units: ASTM C-145-66T Grade U-1 with a minimum net compressive strength of 2000 psi.

4.2 Mortar

ASTM C-270: Type M - 2500 psi for Hollow Units

Type PL - 2000 psi for Solid Units

4.3 Grout

Materials proportioned to produce a grout having a minimum compressive strength of 1500 psi at 28 days.

4.4 Horizontal Joint Reinforcing

"Duro-wall" standard truss type. The thickness of the joint reinforcement measured during the recent inspection was 0.072 inches for the chord members and 0.040 inches for the web members.

4.5 Bar Reinforcement

Hollow Block

ASTM-A15-Intermediate Grade deformed
Yield Stress 40 ksi

Shielding Walls

ASTM-A615 Grade 40

5.0 DESIGN ALLOWABLES

5.1 Stresses

Allowable stresses for the loads and load combinations given in Section 3 will be as given in this section based on the following compressive strengths:

Hollow Concrete Units $f'_m = 1200$ psi

Hollow Concrete Units Grouted Solid $f'_m = 1200$ psi

Solid Concrete Units $f'_m = 1200$ psi

Stresses in the reinforcement and masonry shall be computed using working stress procedures.

The allowable stresses for service loads given in Section 3.1 shall be the S values given in Tables 1 and 2 for reinforced and unreinforced masonry

respectively. The allowable stresses for the factored loads given in Section 3.2 shall be the U values given in Tables 1 and 2 for reinforced and unreinforced masonry respectively.

5.2 Damping

The damping values to be used shall be as follows:

Unreinforced walls

2% - OBE
4% - SSE

Reinforced walls

4% - OBE
7% - SSE

6.0 ANALYSIS AND DESIGN

6.1 Structural Response of Unreinforced Masonry Walls

6.1.1 Out of Plane Effects

1. The wall shall be modeled as a single wythe finite element plate with appropriate boundary conditions. For a multi-mode analysis the modal responses shall be combined using the square root of the sum of the squares.

2. If the calculated stresses exceed the allowables in Step 1, the wall will be evaluated using the alternate acceptance criteria.

6.1.2 Frequency Variations in Out of Plane

Uncertainties in structural frequencies of the masonry wall resulting from variations in mass,, modulus of elasticity, material and section properties shall be taken into account by varying the modulus of elasticity as follows:

Ungrouted walls - $1000f'_m$ to $600f'_m$

Grouted or Solid Walls - $1200f'_m$ to $800f'_m$

If the wall frequency using the lower value of E is on the higher frequency side of the peak of the response spectrum, it is considered conservative to use the lower value of E. If the wall frequency is on the lower frequency side of the peak of the response spectrum, the peak acceleration shall be used. If the frequency of the wall using the higher value of E is also on the lower frequency side of the peak, the higher value of E may be used with its appropriate spectral value provided due consideration is given to frequency variations resulting from all possible boundary conditions.

6.1.3 Combined In Plane and Out of Plane Effects

Provided both the allowable stress criteria for out of plane effects and in plane stress or strain criteria are satisfied, the walls shall be considered to satisfy the re-evaluation criteria. If either criterion is exceeded, walls will be evaluated using the alternate acceptance criteria.

6.1.4 Stress Calculations

All stress calculations shall be performed by conventional methods prescribed by the Working Stress Design method.

6.2 Structural Response of Reinforced Masonry Walls

6.2.1 Out of Plane Effects

The following sequence of analysis methods will be applied.

1. Walls shall be modeled as a finite element plate with appropriate boundary conditions assuming the wall is uncracked. Note that either or both the uncracked section or the section neglecting the block and mortar on the tension side may be used. If the latter is used, the grout core tensile stress is evaluated. If the allowable stresses for an unreinforced wall given in Table 2 are exceeded, the plate will be assumed to crack and the equivalent moment of inertia for a cracked section given in Sec. 6.2.2 shall be used. For a multimode analysis, the modal responses shall be combined using the square root of the sum of squares. If the calculated stresses exceed the allowables of Table 2, the wall will be evaluated using the alternate acceptance criteria.

6.2.2 Equivalent Moment of Inertia

6.2.2.1 Uncracked Condition

The equivalent moment of inertia of an uncracked wall (I_t) shall be obtained from a transformed section consisting of the block, mortar, cell grout or core concrete. (Note that a centrally reinforced wall has the same moment of inertia as an unreinforced section.) Alternatively if the mortar joint is assumed to crack or actually cracks the equivalent moment of inertia may be calculated by neglecting the mortar and block on the tension side.

6.2.2.2 Cracked Condition

If the stresses due to all load combinations exceed the allowables the wall shall be considered to be cracked. In this event the equivalent moment of inertia (I_e) shall either be conservatively calculated from the fully cracked section properties of the wall or as follows:

$$I_e = \left(\frac{M_{cr}}{M_a}\right)^3 I_t + \left[1 - \left(\frac{M_{cr}}{M_a}\right)^3\right] I_{cr} \qquad (1)$$

$$M_{cr} = f_r \left(\frac{I_t}{y}\right) \qquad (2)$$

where:

M_{cr} = Uncracked moment capacity

M_a = Applied maximum moment on the wall

I_t = Moment of inertia of transformed section

I_{cr} = Moment of inertia of cracked section

f_r = S value of tensile stress defined in Table 2 multiplied by 2 for mortar and grout if the masonry joint is assumed to be cracked.

y = Distance of neutral plane from tension face

If I_e of Equation 1 is calculated, this should be used over the full length of the wall. If I_{cr} is used, this can be used in the cracked region only.

If the use of I_e results in an applied moment M_a which is less than M_{cr}, then the wall shall be verified for M_{cr}.

6.2.3 Frequency Variations

Uncertainties in structural frequencies of the masonry wall resulting from variations in mass, modulus of elasticity, material and section properties shall be taken into account by varying the modulus of elasticity from $1200f'_m$ to $800f'_m$. It is considered conservative to use the lower value of E if the wall frequency is on the higher frequency side of the peak response spectrum. If the wall frequency using the lower values of E is on the lower frequency side of peak of the response spectrum the peak acceleration shall be used. If the frequency of the wall using the higher value of E is also on the lower frequency side of the peak, the higher value of E may be used with its appropriate spectral value provided due consideration is given to frequency variations resulting from all possible boundary conditions.

6.2.4 In Plane and Out of Plane Effects

Provided both the allowable stress criteria for out of plane effects and the in plane stress or strain criteria are satisfied, the walls shall be considered to satisfy the re-evaluation criteria. If either criterion is exceeded, the walls shall be considered to satisfy the re-evaluation criteria. If either criterion is exceeded, the walls will be evaluated using the alternate acceptance criteria.

6.2.5 Stress Calculations

All stress calculations shall be performed by conventional methods prescribed by the Working Stress Design method.

6.3 Accelerations

For a wall spanning between two floors, the envelope of the spectra for the floor above and below shall be used to determine the stresses in the walls.

6.4 Interstory Drift Effects

The magnitude of interstory drift effects shall be determined from the original dynamic analysis.

6.5 In Plane Effects

If a masonry wall is a load bearing structural element shear stresses shall be evaluated and compared with the allowable stresses of Tables 1 and 2.

If the wall is an infill panel or non-load bearing element, shear stresses resulting from interstory drift effects will not be calculated. In this case, the imposed interstory deflections of Sec. 6.4 shall be compared to the displacements calculated from the following permissible strains for service loads. For factored loads, the strains shall be multiplied by 1.67. The deflections shall be calculated by multiplying the permissible strain by the wall height.

Unconfined Walls (1)

$$\gamma_u = 0.0001$$

Confined Walls (2)

$$\gamma_c = 0.0008$$

Notes: (1) An unconfined wall is attached on one vertical boundary and its base.

(2) A confined wall is attached in one of the following ways:

(a) On all four sides.
(b) On the top and bottom of the wall.
(c) On the top, bottom and one vertical side of the wall.
(d) On the bottom and two vertical sides of the wall.

If an infill panel or non-load bearing element is subjected to both interstory drift effects and shear stresses due to inplane loads from equipment or piping, the following criteria shall apply.

$$\frac{\text{actual inplane shear stress}}{\text{allowable inplane shear stress}} + \frac{\text{actual inter-story deflection}}{\text{allowable inter-story deflection}} < 1$$

A more refined analysis may be performed if necessary.

6.6 Equipment

If the total weight of attached equipment is less than 100 lbs., the effect of the equipment on the wall shall be neglected. If the total weight of the equipment is greater than 100 lbs., the mass of the equipment shall be added to that of the wall in calculating the frequency of the wall.

Stresses resulting from each piece of equipment weighing more than 100 lbs. shall be combined with the wall inertia loads using the absolute sum method. The SRSS method may be used provided its application is justified.

Stresses resulting from the equipment shall be calculated by applying a static load consisting of the weight of equipment multiplied by the peak acceleration of the response spectrum for the floor level above the wall. If the frequency of the equipment is known, it may be used to determine the static load.

6.7 Distribution of Concentrated Out of Plane Loads

6.7.1 Beam or One Way Action

For beam action, local moments and stresses under a concentrated load shall be determined using beam theory. An effective width of four times the wall thickness shall be used; however, such moments shall not be taken as less than that for two way plate action.

6.7.2 Plate or Two Way Action

For plate action, local moments and stresses under a concentrated load shall be determined using appropriate analytical procedures for plates or determined numerically using a finite element analysis.

A conservative estimate of the localized moment per unit length for plates supported on all edges can be taken as:

$M_L = 0.4P$

where: M_L = Localized moment per unit length (in-lbs/in)

P = Concentrated load perpendicular to wall (lbs)

For loads close to an unsupported edge, the upper limit moment per unit length can be taken as:

$M_L = 1.2P$

6.7.3 Localized Block Pullout

For a concentrated load, block pullout shall be be checked using the allowable values for unreinforced shear walls in Table 2. This allowable shall be used for both reinforced and reinforced walls.

7.0 ALTERNATIVE ACCEPTANCE CRITERIA

7.1 Reinforced Masonry

Where bending due to out-of-plane inertial loading causes flexural stresses in the wall to exceed the allowable stresses for reinforced walls, the wall can be evaluated by the "energy balance technique."

7.1.1 Effects on Equipment

If the deflection calculated by the energy balance technique exceeds three times the yield deflection, the resulting deflection shall be multiplied by a factor of 2 and a determination made as to whether such factored displacements would adversely impact the function of safety-related systems attached and/or adjacent to the wall.

7.1.2 Effects on Walls

The maximumm deflection in the wall due to out-of plane inertia loading shall be limited to 5 times the yield displacement. The yield displacement shall be calculated by reinforced concrete ultimate strength theory, and the masonry compression stresses of $0.85f'_m$ based on a rectangular stress distribution shall be used.

7.2 Unreinforced Masonry

When, due to out-of-plane loading, the allowable stresses for unreinforced masonry are exceeded, the arching theory for masonry walls may be used to measure the capacity of the walls. Due regard must be paid to the boundary conditions.

7.2.1 Limiting Deflection

The deflection of the three hinged arch could be determined by assuming that the arch members are analogous to regular compression members in a truss. The method of virtual work (unit load method) may be used to compute the deflection at the arch interior hinge. The calculated deflection should not be more than 0.3T where the "T" is the thickness of the wall. A determination should be made as to whether such calculated displacements would adversely impact the function of safety-related systems attached and/or adjacent to the wall.

7.2.2 Allowable Stresses

The total resistance of the wall (f) shall be calculated using the following stresses:

I. Tensile stress through the assumed tension crack shall be $6\sqrt{f'_c}$ for grouted walls or f_t for ungrouted walls.

II. The crushing stress of block material = 0.85f'm.

By applying a factor of safety of 1.5 to the total resistance (f) as calculated above, the aboveable load on the wall is limited to f /1.5.

7.2.3 Boundary Supports

The boundary supports should be checked if they are capable of transmitting the reaction forces applied to them. The effect of support stiffness on the reaction forces should be considered.

Table 1: Allowable Stresses in Reinforced Masonry

Description	S		U	
	Allowable (psi)	Maximum (psi)	Allowable (psi)	Maximum (psi)
Compressive				
Axial(1)	$0.22f'_m$	1000	$0.44f'_m$	2000
Flexural	$0.33f'_m$	1200	$0.85f'_m$	2400
Bearing				
On full area	$0.25f'_m$	900	$0.62f'_m$	1800
On one-third area or less	$0.375f'_m$	1200	$0.95f'_m$	2400
Shear				
Flexural members(2)	$1.1\sqrt{f'_m}$	50	$1.7\sqrt{f'_m}$	75
Shear Walls(3,4)				
Masonry Takes Shear				
$M/Vd \geq 1$	$0.9\sqrt{f'_m}$	34	$1.5\sqrt{f'_m}$	56
$M/Vd = 0$	$2.0\sqrt{f'_m}$	74	$3.4\sqrt{f'_m}$	123
Reinforcement Takes Shear				
$M/Vd \geq 1$	$1.5\sqrt{f'_m}$	75	$2.5\sqrt{f'_m}$	125
$M/Vd = 0$	$2.0\sqrt{f'_m}$	120	$3.4\sqrt{f'_m}$	180
Reinforcement				
Bond				
Plain Bars		60		80
Deformed Bars		140		186
Tension				
Grade 40		20,000		$0.9F_y$
Grade 60		24,000		$0.9F_y$
Joint Wire		$.5F_y$ or 30,000		$0.9F_y$
Compression		$0.4F_y$		$0.9F_y$

R2-1

Notes to Table 1:

(1) These values should be multiplied by $\left(1 - \left(\frac{h}{40t}\right)^3\right)$.

(2) This stress should be evaluated using the effective area shown in Figure 1.

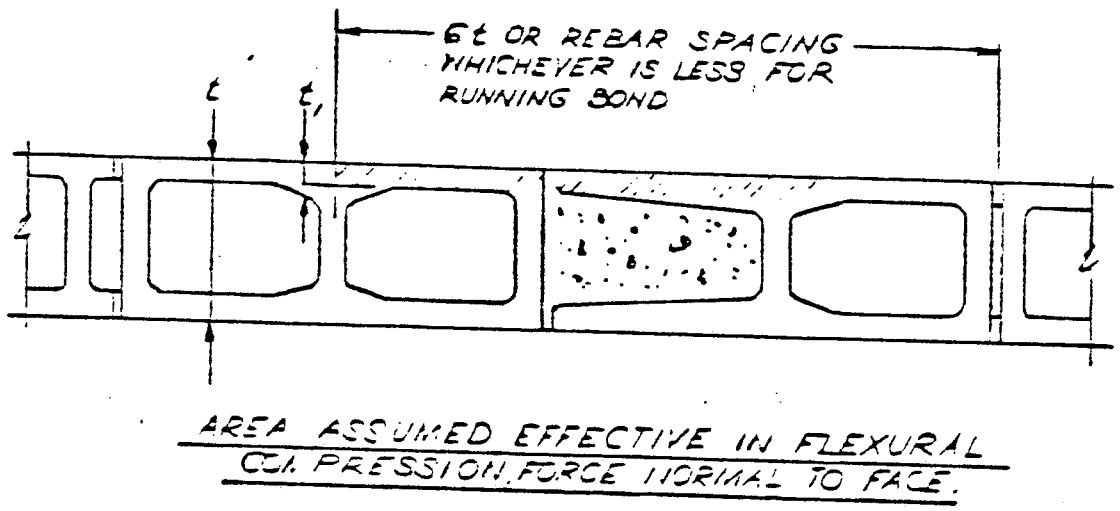

FIGURE 1

(3) Net bedded area shall be used with these stresses.

(4) For M/Vd values between 0 and 1 interpolate between the values given for 0 and 1.

Table 2: Allowable Stresses in Unreinforced Masonry

Description	S		U	
	Allowable (psi)	Maximum (psi)	Allowable (psi)	Maximum (psi)
Compressive				
Axial(1)	$0.22f'_m$	1000	$0.44f'_m$	2000
Flexural	$0.33f'_m$	1200	$0.85f'_m$	3000
Bearing				
On full area	$0.25f'_m$	900	$0.62f'_m$	2250
On one-third area or less	$0.375f'_m$	1200	$0.95f'_m$	3000
Shear				
Flexural members(2,3)	$1.1\sqrt{f'_m}$	50	$1.7\sqrt{f'_m}$	75
Shear walls(2)	$0.9\sqrt{f'_m}$	34	$1.35\sqrt{f'_m}$	51
Tension				
Normal to bed joints				
Hollow units	$0.5\sqrt{\pi_o}$	25	$0.83\sqrt{\pi_o}$	42
Solid or grouted	$1.0\sqrt{\pi_o}$	40	$1.67\sqrt{\pi_o}$	67
Parallel to bed joints(4)				
Hollow units	$1.0\sqrt{\pi_o}$	50	$1.67\sqrt{\pi_o}$	84
Solid or grouted	$1.5\sqrt{\pi_o}$	80	$2.5\sqrt{\pi_o}$	134
Grout Core	$2.5\sqrt{f'_c}$		$4.2\sqrt{f'_c}$	

Notes to Table 2:

(1) These values should be multiplied by $\left(1 - \left(\frac{h}{40t}\right)^3\right)$.

(2) Use net bedded area with these stresses.

(3) For stacked bond construction use two-thirds of the values specified.

(4) For stacked bond construction use two-thirds of the values specified for tension normal to the bed joints in the head joints of stacked bond construction.