SUPPLEMENT NO. 3 TO LICENSEE EVENT REPORT 79-15

SUPPLEMENTAL STRUCTURAL EVALUATION CRITERIA

FOR

OUT-OF-PLANE LOADS

ON

DOUBLE WYTHE MASONRY WALLS

EB-15

TABLE OF CONTENTS

SUPPLEMENTAL STRUCTURAL EVALUATION CRITERIA

FOR

OUT-OF-PLANE LOADS

ON

DOUBLE WYTHE MASONRY WALLS

1. INTRODUCTION

The supplemental structural evaluation criteria defined herein are applicable to all double wythe masonry walls at the Trojan Nuclear Plant, except walls which are demonstrated to have no safety significance.

Sections 1 through 6 of this document cover the evaluation criteria for load combinations containing safe shutdown (SSE) earthquake loads or tornado loads in addition to normal operating loads.

Appendix A of this document covers supplemental evaluation criteria for load combinations containing OBE loads.

2. GOVERNING CODE AND REFERENCE DOCUMENT

Unless stated otherwise, the evaluation of all masonry walls shall be based on applicable portions of the following code and reference document.

2.1 GOVERNING CODE

a. International Conference of Building Officials, "Uniform Building Code" (UBC), 1967 Edition, Volume 1, Chapter 24.

2.2. REFERENCE DOCUMENT

a. Trojan Final Safety Analysis Report, Section 3.8.1

3. MATERIAL PROPERTIES

The material properties used for the evaluation of the masonry walls shall be in accordance with Tables 3-1 through 3-3.

4. LOADS AND LOAD COMBINATIONS

4.1 GENERAL

This section contains the applicable loads and load combinations for which the double wythe masonry walls shall be evaluated.

4.2 DEFINITIONS OF LOADS

The following definitions are used in the load combination equations:

D = Dead load of structure and equipment plus any other permanent loads contributing stresses, such as soil or hydrostatic loads.

L = Live load.

T_o = Thermal loads due to temperature gradient through wall during operating conditions.

H_o = Force on structure due to thermal expansion of pipes during operating conditions.

E' = Safe Shutdown Earthquake (SSE) resulting from ground surface acceleration of 0.25g.

W = Wind Load.

W_t = Tornado wind load.

4.3 LOAD COMBINATIONS

The following load combinations based on Trojan FSAR Section 3.8, excluding those containing OBE loads (See Appendix A), shall be used to evaluate the double wythe masonry walls:

(1) $1.5D + 1.8\ L$

(2) $1.0D + 1.0L + 1.0E' + 1.0T_o + 1.25H_o$

(3) $1.0D + 1.0L + 1.0W_t + 1.0T_o + 1.25H_o$

(4) $1.25(D+L+H_o+W) + 1.0T_o$

(5) $0.9D + 1.25(H_o+W) + 1.0T_o$

5. ALLOWABLE STRESSES

The allowable stress limits for the evaluation of double wythe masonry walls are shown in Table 5-1.

6. ANALYTICAL TECHNIQUES

6.1 SEISMIC EVALUATION

To obtain the structural response in the masonry walls, the following shall be considered:

6.1.1 Stiffness Evaluation

6.1.1.1 Boundary Conditions

For walls above el. 45' one-way and two-way spans considering both simply supported and partially fixed end conditions shall be investigated. For other than simply supported condition, thermal and interstory-drift effects shall be added, where appropriate. For walls below el. 45', actual boundary conditions shall be used for evaluation. Interstory-drift effects need not be investigated for these walls.

6.1.1.2 Equivalent Moment of Inertia, I_e

To determine the out-of-plane frequencies of the double wythe masonry walls, the uncracked behavior and capacities of the walls (step 1) and, if applicable, the cracked behavior and capacities of the walls (step 2) shall be considered.

Step 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 and the cell concrete on the compression side and only the cell concrete on the tension side.

Step 2 - Cracked Condition

If the applied moment (M_a) due to all loads in a load combination exceeds the uncracked moment capacity (M_{cr}), the wall shall be considered to be cracked. In this event, the equivalent moment of inertia (I_e) shall be computed as follows:

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

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

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 the cracked section

f_r = See Table 3-2

y = Distance of centroidal axis from tension face

6.1.1.3 Load Effects To Be Considered

In evaluating the wall's natural frequency of vibration, the effect of possible cracking shall be considered. To determine the extent of cracking, the following conditions shall be considered:

a. The effect of two horizontal and one vertical component of earthquake motion shall be considered by combining the individual responses by the SRSS method. For this evaluation, reinforcing steel yield strength shall be taken as 50 ksi and the modulus of rupture for masonry material and cell concrete shall be limited to those presented in Table 3-3.

b. In-plane loads shall be obtained from the STARDYNE analysis if walls are included directly in the model. Alternatively, the loads will be taken equal to the capacity that can be developed from the vertical reinforcing steel or a load smaller than the total capacity may be taken if justified on a case by case basis.

c. The distribution of the in-plane bending stresses shall consider double or single curvature, as appropriate.

d. When plate action is utilized, horizontal bending effects will be considered.

e. Out-of-plane inertia loads shall be obtained from averaging the accelerations at the top and bottom of the wall.

f. Effect of interstory drift from both horizontal earthquake components shall be evaluated.

g. Dead load, vertical earthquake and membrane forces from gross bending shall be considered, where appropriate.

h. Differential temperature effects shall be included, where applicable.

EB-15

6.1.2 Damping

Structural damping for uncracked ($M_a < M_{cr}$) and cracked ($M_a > M_{cr}$) walls shall be 2% and 5% respectively for SSE.

6.1.3 Accelerations

For a wall spanning between two floors, the effective acceleration shall be the average of the accelerations as given by the floor response spectra corresponding to the wall's natural frequency.

6.1.4 Interstory Drift Effects

Interstory drift effects shall be derived from the STARDYNE analyses. These effects shall be adjusted to account for both transformed and cracked sections, as appropriate.

6.1.5 Stress Calculations

All stress calculations shall be performed by conventional methods prescribed by the Working Stress Design method. The collar joint shear stress shall be determined by the relationship $\frac{VQ}{Ib}$. The effect of cracking shall be appropriately considered in determining section properties.

6.2 STRUCTURAL EVALUATIONS FOR OTHER THAN SEISMIC LOADS

6.2.1 Thermal Effects

Thermal effects, applicable to exterior walls only, shall be considered for partially fixed end conditions, and cracked section analysis shall be used.

6.2.2 Effective Widths

Effective widths of 6t (where t is the thickness of the wall) may be used to resist local loads such as pipe reaction loads.

EB-15

TABLE 3-1

TEST RESULTS FOR COMPONENTS OF DOUBLE WYTHE MASONRY WALLS

MATERIALS	f'_c (psi)	f_t (psi)	E_d (psi)	E_s (psi)	f'_m (psi)	f_y (psi)
HEAVY WT BLOCK	4,100	--	--	--	--	--
STANDARD WT. BLOCK	2,700	--	--	--	--	--
MORTAR	3,700	--	--	--	--	--
CELL CONCRETE	>5,000	643	4.26×10^6	3.71×10^6	--	--
BLOCK/CONCRETE INTERFACE	--	158	--	--	--	--
PRISM TEST (HEAVY WT)	--	--	--	--	4,400	--
PRISM TEST (STD. WT)	--	--	--	--	2,400	--
REINFORCING STEEL	--	--	--	--	--	50,000

Where:

f'_c = Average compressive strength of applicable material

f_t = Average splitting tensile strength or tensile bond strength at material interface

E_d = Average dynamic modulus of elasticity

E_s = Average static modulus of elasticity

f'_m = Average compressive strength of prisms (consisting of cell concrete, block and mortar)

f_y = Average yield strength of reinforcing steel

TABLE 3-2

MATERIAL PROPERTIES FOR STIFFNESS EVALUATION

MATERIALS	f_r[1] (psi)	E (psi)	γ (pcf)	ν
HEAVY BLOCK/MORTAR	--	1.75×10^6	130	0.20
STANDARD BLOCK/MORTAR	--	1.0×10^6	100	0.20
CELL CONCRETE	420	4.0×10^6	145	0.20
BLOCK/CONCRETE INTERFACE	80	--	--	--
REINFORCING STEEL	--	30.0×10^6	--	--

Where:

f_r = Modulus of rupture or tensile bond strength at material interface

E = Modulus of elasticity

γ = Unit Weight

ν = Poisson's Ratio

NOTES

1. The modulus of rupture for cell concrete, and block/concrete interface value have a factor of safety of 2.0 relative to ultimate. The actual modulus of rupture for the cell concrete is based on the splitting tensile strength i.e. $f_t/0.75$. See "Reinforced Concrete Structures" by Park and Pauley. Block/concrete interface value is based on test data value obtained from the composite wall block/concrete tensile bond test.

TABLE 3-3

MATERIAL PROPERTIES FOR CAPACITY EVALUATION

MATERIALS	f'_c (psi)	f_r (psi)	f'_m (psi)	f_y (psi)	E (psi)
HEAVY BLOCK	4,100	215	--	--	1.75×10^6**
STANDARD BLOCK	2,700	175	--	--	1.0×10^6**
MORTAR	3,700	--	--	--	--
CELL CONCRETE	5,000	420	--	--	4.0×10^6
BLOCK/CONCRETE INTERFACE	--	80	--	--	--
PRISM (HEAVY BLOCK)	--	--	4,000	--	--
PRISM (STD. BLOCK)	--	--	2,000	--	--
REINFORCING STEEL	--	--	--	40,000	30.0×10^6

Where:

f'_c = Design compressive strength of applicable material

f_r = Design modulus of rupture or tensile bond strength; For blocks, this value is computed based on $6.7 \sqrt{f'_c}$* with a factor of safety of 2.0 applied

f'_m = Design compressive strength of masonry

f_y = Design yield strength of reinforcing steel

E = Design modulus of elasticity

* "Structural Properties of Block Concrete", by Holm.
** Composite modulus consisting of block and mortar.

TABLE 5-1

ALLOWABLE STRESSES FOR DOUBLE WYTHE MASONRY WALLS

TYPE OF STRESS	LOAD COMBINATIONS			
	HEAVY WEIGHT		STANDARD WEIGHT	
	(1), (2-STEP 2)*, (3) (4) & (5)	(2-STEP 1)*	(1), (2-STEP 2)*, (3) (4) & (5)	(2-STEP 1)*
A. Masonry				
1. Membrane Compression	1.50S	1.50S	1.50S	1.50S
2. Flexural Compression	1,200 psi**	M_{cr}	900 psi**	M_{cr}
3. Flexural Shear	1.50S	1.50S	1.50S	1.50S
4. Collar Joint Shear	10 psi	10 psi	30 psi***	30 psi***
5. Bearing	1.50S	1.50S	1.50S	1.50S
B. Reinforcing Steel				
1. Tension/Compression	$0.9f_y$	--	$0.9f_y$	--

S = Allowable working stress based on Table No. 24H of UBC-1967

f_y = Design yield strength of reinforcing steel

M_{cr} = Uncracked moment capacity of transformed section (see Sect. 6.1.1.2)

* Steps 1 and 2 are defined in Sect. 6.1.1.2

** Flexural compression stress is derived from the lesser of the block and mortar strength divided by a factor of 3.0

*** Based on two in-situ tests of collar joint shear capacity, with average of 82 psi and low value of 70 psi

APPENDIX A

SUPPLEMENTAL STRUCTURAL EVALUATION CRITERIA

FOR

OUT-OF-PLANE OBE LOADS

ON

DOUBLE WYTHE MASONRY WALLS

APPENDIX A

SUPPLEMENTAL STRUCTURAL EVALUATION CRITERIA

FOR

OUT-OF-PLANE OBE LOADS

ON

DOUBLE WYTHE MASONRY WALLS

A1. INTRODUCTION

This appendix defines the supplemental structural evaluation criteria for all double wythe masonry walls at the Trojan Nuclear Plant subjected to out-of-plane loads due to the OBE.

The governing code and document and the material properties are the same as those contained in Supplemental Structural Evaluation Criteria, Sections 2 and 3.

A2. LOADS AND LOAD COMBINATIONS

A2.1 Definitions of Loads

The following definitions are used in the load combination equations:

EK-12

D = Dead load of structure and equipment plus any other permanent loads contributing stresses, such as soil or hydrostatic loads.

L = Live Load.

T_o = Thermal loads due to temperature gradient through wall during operating conditions.

H_o = Force on structure due to thermal expansion of pipes during operating conditions.

E = Operating Basis Earthquake (OBE) resulting from ground surface acceleration of 0.15g.

A2.2 LOAD COMBINATIONS

The following load combinations specified in the Trojan FSAR, Section 3.8 pertaining to OBE loads shall be used to evaluate the double wythe masonry walls.

(1) $1.25(D+L+H_o+E) + 1.0T_o$

(2) $0.90D + 1.25(H_o+E) + 1.0T_o$

A3. ALLOWABLE STRESSES

The allowable stress limits for the evaluation of double wythe masonry walls are shown in Table A3-1.

EK-12

A4. ANALYTICAL TECHNIQUES

The stiffness evaluation, and the evaluations for acceleration, interstory drift effects and methods of stress calculations are the same as those described in the Supplemental Structural Evaluation Criteria for SSE loads, Sections 6.1.1, 6.1.3., 6.1.4 and 6.1.5.

Structural damping for OBE loads shall be taken as 2% unless substantiation for higher damping for cracked conditions is provided.

TABLE A3-1

ALLOWABLE STRESSES FOR DOUBLE WYTHE MASONRY WALLS

TYPE OF STRESS	LOAD COMBINATIONS			
	HEAVY WEIGHT		STANDARD WEIGHT	
	(1-STEP 2, 2 STEP-2)*	(1 STEP-1, 2 STEP-1)*	(1-STEP 2 2-STEP 2)*	(1-STEP 1 2-STEP 1)*
A. Masonry				
1. Membrane Compression	1.50S	1.50S	1.50S	1.50S
2. Flexural Compression	1,200 psi**	M_{cr}	900 psi**	M_{cr}
3. Flexural Shear	1.50S	1.50S	1.50S	1.50S
4. Collar Joint Shear	10 psi	10 psi	30 psi***	30 psi***
5. Bearing	1.50S	1.50S	1.50S	1.50S
B. Reinforcing Steel				
1. Tension/Compression	$0.9f_y$	--	$0.9f_y$	--

S = Allowable working stress based on Table No. 24H of UBC-1967

f_y = Design yield strength of reinforcing steel

M_{cr} = Uncracked moment capacity of transformed section (see Sect. 6.1.1.2)

* Steps 1 and 2 are defined in Sect. 6.1.1.2

** Flexural compression stress is derived from the lesser of the block and mortar strength divided by a factor of 3.0

*** Based on two in-situ tests of collar joint shear capacity, with average of 82 psi and low value of 70 psi