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Beaver Valley Power Station - Unit No. 1
Duquesne Light Company
Pittsburgh, Pennsylvania

CRITERIA FOR REEVALUATION OF CONCRETE MASONRY WALLS FOR I & E BULLETIN 80-11

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CRITERIA FOR REEVALUATION OF CONCRETE MASONRY WALLS

1.0 INTRODUCTION

1.1 Purpose

This document establishes design requirements and criteria for use in reevaluating the structural adequacy of concrete masonry walls as required by the Nuclear Regulatory Commission (NRC) I&E Bulletin 80-11, Masonry Wall Design, dated May 8, 1980. These criteria are applicable to the Beaver Valley Unit No. 1 Nuclear Power Station.

1.2 Scope

The reevaluation as covered by this document pertains to existing masonry walls. These walls are not used as major load-bearing walls and are not included as part of the overall building shear wall system. The primary purposes of these walls are to provide radiation shielding, fire protection, and personnel barriers from equipment.

The reevaluation shall determine whether concrete masonry walls will maintain their structural integrity and perform their intended functions under the loads, and load combinations prescribed herein. Verification of wall adequacy shall include the local transfer of equipment loads into the masonry wall panel as well as the global response of the wall and transfer of wall reactions into supports. Review of the adequacy of anchor bolts and wall support systems is not considered to be within the scope of this reevaluation.

2.0 LOAD AND LOADING CONDITIONS

2.1 Loads

The reevaluation shall include all relevant loads specified in the station Final Safety Analysis Report, (FSAR) for concrete design. A survey of all the masonry walls under consideration concluded that they are not subjected to loads from wind, tornado, missile, pipe whip, or jet impingement. Thermal and pressure differential loads being carried by the wall or

transmitted by supports anchored to the masonry walls shall be included in the reevaluation.

2.1.1 Inertial loads due to Operating Basis Earthquake (OBE) and Design Basis Earthquake (DBE), as defined by the station FSAR and modified by the use of soil structure interaction, shall be used.

2.1.2 Equipment Inertial Loads

Equipment inertial loads shall be calculated based on a load distributed uniformly over part or all of the area of wall, depending on the arrangement of the supports. The resultant may be applied as a single concentrated load or a line load, as appropriate.

Equipment support load imposed on the walls shall be determined on the basis of a simplified dynamic analysis based on fundamental modes described in the FSAR.

2.1.3 Pipe Loads

Pipe restraint loads shall be based on the following criteria:

a. For pipes with design temperature above 150°F, use decal loads in accordance with Stone & Webster Standards-SATM-1 (Z6.1-3).

b. For lines with design temperature less than or equal to 150°F, use the following simplified hand calculation technique:

1. Determine DL from the contributory span for the support

2. From DL determine mass (weight/g)

3. Determine each seismic component by applying to the mass the peak of the appropriate amplified response spectrum increased by 50 percent

2.1.4 Loads for Interstory Displacements

Relative interstory displacements between building elevations from the seismic analysis of the structure shall be imposed on the wall panel where applicable.

Wall loads due to interstory displacements shall be calculated from the displacement values given in Tables 4.5 through 4.8 of Appendix.

2.2 Load Combinations

The reevaluation of masonry walls shall consider the applicable loading combinations that are identified in Appendix B.1.4 of the FSAR titled "Other Class I Structures", for concrete sections. The following loading combinations use a load factor of 1.0 and the allowable stresses are increased according to Section 5 of this criteria.

Load_Category	Load_Combination
Normal	(1) DL + LL
Severe Environmental	(2) DL + LL + OBE
	(3) DL + LL + W
Extreme Environmental	(4) DL + LL + To + DBE
	(5) DL + LL + To + Wt

If thermal stresses due to To are present, the following load combinations are considered:

(1a) DL + LL + To

(2a) DL + LL + To + OBE

(3a) DL + LL + To + W

Both cases of LL having its full value or being completely absent shall be checked.

where DL = dead load
LL = live load
W = Loads generated by the plant design wind

To = thermal load during normal plant operating conditions
OBE = loads generated by operating basis earthquake
DBE = loads generated by safe shutdown earthquake
Wt = tornado loads including tornado wind pressure, tornado created differential pressure, and tornado missiles

3.0 MATERIAL PROPERTIES

Properties for masonry, mortar, grout, and steel shall be as specified in Table 3.1. Definitions of terms are those given in the American Concrete Institute (ACI), "Building Code Requirements for Concrete Masonry Structures" (ACI 531-79), Section 2.1. Block cross-sectional dimensions shall be as given in Table 3.2 for hollow block walls. Overall wall size and as-built information shall be taken from the original issue of the as-built sketches and wall package data from Duquesne Light Company in conjunction with the RC-Series drawings.

4.0 ANALYSIS PROCEDURES

4.1 Masonry walls shall be reevaluated for earthquake on the basis of determining the effects of: (1) wall inertial loads, (2) equipment inertial loads, and (3) interstory displacement.

The resultant of the combination of the various types of statistically independent seismic loads may be determined by SRSS.

4.2 The initial analysis shall assume an elastic (uncracked) section, ignoring the effects of horizontal joint reinforcement.

Analysis results shall be compared against the acceptance criteria defined in Section 5.0.

4.2.1 Frequency - Fundamental frequencies of the masonry walls shall be calculated based on elastic plate or beam theory and appropriate boundary conditions. To account for variations in material properties and assumed boundary conditions, the seismic response of masonry walls shall be calculated using an amplified response spectrum which has had its peaks broadened. The cutoff frequencies are given in Tables 4.1 through 4.4.

4.2.2 Wall Inertial Loads - Transverse loads shall be calculated, using the acceleration of the appropriate dampened amplified response spectrum, in a simplified dynamic analysis, using the fundamental modes of vibration.

More refined analysis may be used in some cases.

4.2.3 Equipment Inertial Loads - Equipment inertial loads shall be calculated based on a load distributed uniformly over part or all of the area of wall, depending on the arrangement of the supports. The resultant may be applied as a single concentrated load or a line load, as appropriate.

Equipment support loads imposed on the walls shall be determined on the basis of a simplified dynamic analysis based on fundamental modes described in the FSAR.

4.2.4 Interstory Displacement - Relative interstory displacements between building elevations from the seismic analysis of the structure shall be imposed on the wall panel, where required and its effects accounted for in the reevaluation analysis. Interstory displacements shall be calculated from displacement profiles given in Tables 4.5 through 4.8.

4.2.5 Damping - Masonry wall damping values for unreinforced walls shall be a maximum of 2 percent of critical damping for severe environmental (OBE) case and 4 percent for extreme environmental (DBE) case.

4.3 Further analysis, utilizing the ultimate strength of the wall, shall be performed as appropriate.

5.0 ACCEPTANCE CRITERIA

5.1 Allowable Stresses

Allowable stresses for reevaluation analysis of masonry walls shall be those given in Table 10.1 of the American Concrete Institute (ACI), "Building Code Requirements for Concrete Masonary Structures" (ACI 531-79). It is the intent of these criteria to utilize only the above provision of ACI 531-79 as the basis of acceptance. A one-third increase of the allowable stress values shall be taken in consideration of severe environmental loads. For extreme environment loads, the allowable stresses shall be increased by a factor of 1.67.

The allowable collar joint stress for shear and tension shall be 8 psi for severe environmental loads and 12 psi for extreme environmental loads, with no additional increase permitted.

Other applicable codes (i.e., AISC "Specification for the Design Fabrication and Erection of Structural Steel for Buildings") are as referenced in the FSAR, and shall be used in the reevaluation program as necessary.

Allowable stresses represent levels of stress for which significant damage to the wall shall not occur.

5.2 In-Plane Effects

The walls considered by this procedure are not lateral load-carrying walls for major structural elements. In addition, because of the complex interaction between masonry walls and confining primary structural elements, in-plane stresses cannot be properly described. As a result, strain or displacement is a more meaningful index of in-plane performance.

The in-plane shear strain defined by

$$\gamma = \frac{\Delta T - \Delta B}{H}$$

where

ΔT = displacement at the top of the wall

ΔB = displacment at the bottom of the wall, inches

H = height of wall, inches

shall be limited to .001 in/in for walls which are confined at least top and bottom, or on three sides by concrete or primary steel structural elements. All other walls (unconfined) shall be limited to an in-plane shear strain of .0001 in/in.

TABLE 3.1

BUILDING	* BLOCK	MORTAR, m_o	GROUT	REINFORCING
AUXILIARY	NORMAL WEIGHT CONCRETE-SOLID BLOCK 2500 PSI NET AREA ASTM C145, f'm = 1550 PSI	2500 PSI (TYPE M)		1/32" DURO-WALL 33,350 PSI (YIELD STRESS.)
CABLE VAULT	NORMAL WEIGHT CONCRETE-SOLID BLOCK 2500 PSI NET AREA ASTM C145, f'm = 1550 PSI	2500 PSI (TYPE M)		
FUEL BUILDING	LIGHT WEIGHT CONCRETE-HOLLOW BLOCK 2000 PSI NET AREA ASTM C90, f/m = 1000 PSI	750 PSI (TYPE N)		
SERVICE BUILDING AT EL.713'-6" (SB1)	NORMAL WEIGHT CONCRETE-HOLLOW BLOCK WITH CONCRETE FILL 2500 PSI NET AREA ASTM C90, f'm = 1530 PSI	2500 PSI (TYPE M)	2500 PSI	1/32" DURO-WALL 33,350 PSI. (YIELD STRESS)
SERVICE BUILDING AT EL. 722'-6" (SB2) AT EL. 735'-6" (SB3)	LIGHTWEIGHT CONCRETE-HOLDOW BLOCK WALLS-SB3-8, 9 & 12 2000 PSI NET AREA LOAD BEARING ASTM C90, f'm=1000 PSI WALLS REMAINING 700 PSI NET AREA ASTM C129, f'm = 500 PSI	750 PSI (TYPE N)		

* NORMAL WEIGHT CONCRETE = 135 LB. PER CU. FT.

LIGHT WEIGHT CONCRETE = 105 LB. PER CU. FT.

TABLE 3.2

HOLLOW LOAD-BEARING CONCRETE MASONRY UNITS
ASTM C90 GRADE N TYPE 1

* THESE PROPERTIES CAN ALSO BE USED FOR C129 MASONRY UNITS

NOMINAL DIMENSIONS (IN)	DESCRIPTION	WEIGHT (LBS)	LENGTH (IN)	WIDTH (IN)	HEIGHT (IN)	SHELL (IN)	WEB (IN)	Iyy	Syy	Ixx	Sxx	AREA (NET)
4X8X16	2 CELL HOLLOW BLOCK NORMAL WEIGHT	24	15 7/16	3 5/8	7 5/8	1	1	27.54	15.19	56.83	31.34	35.75
6X8X16	2 CELL HOLLOW BLOCK NORMAL WEIGHT	29.3	15 1/2	5 11/16	7 11/16	1	1 1/16	85.76	30.15	186.23	65.48	42.76
8X8X16	2 CELL HOLLOW BLOCK NORMAL WEIGHT	39.3	15 7/16	7 5/8	7 11/16	1 3/8	1	209.78	55.00	405.23	118.1	57.07
12X8X16	2 CELL HOLLOW BLOCK NORMAL WEIGHT	52.0	15 5/8	11 5/8	7 5/8	1 1/2	1 5/16	500.6	101.6	1420.6	244.4	80.83
8X8X16	2 CELL HOLLOW BLOCK LIGHT WEIGHT	30.3	15 5/8	7 3/4	7 5/8	1 3/8	1 3/8	216.4	55.83	486.0	125.0	63.6
10X8X16	2 CELL HOLLOW BLOCK NORMAL WEIGHT	44.6	15 5/8	9 5/8	7 7/16	1 5/16	1 3/16	340.0	89.2	816.2	214.1	65.97
4X8X16	2 CELL HOLLOW BLOCK LIGHT WEIGHT	20.03	15 9/16	3 5/8	7 3/4	1	1	28.0	15.45	57.28	31.6	36.0
6X8X16	2 CELL HOLLOW BLOCK LIGHT WEIGHT	23.7	15 9/16	5 11/16	7 5/8	1 1/4	1 1/4	96.32	33.87	206.76	72.7	50.84

TABLE 4.1

RIGID RANGE CUT-OFFS*						
ELEV.	OPERATING B.E. (G)			FREQUENCY CPS		
	X	Y	Z	X	Y	Z
790.0	.12	.06	.11	14.3	33.3	20.0
768.58	.08	.06	.09	25.0	33.3	25.0
752.50	.09	.06	.09	25.0	33.3	25.0
735.5	.08	.06	.08	18.2	33.3	25.0
714.0	.06	.06	.06	18.2	33.3	18.2

*DAMPING 0.5 %

RIGID RANGE CUT-OFFS**						
ELEV.	DESIGN B.E. (G)			FREQUENCY CPS		
	X	Y	Z	X	Y	Z
790.0	.20	.11	.21	20.0	33.3	20.0
768.58	.18	.11	.17	15.4	33.3	16.7
752.50	.18	.11	.18	15.4	33.3	14.3
735.5	.14	.11	.14	15.4	33.3	14.3
714.0	.12	.11	.12	15.4	33.3	14.3

**DAMPING 1.0 %

MAXIMUM ACCELERATION VALUES						
ELEV.	OPERATING B.E (G)			DESIGN B.E. (G)		
	X	Y	Z	X	Y	Z
790.0	.756	.445	.779	1.165	.685	1.179
768.58	.649	.443	.620	1.006	.683	.945
752.50	.596	.442	.591	.904	.681	.897
735.5	.558	.440	.559	.858	.679	.861
714.0	.510	.438	.520	.806	.677	.817

AUXILIARY BLDG

TABLE 4.2

RIGID RANGE CUT-OFFS*						
ELEV.	OPERATING B.E. (G)			FRECUENCY CPS		
	X	Y	Z	X	Y	Z
789.50	.10	.07	.13	20.0	33.3	16.7
767.83	.09	.07	.12	20.0	33.3	16.7
753.50	.08	.07	.10	20.0	33.3	16.7
734.75	.08	.07	.09	20.0	33.3	20.0
716.50	.07	.07	.06	16.7	33.3	20.0

*DAMPING 0.5 %

RIGID RANGE CUT-OFFS**						
ELEV.	DESIGN B.E. (G)			FREQUENCY CPS		
	X	Y	Z	X	Y	Z
789.50	.20	.11	.26	20.0	33.3	15.4
767.83	.16	.11	.20	20.0	33.3	16.7
753.50	.16	.11	.20	20.0	33.3	16.7
734.75	.14	.11	.16	16.7	33.3	15.4
716.50	.12	.11	.16	16.7	33.3	16.7

**DAMPING 1.0 %

MAXIMUM ACCELERATION VALUES						
ELEV.	OPERATING B.E (G)			DESIGN B.E. (G)		
	X	Y	Z	X	Y	Z
789.50	.684	.362	1.326	1.086	579	2.013
767.83	.615	.373	1.066	.916	.595	1.626
753.50	.565	.368	.865	.877	.587	1.327
734.75	.499	.366	.648	.800	.585	.961
716.50	.471	.363	.469	.746	.581	.741

CABLE VAULT

TABLE 4-3

RIGID RANGE CUT-OFFS*						
ELEV.	OPERATING B.E. (G)			FREQUENCY CPS		
	X	Y	Z	X	Y	Z
766.33	.09	.05	.11	20.0	33.3	16.7
752.42	.08	.06	.10	20.0	33.3	15.4
735.50	.08	.06	.08	20.0	33.3	18.2
727.33	.07	.05	.07	20.0	33.3	20.0

*DAMPING 0.5%

RIGID RANGE CUT-OFFS**						
ELEV.	DESIGN B.E. (G)			FREQUENCY CPS		
	X	Y	Z	X	Y	Z
766.33	.17	.10	.24	20.0	33.0	13.3
752.44	.16	.11	.22	20.0	33.3	14.3
735.50	.16	.11	.18	16.7	33.3	14.3
727.33	.16	.11	.15	15.4	33.3	16.7

**DAMPING 1.0%

MAXIMUM ACCELERATION VALUES						
ELEV.	OPERATING B.E. (G.)			DESIGN B.E. (G)		
	X	Y	Z	X	Y	Z
766.33	.727	.423	1.139	1.170	.681	1.827
752.42	.691	.422	.971	1.095	.679	1.533
735.50	.644	.423	.770	1.007	.681	1.185
727.33	.620	.404	.571	.964	.645	.905

FUEL BLDG.

TABLE 4-4

RIGID RANGE CUT-OFFS*						
ELEV.	OPERATING B.E. (G)			FREQUENCY CPS		
	X	Y	Z	X	Y	Z
767.50	.14	.07	.10	20.0	33.3	25.0
752.50	.10	.06	.09	20.0	33.3	25.0
735.50	.06	.06	.07	20.0	33.3	15.4
725.50	.06	.06	.07	20.0	33.3	16.7
713.50	.06	.05	.07	15.4	33.3	14.3

*DAMPING 0.5%

RIGID RANGE CUT-OFFS**						
ELEV.	DESIGN B.E. (G)			FREQUENCY CPS		
	X	Y	Z	X	Y	Z
767.50	.24	.11	.17	20.0	33.3	33.3
752.50	.18	.11	.15	20.0	33.3	25.0
735.50	.11	.11	.12	20.0	33.3	16.7
725.50	.10	.11	.12	20.0	33.3	6.7
713.50	.11	.11	.12	16.7	33.3	4.3

**DAMPING 1.0%

MAXIMUM ACCELERATION VALUES						
ELEV.	OPERATING B.E. (G)			DESIGN B.E. (G)		
	X	Y	Z	X	Y	Z
767.50	.483	.353	.785	.698	.562	1.066
752.50	.438	.351	.679	.685	.560	.958
735.50	.414	.348	.537	.667	.557	.762
725.50	.407	.347	.476	.659	.555	.680
713.50	.397	.346	.395	.648	.553	.627

SERVICE BLDG.

TABLE 4.5

DEFLECTION TABULATION (IN) - AUXILIARY BLDG.

JT	ELEV.	DBE			OBE		
		E-W	VERT	N-S	E-W	VERT.	N-S
1	714.0'	0.0	0.0	0.0	0.0	0.0	0.0
2	735.5'	0.004491	0.000592	0.003514	0.002390	0.000284	0.001871
3	752.5'	0.007109	0.000899	0.005573	0.003780	0.000432	0.002979
4	768.5'	0.008943	0.001080	0.007107	0.004727	0.000518	0.003778
5	790.0'	0.011205	0.001378	0.026266	0.005903	0.000661	0.014298

TABLE 4.6

DEFLECTION TABULATION (IN) CABLE VAULT

JT	ELEV.	DBE			OBE		
		E-W	VERT.	N-S	E-W	VERT.	N-S
1	716.50'	0.0	0.0	0 0	0.0	0.0	0.0
2	734.75'	0.003984	0.000652	0.007797	0.001907	0.000290	0.00368
3	753.50'	0.007262	0.001075	0.013650	0.003493	0.000478	0.006408
4	767.87'	0.009193	0.001298	0.017996	0.004411	0.000577	0.008429
5	789.50'	0.011466	0.001484	0.023403	0.005537	0.00066	0.011024

TABLE 4.7

DEFLECTION TABULATION (IN)- FUEL BLDG.

JT	ELEV.	DBE			OBE		
		E-W	VERT.	N-S	E-W	VERT.	N-S
1	727.33'	0.0824	0.0243	0.0739	0.0374	0.00965	0.0331
2	735.50'	0.0862	0.0280	0.1060	0.0390	0.01130	0.0463
3	752.42'	0.0938	0.0278	0.1360	0.0422	0.01122	0.0583
4	766.33'	0.0993	0.0279	0.1610	0.0447	0.01128	0.0685

TABLE 4.8

DEFLECTION TABULATION (IN) - SERVICE BLDG.

JT	ELEV.	DBE			OBE		
		E-W	VERT.	N-S	E-W	VERT.	N-S
5	713.50'	0.0	0.0	0.0	0.0	0.0	0.0
4	725.50'	0.001671	0.000331	0.003533	0.000858	0.000160	0.001876
3	735.50'	0.002739	0.000538	0.005858	0.001403	0.000259	0.003105
2	752.50'	0.006011	0.001098	0.011975	0.003042	0.000529	0.006273
1	767.46'	0.008533	0.001414	0.015356	0.004301	0.000681	0.008005