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July 16, 1984

Mr. Harold R. Denton, Director
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Subject: Byron Generating Station Units 1 and 2
Braidwood Generating Station Units 1 and 2
Masonry Walls
NRC Docket Nos. 50-454/455/456/457

Reference (a): March 22, 1984 letter from B. J. Youngblood to D. L. Farrar

Dear Mr. Denton:

This is to provide additional information regarding the design of Category I masonry walls at Byron and Braidwood Stations. NRC review of this information should eliminate the need for License Condition 2 listed in the Byron SER.

In reference (a) the NRC requested additional information regarding masonry wall design. Enclosed with this letter are responses to FSAR Questions 130.58, 130.59 and 130.60. These responses will be incorporated into the FSAR in the next amendment.

Please direct further questions regarding this matter to this office.

One (1) signed original and fifteen (15) copies of this letter and the enclosures are provided for NRC review.

Very truly yours,

E. Douglas Swartz
for T. R. Tramm
Nuclear Licensing Administrator

Enclosures

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QUESTION 130.58

"Paragraph 2.2.2 of the December 3, 1983 letter from T. R. Tramm to Harold R. Denton discusses a parametric study to investigate the effect of column flexibility. Provide sufficient information which would allow the staff to confirm that similarity does exist between the safety-related walls at Byron/Braidwood plants and those tested in the study. This information should include, but not be limited to, such items as the basic assumptions and methods used in design, properties of materials, material property testing procedures, method of construction, and QA/QC requirements."

RESPONSE

As mentioned in our earlier response sent with the letter dated December 3, 1983, the masonry walls at Byron/Braidwood stations are not supported at the top and are provided with a 1-inch gap at the top. Steel columns have been used to provide lateral support for out-of-plane loads. As such, the walls have been designed for horizontally spanning beam strip moments. A parametric study was performed to estimate the magnitude of vertical moments resulting from the flexibility of the steel columns. The possible variations in design parameters, such as column size, number of steel columns used in a wall, wall thickness, and length of wall, were considered by using more generalized design items A* and 1* which are described below and were also explained in Appendix A of the response dated December 3, 1983.

A* = Ratio of total wall mass to the total mass of steel columns for a given wall.

= $P_m wt/P_s A_s$

I* = Ratio of total wall rigidity to the rigidity provided by steel columns.

= $E_m wt^3/E_s I_s$

H/s = Ratio of block wall column height to block wall column spacing.

where:

h = height of wall or block wall column

w = width of wall

t = thickness of wall

s = spacing of block wall columns

E_m = masonry modulus of elasticity

E_s = steel modulus of elasticity

P_m = masonry mass density

P_s = Steel mass density

A_s = total area of steel columns

I_s = total moment of inertia of steel columns

For a given ratio of h/w and h/s, plate vertical and horizontal moment coefficients can be generated for various valves of A* and I*.

Of 236 unreinforced masonry walls at Byron Station Unit 1, 114 have been reviewed for the variations in A* and column aspect ratio h/s. Due to the geometry and construction of three walls, use of the A* and I* approach is not appropriate. These walls have been analyzed using the finite element method which considers the effect of column flexibility. All the remaining walls have not been provided with block wall columns and, thus, are not subject to the effects of column flexibility.

The masonry walls at Byron Unit 2 and Braidwood Units 1 and 2 have similar geometry, have been designed using the same criteria, and have been constructed in accordance with the same specification. Therefore, this review is valid for unreinforced masonry walls at both Byron and Braidwood Stations.

Table Q130.58-1 gives the approximate breakdown of 114 unreinforced masonry walls with block wall columns in different groups of A* and I* for various types of column aspect ratios (h/s).

Since the last reponse of December 3, 1983, all the 114 masonry walls at Byron Station Unit 1 were studied to determine the effect of column flexibility on the design of masonry walls. For a given wall, plate vertical moments are calculated using finite element analysis, and the effect of column flexibility

is evaluated by determining if the moments in the vertical direction are less than the cracking moments. If so, the masonry wall design, based on calculation of design moments using a horizontally spanning beam strip between steel columns, is valid.

Since the allowable stresses perpendicular to the bed joints are approximately one-half of the allowable stresses parallel to the bed joints, the permissible values of plate vertical moment are determined by considering plate vertical cracking moments equal to one-half of the plate horizontal cracking moments. The horizontal cracking moments for hollow walls are based on the modulus of rupture determined by testing for the Clinton Power Station. The modulus of rupture for solid masonry wall is obtained by adjusting the modulus of rupture of hollow block wall with a factor equal to the ratio of the SEB allowable stress for solid masonry to the SEB allowable stress for hollow masonry.

Review of the actual plate vertical moments for the masonry walls at Byron Station Unit 1 indicates that all the masonry walls have actual plate vertical moments less than the vertical cracking moments based on the elastic analysis. The vertical moments which are developed due to flexibility of the block wall columns do not affect the structural integrity of the walls. Hence, the design of unreinforced masonry walls at Byron Station Units 1 and 2 and Braidwood Station Units 1 and 2, based on horizontally spanning beam strip moments, is acceptable.

TABLE Q130.58-1

SUMMARY OF MASONRY WALLS WITH STEEL COLUMNS BASED ON DESIGN PARAMETERS FOR BYRON UNIT 1

TYPE OF ASPECT RATIO	h/s	APPROXIMATE NUMBER OF MASONRY WALLS WITH STEEL COLUMNS				
		GROUP 1 A*>75 I*>500	GROUP 2 A*=38-75 I*=100-500	GROUP 3 A*=25-37 I*=50-99	GROUP 4 A*<25 I*<50	ALL VALUES OF A* & I*
1	≤2.0	47	19	10	12	88
2	>2.0 & ≤3.0	6	8	2	3	19
3	>3.0	3	-	-	4	7
All Types	All Values	56	27	12	19	114

QUESTION 130.59

"Paragraph 2.6.D.2 references static monotonic tests performed by various research organizations which form the basis for the statement that the average factor of safety is 5.6 under the OBE condition and 3.35 under the SSE condition. Provide sufficient information to justify both the relevancy and applicability of the tests to the Byron/Braidwood safety-related masonry walls. This information should contain such details as the basic assumptions and modeling methods, properties of the material, material property testing procedures, and details of construction."

RESPONSE

Allowable Tensile Stresses Parallel to the Bed Joints

The project allowable stress parallel to the bed joints is in accordance with National Concrete Masonry Association's (NCMA), "Specification for the Design and Construction of Load Bearing Concrete Masonry."

Review of the background information regarding allowable tensile stresses parallel to the bed joints indicates that the allowable values have been established by doubling the allowable stresses perpendicular to the bed joints which are based on mortar tensile bond strength. The stresses parallel to the bed joints are more a function of masonry unit strength than mortar. As such, it is conservative to use double the vertical span values.

Table Q130.59-1 gives the summary of test results used to arrive at the value of modulus of rupture for horizontally spanning walls and, hence, the tensile stress parallel to the bed joint. The safety factors in the table have been calculated by dividing the actual modulus of rupture values by the allowable stress values, 32 psi for Type N and O mortar, and 46 psi for Type M mortar.

For 15 concrete masonry walls with joint reinforcement, as is the case for masonry walls at Byron/Braidwood Stations, the safety factors averaged 5.6 for normal and OBE load combinations, and 5.6/1.67 = 3.35 for SSE load combinations. In addition, the test results for 43 walls containing no joint reinforcement indicate an average factor of safety of 5.3 for normal and OBE load combinations, and 5.3/1.67 = 3.17 for SSE load combinations. These values are comparable but slightly less than those for walls with joint reinforcement.

TABLE Q130.59-1

FLEXURAL STRENGTH HORIZONTAL SPAN, NONREINFORCED CONCRETE MASONRY WALLS

CONSTRUCTION	MORTAR TYPE	LOADING TYPE	LOADING psf	MODULUS OF RUPTURE NET AREA (psi)	SAFETY FACTOR ACTUAL/ ALLOWABLE
8-inch Monowythe	N	Uniform	127	102	4.13
Hollow, 3-Core	N	Uniform	136	141	4.41
(Reference 1)	N	Uniform	127	132	4.13
	N	Uniform	169	176	5.50
	N	Uniform	173	180	5.63
	O	Uniform	123	128	4.00
	O	Uniform	158	164	5.13
8-inch Monowythe	N	Uniform	149	155	4.84
Hollow Joint	N	Uniform	160	166	5.19
Reinforced @ 16 inch	N	Uniform	193	201	6.28
center to center	O	Uniform	150	156	4.88
(Reference 1)	O	Uniform	186	193	6.03
8-inch Monowythe	N	Uniform	203	211	6.59
Hollow Joint	N	Uniform	196	204	6.38
Reinforced @ 8 inch	O	Uniform	202	210	6.56
center to center	O	Uniform	195	203	6.34
(Reference 1)					
8-inch Monowythe	N	1/4 pt	56	58	1.81
Hollow (Reference 2)	N	1/4 pt	38	39	1.22
	N	1/4 pt	61	63	1.97
	N	1/4 pt	60	62	1.94
	N	1/4 pt	69	71	2.22
	N	1/4 pt	93	96	3.00
8-inch Monowythe	M	Center	199	217	4.72
Hollow, 2-Core	M	Center	176	192	4.17
(Reference 3)	M	Center	151	165	3.59
4-2-4 Cavity Wall,	M	Center	111	210	4.57
Hollow Units	M	Center	135	255	5.54
(Reference 3)	M	Center	95	180	3.91

TABLE Q130.59-1 (Cont'd)

CONSTRUCTION	MORTAR TYPE	LOADING TYPE	LOADING psf	MODULUS OF RUPTURE NET AREA (psi)	SAFETY FACTOR ACTUAL/ ALLOWABLE
8-inch Monowythe	M	Center	159	173	3.76
Hollow 2-Core	M	Center	159	173	3.76
Joint Reinforced	M	Center	191	208	4.52
@ 8" center to center					
(Reference 3)					
4-2-4 Cavity of	M	Center	159	300	6.52
Hollow Units Tied	M	Center	159	300	6.52
with Joint	M	Center	159	300	6.52
Reinforced @ 8"					
center to center					
(Reference 3)					
4-inch Hollow	N	Center	138	365	11.41
Monowythe	N	Center	157	415	12.97
(Reference 4)	N	Center	101	268	8.38
8-inch Hollow	M	Center	268	202	4.39
Monowythe	M	Center	314	237	5.15
(Reference 4)	M	Center	314	237	5.15
8-inch Hollow	N	Center	277	210	6.56
Monowythe	N	Center	314	237	7.41
(Reference 4)	N	Center	314	237	7.41
8-inch Hollow	O	Center	259	195	6.09
Monowythe	O	Center	277	210	6.56
(Reference 4)	O	Center	277	210	6.56
8-inch Hollow	M	Center	268	202	4.39
Monowythe	M	Center	297	224	4.87
(Reference 4)	M	Center	277	210	4.56
8-inch Hollow	N	Center	277	210	6.56
Monowythe	N	Center	259	195	6.09
(Reference 4)	N	Center	297	224	7.00
8-inch Hollow	O	Center	360	271	8.45
Monowythe	O	Center	297	224	7.00
(Reference 4)	O	Center	268	202	6.31

TABLE Q130.59-1 (Cont'd)

CONSTRUCTION	MORTAR TYPE	LOADING TYPE	LOADING psf	MODULUS OF RUPTURE NET AREA (psi)	SAFETY FACTOR ACTUAL/ ALLOWABLE
12-inch Hollow	N	Center	352	142	4.44
Monowythe	N	Center	314	127	3.97
(Reference 4)	N	Center	333	134	4.19

a) Total number of tests without joint reinforcement = 43
Average safety factor (SF) = 5.3

b) Total number of tests with joint reinforcement = 15
Average safety factor (SF) = 5.6

REFERENCES:

1. Hedstrom, R. O., "Load Tests of Patterned Concrete Masonry Walls," Proceedings, American Concrete Institute, Vol. 57, p. 1265, 1961.

2. Fishburn, Cyrus C., "Effect of Mortar Properties on Strength of Masonry Monograph 36," National Bureau of Standards, 1961.

3. Cox, F. W., and Ennenga, J. L., Transverse Strength of Concrete Block Walls, "Proceedings," ACI, Vol. 54, p. 951, 1958.

4. Livingston, A. R., Mangotich, E., and Dikkers, R. "Flexural Strength of Hollow Unit Concrete Masonry Walls in the Horizontal Span," Technical Report No. 62, NCMA, 1958.

QUESTION 130.60

"Provide the report on the survey of the structural cracks that exist in the Braidwood Units 1 and 2 safety related walls with explanation of their origin and of their effects on the wall design strength and structural integrity."

RESPONSE

The survey and evaluation of the structural cracks in the Braidwood Station masonry walls will be completed in April 1985.