NORTHERN STATES POWER COMPANY

PRAIRIE ISLAND NUCLEAR POWER PLANT

PROJECT: 832846 (21-7450)

MASONRY WALLS - IE BULLETIN 80-11

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

SEPTEMBER 1982

INQUIRY 1.

Indicate whether the walls are stack bond or running bond. If any stack bond wall exists, provide sample calculation to obtain moment and shear stress of a typical wall.

RESPONSE:

All masonry walls evaluated in response to IE Bulletin 80-11 are built with running bond pattern.

INQUIRY 2.

According to attachment A, section 2.5 of Reference 3, the masonry walls in the hydrogen room and those around the elevator shaft were designed as shear walls. Indicate whether these shear walls are safety-related. If yes, have they been analyzed?

RESPONSE:

The walls around the hydrogen room are not safety related walls. They were designed as bearing walls at the time of original plant design.

The masonry walls around the elevator shafts are not shear walls and as such were not designed as shear walls.

The masonry walls around some of the elevator shafts were classified as safety related walls because of the proximity of these walls to the safety related equipment and/or the attachment of safety related piping or equipment to the walls. These walls were reanalyzed per criteria of reference 3.

INQUIRY 3.

Provide test results of the compressive strength of masonry block, mortar and grout.

RESPONSE

Masonry block:

Project specifications required blocks to conform to ASTM C90-66T Grade U-1. Test results show the blocks meet the requirements of ASTM C90-66T grade U1.

Samples of the test results are attached. (See sheets 15 thru 17)

Motar:

Project specifications required mortar to conform to ASTM C476, type PL. Test results show the mortar meets the requirements of the specifications.

A sample of test results is attached. (See sheet 18)

Grout:

Project specifications required grout to conform to ASTM C476, Fine Grout type. The grout meets the requirements of the specifications.

ASTM C476 does not have any compressive strength requirements for the grout.

INQUIRY 4.

Indicate how the earthquake forces in three directions were considered in the analysis.

RESPONSE:

Prairie Island Nuclear Plant was designed for the two dimensional seismic forces. These include:

a) North South Direction Earthquake combined with Vertical Earth Quake.

b) East-West Direction Earthquake combined with Vertical Earthquake.

For the design/analysis of the masonry walls the same philosophy was continued.

For the walls, the computed stresses due to each component of the earthquake are conservatively added by an absolute sum method.

Transverse Forces:

The forces due to seismic motion transverse to the wall are computed as described in section 3.2 of reference 3.

Longitudinal Forces:

The seismic forces in the longitudinal direction of the wall for the Prairie Island Plant are insignificant. This is due to the fact that the masonry walls are not rigidly attached to the ceiling and permit inter-storey drift without stressing the walls. Besides walls are very stiff in the longitudinal direction and floor

Inquiry 4 - continued

spectral acceleration at these frequencies are very small.

Vertical Forces:

The walls are very stiff in the vertical direction. The design considers the peak floor spectral accelerations for computing stresses in the walls.

INQUIRY 5

Regulatory Guide 1.61 allows 4% damping for OBE and 7% damping for the safe shut down earthquake (SSE). Section 3.2.2 of reference 3 specified a damping value of 5% for both OBE and SSE conditions. Justify this value for OBE condition.

RESPONSE:

Most all of the masonry walls for the Prairie Island Plant were analyzed as uncracked reinforced masonry walls with 2% damping.

Few walls, which were analyzed as cracked reinforced masonry walls, were analyzed with 5 percent damping for both operating basis and design basis earthquakes. 5 percent damping was proposed for the design of the walls at the time of the original plant design. NRC has adopted regulatory guide 1.61 for the damping values for masonry walls after our criteria for the re-evaluation of masonry walls was developed.

We have re-reviewed floor spectra for the Prairie Island Plant for 4, 5 and 7 percent damping and have concluded that our walls with 5% damping are conservative as designed and will meet the requirements of Reg. Guide 1.61. The conclusions are based on the following facts:

a) Safe shutdown ground accelerations are twice as large as operating basis earthquake.

b) Allowable stresses are fifty percent greater for load combinations including safe shutdown earthquake than those including operating basis earthquake.

c) Ratios of floor response spectral accelerations for 4 and 5 percent damping are less than 2/1.5 = 1.33.

INQUIRY 6

Provide sample calculations to indicate how the effect of higher mode of vibration are considered in the analysis.

RESPONSE:

Masonry walls are analyzed as beams and/or plates. Seismic loads for typical walls are applied as uniform loads on the entire wall. The intensity of the loads is based upon the spectral accelerations corresponding to the fundamental mode of vibration. The mid span bending moment for a simply supported beam with a uniformly distributed load is approximately 22% greater than for the load corresponding to the Fundamental mode.

INQUIRY 6 - continued

For walls of uniform mass and stiffness this approach is considered adequate. The detailed analysis to compute stresses due to higher modes and then combining them by the SRSS method is not required. The conclusion is illustrated with the case of a simple beam.

The second, third, and fourth, natural frequencies of the uniform beam are 4, 9 and 16 times that of the fundamental frequency. The participation factors for the beams for these modes are 1/2, 1/3 and 1/4, respectively.

The maximum bending moment for the beam is at its midspan. The even number of modes do not contribute to this moment. The contribution of third mode to the mid span bending moment for a constant spectral acceleration is, therefore, 1/27 times the bending moment due to the 1st mode. If these moments were combined by the SRSS method then the contribution of the third mode is

$$\sqrt{1^2 + \left(\frac{1}{27}\right)^2} - 1 \simeq 0.$$

Similarly, it can be shown that the maximum shear in the beam, when all modes are considered, is less than the shear due to uniform load on the beam where intensity is based on the Fundamental mode.

INQUIRY 7

Indicate whether load combinations not involving loads due to thermal gradiant wind, operating pressure, accident pressure, pipe rupture, etc., are according to FSAR specifications. Also justify the use of a factor of 2/3 for the load combination in Section 7.3.2 of Reference 3.

RESPONSE:

All load combinations used for the re-evaluation of masonry walls are in accordance with FSAR of Prairie Island Nuclear Plant.

In Section 7.3.2 a factor of 2/3 for the load combination is used for a load case involving safe shut-down (design basis) earthquake loads. This is consistent with Prairie Island Plant FSAR. FSAR allows fifty percent (50%) increase in the allowable stresses for the load combinations involving SSE loads. For the linear elastic analysis, this is equivalent to a reduction of loads to two thirds without increase in the code allowable stresses.

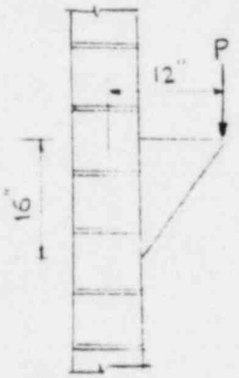
INQUIRY 8

Provide sample calculations for block pullout analysis.

RESPONSE:

In case of Prairie Island Nuclear Plant no major pipe thrust or other heavy loads are attached on any of the safety related masonry wall. Typical attachment weighs well below 100 lbs.

Sample calculations for block pullout analysis is provided below:



Given P = 400 lbs.

Seismic forces: Vertical = 500 lbs.

Horizontal = 600 lbs.

Horizontal load on block A due to eccentricity

= 400 x 12/16 = 300 lbs.

Therefore, Total Horz. load on block

A = 600 + 300

= 900 lbs.

For one hollow block, 7-5/8" x 7-5/8" x 15-5/8";

end area (2 sides) = 7-5/8" x 7-5/8"x 2 = 116 in^2

Top surface (Net) = 15-5/8" x 4.04 = 63 in^2

Bott. Surface (Net) = 15-5/8" x 4.04 = 63 in^2

Total Area = 242 in^2

Allowable shear stress = $0.9\sqrt{f_m'}$ = $0.9\sqrt{1350}$

= 33 psi

Available Pullout resistance = 33 psi x 242 in^2

= 7,986 lbs.

>> 900 lbs. O.K.

INQUIRY 9

According to section 7.4.4.3, Attachment A of reference 3, a limit of 25 psi has been used for tension between wythes of multi-wythe walls in composite action. Justify this value by any existing test data. Also provide and justify by any existing test data the value for allowable collar joint shear stress. Provide sample calculations illustrating the analysis of multi-wythe walls in composite action.

RESPONSE:

Tension Between Block and Fill:

Multiwythe walls for Prairie Island Nuclear Plant are solid grouted between the wythe and grout was puddled or vibrated in place. The bond between the block and grout is expected to be the same as the bond between block and mortar. ACI 531-79 allows 40 psi for tension normal to bed joints for mortar of 2000 psi.

Tests of tensile bond strength of concrete blocks to grout fill were made by Northwest Testing Lab for Portland General Electric's Trojan Nuclear plant. Specified compressive strength for blocks was 2000 psi and for fill was 3000 psi. These tests indicated average tensile bond strength between blocks and grout to be 194 psi, with a range of 143 to 236 psi. One specimen tested at only 43 psi, however, it was discarded because fill did not bond to the block on about one half of the interface.

Inquiry 9 - continued

The multiwythe walls of Prairie Island Plant are not subjected to loads normal to the walls except for the seismic forces due to self weight and minor attachments. These walls, also, have reinforcing ties to connect the wythes. This reinforcement consists of #3 ties at 16" c/c vertically and 32" to 48" c/c horizontally. The maximum computed tensile stresses between blocks and fill material is less than 3 psi.

Collar Joint Shear Stress;

Prairie Island Nuclear Plant uses a conservative value of 10 psi as the allowable collar joint shear stress. This is compared with the Flexural shear stress of $1.1\sqrt{f_m'}$ permitted per ACI 531-79. For the Prairie Island Plant this translates into 43 psi allowable shear stress.

The maximum computed value of collar joint shear stress for multiwythe walls is less than 5 psi including SSE loads.

Sample Calculation:

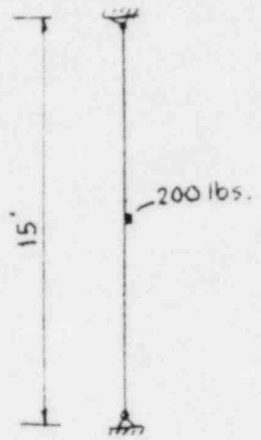
Given: 18" Double Wythe solid grouted wall

: Span = 15', both ends simply supported

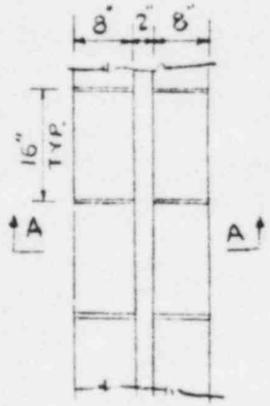
: Attached load on wall = 200 lb. rigidly attached

Assume: Wall is uncracked

Inquiry 9 - continued



SECT. A-A



PLAN

Tension Between Wythes:

Frequency at Vibration as Simple Beam = 21.3 cps

Horizontal Floor Spectral Acceler-

ation due to operating basis earthquake

= 0.094 g

Horizontal Force due to attachment

= .094 x 200 = 19 lbs.

Tension between Wythes due to

Attachment (assume one block area)

= 19/ (16 x 8) = 0.15 psi

Transverse seismic loads on wall

= .094 x 150 x 18/12 = 21.4 lbs/sft

Tensile stress (between wythes)

= 21.4/2 x 144 = .07 psi

Total tensile stress = .07 + 0.15 = 0.22 psi

Collar Joint Shear Stress:

Shear V = (21.4 x 15/2 + 19) = 180 lbs.

$I/Q = 1/12 \times 18^3 / (8 \times 8/2) = 15.2$

Shear stress $= \frac{VQ}{Ib} = \frac{180}{15.2 \times 12} = 1$ psi

Shear stress (SSE) = 2 psi

INQUIRY 10

Provide any increase factors that may have been used for allowable stresses under abnormal conditions. If they are higher than those factors listed in the SEB criteria (4), provide justification. The SEB factors are listed below by type of stress.

Axial or flexural compression	2.5
Bearing	2.5
Reinforcement stress except sheer	2.0, but not to exceed 0.9 fy
Shear reinforcement and/or bolts	1.5
Masonry tension parallel to the bed joint	1.5
Shear carried by masonry	1.3
Masonry tension perpendicular to the bed joint	
Reinforced masonry	0
Unreinforced masonry	1.3

RESPONSE:

Under abnormal load conditions all allowable stresses are increased by 50 percent. These factors are equal or lower in all cases except for the 1.3 Factors permitted for shear carried by masonry and the tension perpendicular to the bed joint.

The re-evaluation criteria for the project was established to agree with plant's FSAR prior to the publication of Appendix A to SRP 3.8.4.

Safety-related Masonry walls at Prairie Island Plant are reinforced walls but many of them were analyzed as unreinforced masonry walls with 2% damping.

INQUIRY 11

Indicate whether the walls are subject to impulsive or impactive loads such as missile or jet impingement loads. If so, provide sample calculations showing how they were considered in the analysis.

RESPONSE:

Masonry walls in the plant are not subjected to impulsive and/or impactive loads such as missile or jet impingement. High energy pipes are not in the vicinity of the walls and impact due to any of the postulated missiles is not feasible.

INQUIRY 12

Indicate the current status of the modifications and provide detailed drawings of some sample modifications.

RESPONSE:

Table 1 of reference 3 provides a list of walls which needed modifications. Engineering and construction of modifications have been completed.

A print of Drawing NF 38504-1 is attached to provide details for sample modifications.

REFERENCES

1. IE Bulletin 80-11
Masonry Wall Design
NRC, 08-May-80

2. D. E. Gilberts
Letter to J. G. Rappler, NRC. Subject: Prairie Island Nuclear Generating Plant - Response to IE Bulletin 80-11, Items 1, 2a and 3
Northern States Power Co., 08-Jul-80

3. D. E. Gilberts
Letter to J. G. Keppler, NRC, Subject: Prairie Island Nuclear Generating Plant - Response to IE Bulletin 80-11, Item 2b
Northern States Power Co., 04-Nov-80

4. Criteria for Safety-Related Masonry Wall Evaluation
SRP 3.8.4, Appendix A
NRC, 00-Jul-81

5. Uniform Building Code
International Conference of Building Officials, 1979

6. Building Code Requirements for Concrete Masonry Structures
Detroit: American Concrete Institute, 1979
ACI 531-79 and ACI 531-R-79

TWIN CITY TESTING AND ENGINEERING LABORATORY, INC.

ENGINEERS AND CHEMISTS
662 Cromwell Avenue - St. Paul, Minn. 55114

REPORT OF: CONCRETE BLOCK TEST ✓

PROJECT: NORTHERN STATES POWER COMPANY
NUCLEAR GENERATING PLANT

REPORTED TO: PRAIRIE ISLAND, MINNESOTA
Standard Building Material Company
(8) 1201 South Concord
South St. Paul, Minnesota 55075

DATE: December 11, 1969

FURNISHED BY: Standard Building Material Co.

COPIES TO:

LABORATORY No. 6-6736

DIMENSIONS:

	11	12	13	14	15	ASTM C90-66T SPECIFICATIONS GRADE "U-I" Individual Units	Average of 5 Units
Sample Number							
Size and Type of Block	12" X 8" X 16" Sand Concrete						
Length (in.)	15 5/8	15 5/8	15 5/8	15 5/8	15 5/8		
Width (in.)	11 5/8	11 5/8	11 5/8	11 5/8	11 5/8		
Height (in.)	7 5/8	7 5/8	7 5/8	7 5/8	7 5/8		
Shell Thickness (in.)	1 9/16	1 9/16	1 9/16	1 5/8	1 5/8		Min. 1½"
Web Thickness (in.)	1 17/64	1 17/64	1 21/64	1 19/64	1 17/64		Min. 1 1/8"
Weight as Received (lb.)	51.52	51.83	51.98	51.49	51.38		
Number of Cells	2	2	2	2	2		
Voids (%)	51	51	51	51	51		
Equivalent Web (in./lin. ft.)	3.13	2.92	3.16	3.02	2.92		Min. 2½"
Date Cast							

ABSORPTION:

Per Cent
Lb./Cu. Ft.

DRY DENSITY (pcf)

MOISTURE CONTENT AS RECEIVED:

Per Cent of Total Absorption

COMPRESSION:

Load (lb.)	304,000	312,000	247,000	310,000	297,000		
Gross Area (sq. in.)	182	182	182	182	182		
Gross Unit Load (psi)	1670	1720	1360	1710	1640	Min. 800psi	Min.1000psi
Net Area (sq. in.)	89.5	89.7	89.7	89.7	89.7		
Net Unit Load (psi)	3400	3480	2750	3450	3310	Min.1600psi	Min.2000psi
Date of Test	December 9, 1969						

POTENTIAL SHRINKAGE (%)

REMARKS: The above blocks meet the compressive strength requirements of ASTM Specification C90-66T for Grade U-I Hollow Load-Bearing Concrete Masonry Units. Samples were submitted to the laboratory and received here on November 28, 1969.

Twin City Testing and Engineering Laboratory, Inc.

By Theodore C. Johnson

TWIN CITY TESTING AND ENGINEERING LABORATORY, INC.

645-3601

ENGINEERS AND CHEMISTS

662 Cromwell Avenue - St. Paul, Minn. 55114

REPORT OF: CONCRETE BLOCK TEST

PROJECT: NORTHERN STATES POWER COMPANY
NUCLEAR GENERATING PLANT

REPORTED TO: PRAIRIE ISLAND, MINNESOTA
Foley Brothers, Inc.
Route 2
Welch, Minnesota 55089
Attn: Mr. Joe Maitland

DATE: August 31, 1970

FURNISHED BY: Standard Building Materials (
South St. Paul, Minnesota

COPIES TO: (1) NSP (Job)
Attn: John Meier

LABORATORY No. 6-7799

DIMENSIONS:

	1	2	3	4	5	6	ASTM C90-66T SPECIFICATIONS GRADE "U-I" Individual Unit	Average of 5 Units
Sample Number								
Size and Type of Block	8" x 8" x 16" Lightweight							
Length (in.)	15 5/8	15 5/8	15 5/8	15 5/8	15 5/8	15 5/8		
Width (in.)	7 5/8	7 5/8	7 5/8	7 5/8	7 5/8	7 5/8		
Height (in.)	7 5/8	7 5/8	7 5/8	7 5/8	7 5/8	7 5/8		
Shell Thickness (in.)	1 17/64	1 1/4	1 9/32	1 9/32	1 17/64	1 19/64		Min. 1 1/4'
Web Thickness (in.)	1 3/64	1 3/64	1 1/32	1 3/64	1 3/64	1 3/64		Min. 1"
Weight as Received (lb.)	24 69	24.69	24.42	24.61	24.48	24.81		
Number of Cells	2	2	2	2	2	2		
Voids (%)								
Equivalent Web (in./lin. ft.)	2.43	2.43	2.45	2.45	2.43	2.45		Min. 2 1/4'
Date Cast								

ABSORPTION:

Per Cent .....
Lb./Cu. Ft. .....

DRY DENSITY (pcf) .....

MOISTURE CONTENT AS RECEIVED:

Per Cent of Total Absorption .....

COMPRESSION:

Load (lb.)	156,000	137,000	133,000	148,000	128,000	142,000		
Gross Area (sq. in.)	119	119	119	119	119	119	Min.	Min.
Gross Unit Load (psi)	1310	1150	1120	1240	1080	1190	800 psi	1000 psi
Net Area (sq. in.)								
Net Unit Load (psi)								
Date of Test	August 31, 1970							

POTENTIAL SHRINKAGE (%) .....

REMARKS: The above block meet ASTM Compression Specifications for Grade U-I Hollow Load-Bearing Concrete Masonry Units. Samples were taken from the project stockpile located on the west end of the storage area by Mr. Bill Mahoney on August 26, 1970.

Twin City Testing and Engineering Laboratory, Inc.

By Richard E. Hinson

TWIN CITY TESTING AND ENGINEERING LABORATORY, INC.

ENGINEERS AND CHEMISTS
662 Cromwell Avenue - St. Paul, Minn. 55114

REPORT OF: CONCRETE BLOCK TEST

PROJECT: NORTHERN STATES POWER COMPANY
NUCLEAR GENERATING PLANT
PRAIRIE ISLAND, MINNESOTA

REPORTED TO: Foley Bros Inc
Route 2
Welch, MN 55089
Attn: Donald E. Johnson

DATE: March 13, 1974

FURNISHED BY:

COPIES TO:

LABORATORY No. 6-12760

DIMENSIONS:

	1	2	3	4	5	ASTM C90-66T SPECIFICATIONS GRADE "U-I" Individual Unit	Average of 5 Units
Sample Number							
Size and Type of Block	8" x 8" x 16" Sand Concrete						
Length (in.)	15 5/8	15 5/8	15 5/8	15 5/8	15 5/8		
Width (in.)	7 5/8	7 5/8	7 5/8	7 5/8	7 5/8		
Height (in.)	7 5/8	7 5/8	7 5/8	7 5/8	7 5/8		
Shell Thickness (in.)	1 19/64	1 9/32	1 11/32	1 5/16	1 5/16		Min. 1¼"
Web Thickness (in.)	1 1/16	1 1/16	1 3/32	1 1/32	1 3/32		Min. 1"
Weight as Received (lb.)	38.14	37.96	37.99	37.15	36.78		
Number of Cells	2	2	2	2	2		
Voids (%)	48	48	47	48	48		
Equivalent Web (in./lin. ft.)	2.47	2.46	2.52	2.45	2.52		Min. 2¼"
Date Cast							

ABSORPTION:

Per Cent	5.8	5.4	5.5	6.3	6.4		
Lb./Cu. Ft.	7.9	7.4	7.5	8.4	8.6		Max. 10 p
DRY DENSITY (pcf)	136	137	136	134	134		
MOISTURE CONTENT AS RECEIVED:							
Per Cent of Total Absorption	37	18	19	28	15		Max. 35%

COMPRESSION:

Sample Number	6	7	8	9	10		
Load (lb.)	185,000	195,000	215,000	240,000+	227,500		
Gross Area (sq. in.)	119	119	119	119	119	Min.	Min.
Gross Unit Load (psi)	1550	1650	1810	2020+	1910	800 psi	1000 psi
Net Area (sq. in.)	62	62	62	62	62	Min.	Min.
Net Unit Load (psi)	2980	3140	3470	3880+	3670	1600 psi	2000 psi
Date of Test							

POTENTIAL SHRINKAGE (%) .....

REMARKS: The above block meet ASTM specifications for Grade U-I Hollow Load-Bearing Concrete Masonry Units.
Samples were taken at the job site by Twin City Testing and Engineering Laboratory, Inc. on March 6, 1974.

This work was authorized by your Purchase Order Number NSP30.

Twin City Testing and Engineering Laboratory, Inc.

By

TWIN CITY TESTING AND ENGINEERING LABORATORY, INC.

ENGINEERS AND CHEMISTS
662 Cromwell Avenue - St. Paul, Minn. 55114

REPORT OF: **MORTAR COMPRESSION TESTS**

PROJECT: NORTHERN STATES POWER COMPANY
NUCLEAR GENERATING PLANT
PRAIRIE ISLAND, MINNESOTA

REPORTED TO: Foley Brothers, Inc.
Route 2
Welch, Minnesota 55089
Attn: Mr. Don Johnson

DATE: September 21, 1971

FURNISHED BY: Job Mixed

COPIES TO: (1) Northern States Power Co. (Job
Route 2 - Welch, Minnesota
Attn: Mr. John Meier

FIELD DATA:				
Job Identification	1A	1B	2A	2B
Date Cast	August 23, 1971			
Age to be Tested, days	7	28	7	28
Type of Sample	Two 3" x 6" Mortar Cylinders			
Location Placed	Concrete Block Wall for Chemical Drain Tank, Grid location 7 to 8 & J to K, Elevation 695'-0" to 704'-5"			
Specified Strength (ASTM:C476 Type PL)	Minimum 1600 psi @ 7 Days, 2500 @ 28 Days			
Mix Proportions: Cement Lime Sand	1 part (1 sack) Portland cement 1/2 part(1/2 sack) Hydrated lime 4 parts (27 shovels) Masonry Sand furnished by Pepin Concrete Products Company			

COMPRESSIVE STRENGTH:				
Laboratory Number	883	883	884	884
Date Received	August 26, 1971			
Method of Curing:				
Days on Job & Enroute	3	3	3	3
Days Lab. Cured	4	25	4	25
Area, square inches	7.07	7.07	7.07	7.07
Load at Failure, pounds	16,860	27,780	16,770	27,100
Strength, psi	2380	3930	2370	3830

REMARKS: The above samples meet project specifications.

Twin City Testing and Engineering Laboratory, Inc.

By Theodore O. Johnson