August 26, 1985

Docket No. 50-302

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Mr. Walter S. Wilgus
Vice President, Nuclear Operations
Florida Power Corporation
ATTN: Manager, Nuclear Licensing
& Fuel Management
P. O. Box 14042; M.A.C. H-3
St. Petersburg, Florida 33733

Dear Mr. Wilgus:

We have reviewed the information on masonry wall design (IE Bulletin 80-11) for Crystal River Unit 3 submitted with your letter dated February 29, 1984, and find that additional information is still needed in order to complete our review of this matter. The requested information is contained in the enclosure.

Please provide the information requested within 30 days of receipt of this letter.

Sincerely,

"ORIGINAL SIGNED BY
JOHN F. STOLZ"

John F. Stolz, Chief
Operating Reactors Branch #4
Division of Licensing

Enclosure:
As Stated

cc w/enclosure:
See next page

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REQUEST FOR ADDITIONAL INFORMATION
MASONRY WALL DESIGN, IE BULLETIN 80-11
CRYSTAL RIVER UNIT 3
DOCKET NO. 50-302
STRUCTURAL AND GEOTECHNICAL ENGINEERING BRANCH
STRUCTURAL ENGINEERING SECTION A

1. According to Section 1.2.3 of Reference 1, a portion of wall 1 has been removed to eliminate the wall's possible effect on safety-related equipment (see Figure 4, Ref. 1). Explain how this modification removes the safety concern of wall collapse on equipment near wall 1.

2. According to Reference 1, walls 2 and 3 exceed ACI 531-79 allowable stresses by 50% to 60%; however, according to the cover letter of Reference 1, a recent inspection has shown that the collapse of walls 2 and 3 would not have an adverse effect on safety-related equipment in the area. Indicate the recent findings that have permited these walls to be considered differently than in the original evaluation (Reference 2), which presented wall 2 and 3 as safety-related. Also, provide the documentation of the evaluation of these walls that, according to the cover letter of Reference 1, was due by April 30, 1984 but has not yet been provided.

3. The response to Item 4 in Reference 1 indicates that for the five control complex walls, a "fixed" boundary condition is assumed for mortared joints at masonry wall bases, top edges along a support slab, and side edges where the corner is integral with another masonry wall. No dowels, anchors, or other boundary reinforcements are present. Provide the justification for the assumption of fixed conditions for mortared joints by examining a typical connection in detail. Indicate the effect of joint flexibility on calculated results.

4. With respect to Section 3.1.2 of Reference 1, walls 1, 4, and 5 do not meet the ACI minimum requirements for thickness, so the ACI 531-79 formula, $F_a = 0.255 f'_m [1 - (h/40t)^3]$, for allowable axial compression becomes negative. These walls were qualified using the Southern Standard Building Code (SSBC) compression stress allowable of 70 psi. Also, fixed side boundary conditions in walls 4 and 5 were relaxed to allow for a redistribution of moment, which helped to keep stresses within allowable limits. Provide and justify the reasons for accepting these walls as meeting the SGEB criteria.

5. With respect to the seismic analysis of the instrument room walls in the turbine building, Section 3.2 in Reference 1 indicates that the effect of the first mode of vibration was increased by 5% to account for higher modes. Indicate why these walls were not checked with an eight mode analysis as were the five walls in the control complex. Indicate whether there are other differences in

the criteria between the control complex walls and the instrument room walls. Also, Figures 22 and 23 show "knife edge" boundary conditions for walls in the turbine building. Indicate whether these conditions were changed to "fixed" or "free" as in the control complex walls, and specify the physical boundary connections. The staff does not accept the use of arching or wedging action at boundary connections in qualifying masonry walls (the staff position is attached).

REFERENCES

1. G.R. Westafer
   Letter with Attachment to J. R. Stolz (NRC)
   Subject: Crystal River Unit 3, IE Bulletin 80-11, Request for Additional Information
   Florida Power Corporation
   29-Feb-84

2. P. Y. Baynard
   Letter to J. P. O'Reilly (NRC)
   Subject: Crystal River Unit 3, IE Bulletin 80-11, Masonry Wall Design
   Florida Power Corporation
   17-Nov-80

ATTACHMENT

SGEB Staff Position on Use of Arching Action Theory to Qualify Unreinforced Masonry Walls in Nuclear Power Plants

INTRODUCTION

Unreinforced hollow block masonry walls have a very limited capacity under the action of out-of-plane loads. Higher resistance could be developed by creating large in-plane clamping forces, thereby forming a three hinged arch mechanism after mid-span and support flexural cracking has occurred. The most important conditions for the arching mechanism to develop are the existence of rotational restraint at the boundaries and the prevention of gross sliding of the wall at support sections. Some of the licensees have relied on the development of this arching mechanism (referred to herein as 'arching action theory') to qualify unreinforced masonry walls in their plants.

The staff and their consultants have reviewed the basis provided by licensees to justify the use of arching action theory to qualify the unreinforced masonry walls. The staff met with a group of licensees representing approximately eleven utilities and twenty two units on November 3, 1982 and January 20, 1983 to discuss this issue. Further, a

site visit and detailed review of design calculations were conducted by the staff and consultants to gain first-hand knowledge of field conditions and the application of arching action theory in qualifying in-place masonry walls. Based on the information gained through the above activities, the staff has formulated the following position on the acceptability of the use of arching action theory to qualify unreinforced masonry walls in operating nuclear power plants. The staff's technical basis for the position is discussed in the attached report.

POSITION

The use of arching action theory to qualify unreinforced masonry block walls is not acceptable. Therefore, the licensee shall fix the walls currently qualified by the use of arching action theory such that they meet the staff acceptance criteria based on the working stress approach.

ENCLOSURE TO ATTACHMENT

EVALUATION OF ARCHING THEORY IN UNREINFORCED MASONRY WALLS IN NUCLEAR POWER PLANTS

Prepared by

Ahmed A. Hamid[1]

Harry G. Harris[1]

Vu Con[2]

June 1983

1. Department of Civil Engineering, Drexel University
2. Nuclear Engineering Department, Franklin Research Center

INTRODUCTION

In response to IE Bulletin 80-11, a total of 16 nuclear power plants have indicated that the arching action technique has been employed to qualify some unreinforced masonry walls. Based on the review of submittals provided by the licensees and published literature, Franklin Research Center (FRC) staff and FRC consultants have concluded that the available data in the literature do not give enough insight for understanding the mechanics and performance of unreinforced masonry walls under cyclic, fully reversed dynamic loading. As a result, a meeting with representatives of the affected plants was held at the NRC on November 3, 1982 so that the NRC, FRC staff, and FRC consultants could explain why the applicability of arching theory to masonry walls in nuclear power plants is questionable [1]. In a subsequent meeting on January 20, 1983, consultants of utility companies presented their rebuttals [2] and requested that they should be treated on a plant-by-plant basis. In accordance with their requests, the NRC staff has started the process of evaluating each plant on an individual basis. In this process, the NRC, FRC staff, and consultants have initiated visits to various nuclear plants to examine the field conditions of unreinforced masonry walls in the plants and to gain first-hand knowledge on how the arching theory is applied to actual walls. Key calculations have been reviewed with regard to the arching theory.

EVALUATION OF ARCHING THEORY

Test of unreinforced concrete masonry walls were recently conducted by Agbabian Associates, S. B. Barnes and Associates, and Kariotis and Associates [3] (this joint venture work is designated as ABK). Based on the visit to Oconee Nuclear Station, the results of the ABK tests, and all relevant information submitted by the licensees including the rebuttals given by the licensees in the January 20, 1983 meeting, the NRC, FRC staff, and consultants have made the following evaluations:

1. The design methodology used at various nuclear plants was developed by McDowell et al. [4] in 1956 for solid brick walls under static monotonic loading. No test data are available to check the adequacy of hollow block masonry under cyclic, fully reversed dynamic loading.

2. The only dynamic test data for arched masonry walls are the URS tests [5] for blast loading. This type of loading is not a true representation of earthquake loading because it is not fully reversed and has a decayed nature. Under very short-duration blast loading, masonry walls, which have much lower natural frequencies, would not fully respond to the applied load. In addition, only two walls were tested under cyclic blast loading at URS for arched masonry walls.

3. Extrapolation of test data from solid masonry to hollow block masonry is questionable. Recent test data [6] of eccentrically loaded masonry assemblages showed that the failure mechanism, strain distribution, and overall behavior of hollow masonry are quite different from those of solid or grouted masonry.

4. Hollow block masonry walls are more susceptible to premature web-shear failure or crushing compression failure. Precluding these types of failure is neccesary for the development of the arching mechanism. No data are available at the present time to determine the safety factors against these brittle failures under seismic loading.

5. Recent ABK dymanic tests [3] showed that unreinforced block masonry walls did <u>fail</u> (collapse) under earthquake loads with ground acceleration (effective peak acceleration) of about 0.3g to 0.4g, which is typical for nuclear plants. Also, some walls experienced local crushing at the base before failure by instability, which emphasizes the possibility of premature compression failure of arched walls. It must be noted, however, that the ABK test walls were not restrained at top to develop arching. The effect of boundary conditions could be significant and cannot be evaluated without further testing.

6. Unreinforced block masonry walls are extremely brittle, and flexural failure occurs without warning. The sensitivity of unreinforced masonry to crack development due to temperature and shrinkage is evident. Also, the inherent strength variability indicates the necessity of different safety indexes in ultimate failure analysis.

7. Masonry walls in nuclear plants usually have openings and attachments. Their effects on wall stability under seismic loading are unknown and cannot be rationally evaluated without testing.

8. No test data are available for gapped arching block walls under cyclic loading. In some cases, restrainers are provided around the gap to prevent gross sliding; this repair measure does not necessarily change the wall behavior from gapped arch to rigid arch.

CONCLUSION

A review and evaluation of the available information on the applicability of arching theory to unreinforced masonry walls in nuclear power plants has been presented. NRC, FRC staff, and consultants are firmly convinced that their original position expressed to the licensees in the November 3, 1983 meeting is still valid. It is evident that test data are needed to quantitatively determine the effects of different wall geometries, material properties, and boundary conditions on unreinforced block masonry walls' resistance to earthquake loading. It is recommended that a confirmatory testing program be performed to investigate the applicability of arching theory to unreinforced block masonry walls in nuclear power plants.

REFERENCES

1. Hamid, A. A. and Harris, H. G., "Applicability of Arching Theory to Unreinforced Block Masonry Walls Under Earthquake Loading," Franklin Research Center, Philadelphia, PA
   August 1982

2. "Rebuttal to Applicability of Arching Theory to Unreinforced Block Masonry Walls Under Earthquake Loading," Computech Engineering Services, Inc., URS/J. A. Blume & Associates and Bechtel Power Corporation, January 1983

3. "Methodology of Mitigation of Seismic Hazards in Existing Unreinforced Masonry Buildings: Wall Testing, Out-of-Plane," ABK report, El Sequndo, CA
   1981

4. McDowell, E. L., McKee, M. E., and Sevin, E., "Arching Action Theory of Masonry Walls," ASCE Proceedings, Journal of the Structural Division, ST2
   March 1956

5. Gabrielsen, B., Wilton, C., and Kaplan, K., "Response of Arching Walls and Debris from Interior Walls Caused by Blast Loading," Report No. 7030-23, URS Research Company, San Mateo, CA
   February 1975

6. Drysdale, R. G. and Hamid, A. A., "Capacity of Concrete Block Masonry Prisons Under Eccentric Compressive Loading," ACI Journal, Proceedings, Vol. 80
   March-April 1983

Mr. W. S. Wilgus
Florida Power Corporation

Crystal River Unit No. 3 Nuclear
Generating Plant

cc:
Mr. R. W. Neiser
Senior Vice President
and General Counsel
Florida Power Corporation
P. O. Box 14042
St Petersburg, Florida 33733

Nuclear Plant Manager
Florida Power Corporation
P. O. Box 219
Crystal River, Florida 32629

Mr. Robert B. Borsum
Babcock & Wilcox
Nuclear Power Generation Division
Suite 220, 7910 Woodmont Avenue
Bethesda, Maryland 20814

Resident Inspector
U.S. Nuclear Regulatory Commission
Route #3, Box 717
Crystal River, Florida 32629

Regional Administrator, Revion II
U.S. Nuclear Regulatory Commission
101 Marietta Street, Suite 3100
Atlanta, Georgia 30303

Mr. Ulray Clark, Administrator
Radiological Health Services
Department of Health and
Rehabilitative Services
1323 Winewood Blvd.
Tallahassee, Florida 32301

Administrator
Department of Environmental Regulation
Power Plant Siting Section
State of Florida
2600 Blair Stone Road
Tallahassee, Florida 32301

Attorney General
Department of Legal Affairs
The Capitol
Tallahassee, Florida 32304

Bureau of Intergovernmental Relations
660 Apalachee Parkway
Tallahassee, Florida 32304

Mr. Wilbur Langely, Chairman
Board of County Commissioners
Citrus County
Inverness, Florida 36250