OCONEE NUCLEAR STATION

# DYNAMIC TESTING

# UNREINFORCED CONCRETE MASONRY WALLS ARCHING ACTION VALIDATION

## MASONRY WALL CONFIRMATORY TEST PROGRAM

## CORRELATION WITH ARCHING THEORY AND SUMMARY OF RESULTS

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## SECTION 1 INTRODUCTION

Unreinforced masonry walls have traditionally been designed to behave elastically to prevent cracking for out-of-plane loading. However, it has been shown analytically and experimentally that unreinforced masonry walls do have reserve strength and resistance to out-of-plane loading after the formation of first cracks. For walls with stiff boundaries this reserve strength has generally been attributed to arching action.

Prior to the initiation of this test program arching action theory had been experimentally verified for blast loadings on masonry walls. Two approaches for blast loading have been developed, one by McDowell, McKee and Sevin [1,2] and one by Gabrielson, et. al. [3,4,5]. Neither approach had been validated for its applicability to seismic loads.

The objective of this confirmatory test program was to demonstrate the validity of the arching action analysis methodology developed and used by Duke Power Company for the structural analysis of the masonry walls at the Oconee Nuclear Station. The total test program consisted of a pilot wall (Wall No. 0) and four additional test specimens labeled Walls No. 1, 2, 3 and 4. Two of the walls had openings (Walls No. 3 and 4) and two of the walls had attachments (Walls No. 2 and 4).

The test walls were constructed in as similar a manner as possible to the walls at the plant. The 14'-8" height of the test specimens was equal to or exceeded the height of 89% of the walls at the plant that were qualified by the arching action methodology.

Parameters that were included in the program are:

(1) The effect of openings.

(2) The effect of attachments.

(3) Different input motions at the top and bottom of the wall.

(4) The effect of two different types of time histories that envelop the SSE floor spectra. These SSE floor spectra were obtained by enveloping the floor response spectra at all elevations containing masonry walls qualified by arching in both the North-South and East-West Directions. This was done for the respective response spectra at both the top and the base of the Oconee walls.

(5) The level of the input motion on all test specimens was gradually increased to evaluate the overall factor of safety of the walls and of the analytical methodology.

In general all the walls were tested in two stages: uncracked and cracked. Between the uncracked and cracked test sequences the walls were intentionally cracked by applying a load at midheight of the walls such that cracks at the top, center and base bedjoints were clearly visible. Each stage of testing included low level dynamic tests (pull back - free vibration) and high level dynamic tests. The high level tests used earthquake time history input signals up to intensity levels of approximately three times the envelope SSE for the Oconee Nuclear Station.

In addition to the wall tests, material tests were performed in order to determine the material properties of the wall specimens.

Two reports providing a detailed description of the test procedures and test results of the wall specimens have been issued. The first of these [6] details the results for Walls No. 0, 1 and 2 (walls without an opening) whereas the second [7] details the results for Walls 3 and 4 (walls with an opening). Both reports attempt to quantify the factor of safety for the Oconee walls as evaluated from the various response parameters obtained from the testing of the walls.

This report summarizes the test results and major findings, correlates the quasi-static test results with Duke Power Company's arching theory and applies the theory in the arching action analysis methodology to the results from seismic testing. The report also comments on the adequacy of the methodology to evaluate the Oconee masonry walls.

The reference to the SSE in this report and [6,7] is used to be consistent with current terminology. In the Oconee FSAR the terminology is for a design base earthquake and a maximum hypothetical earthquake. The use of SSE is synonymous with maximum hypothetical earthquake.

## SECTION 10 REFERENCES


[1] McDowell, E., McKee, K. and Sevin, E., "Arching Action Theory of Masonry Walls", Journal of the Structural Division, Proceedings of ASCE, ST2, Paper 915, March 1956.

[2] McKee, K. and Sevin, E., "Design of Masonry Walls for Blast Loading", ASCE Transactions, Paper No. 2988, Volume 124, 1959.

[3] Gabrielsen, B. and Kaplan, K., "Arching in Masonry Walls Subjected to Out-of-Plane Forces", pp 283-313, Earthquake Resistant Masonry Construction : National Workshop, National Bureau of Standards, NBS Building Science Series 106, September, 1977.

[4] Gabrielsen, B. and Wilton, C., "Shock Tunnel Tests of Arched Wall Panels", Report No. 7030-19, URS·Research Company, San Mateo, CA, February 1974.

[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] Computech Engineering Services, Inc., Berkeley, California. Dynamic Testing: Unreinforced Concrete Masonry Walls - Arching Action Validation. Masonry Wall Confirmatory Test Program performed for Duke Power Company, Charlotte, North Carolina. Results from Testing Walls No. 0, 1 and 2. Report No. R561-70-05 (Partially Proprietary).

[7] Computech Engineering Services, Inc., Berkeley, California. Dynamic Testing: Unreinforced Concrete Masonry Walls - Arching Action Validation. Masonry Wall Confirmatory Test Program performed for Duke Power Company, Charlotte, North Carolina. Results from Testing Walls No. 3 and 4. Report No. R561-70-06 (Partially Proprietary).

[8] Simitses, G. J., An Introduction to the Elastic Stability of Structures, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1976.

Duke Power Company
Oconee Nuclear Station

Attachment 1

Proprietary Test Reports

Test Report No. R561-70-05
Test Report No. R561-70-06
Test Report No. R561-70-07