50-271

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

April 18, 1996

LICENSEE: Vermont Yankee Nuclear Power Corporation

FACILITY: Vermont Yankee Nuclear Power Station

SUBJECT: SUMMARY OF MARCH 28, 1996, MEETING WITH REPRESENTATIVES OF VERMONT YANKEE NUCLEAR POWER CORPORATION

On March 28, 1996, pursuant to notice, the NRC staff met with representatives of Vermont Yankee Nuclear Power Corporation (the licensee) at Rockville, Maryland, to discuss the licensee's use of arching action methodology in the determination of operability of the masonry wall between the main station batteries at Vermont Yankee Nuclear Power Station (VYNPS). The list of attendees is provided as Attachment 1. The licensee's slides are provided as Attachment 2. The licensee's contractor's slides are provided as Attachment 3.

On March 5, 1996, during the internal review of its summary report on verification of the seismic adequacy of equipment, the licensee identified non-conservative erroneous assumptions in the calculations used to qualify the masonry wall between the main station batteries. The licensee conferred with a contractor regarding determination of operability of the wall which supports both batteries. The contractor, EQE International, Inc., provided analysis supporting operability of the wall using the arching action methodology (AAM). The NRC staff has not previously approved use of this methodology for wall configurations like that at VYNPS. The staff expressed concerns with the ability of AAM to predict the seismic capacity of an unreinforced masonry wall like the one in question.

DF01
1/1

290008

NRC FILE CENTER COPY

The licensee stated that it intended to install modifications to restore the battery racks and the wall to full qualification during the 1996 RFO. The 1996 RFO is scheduled to begin on or about August 24, 1996, and last approximately 29 days.

ORIGINAL SIGNED BY:

Daniel H. Dorman, Project Manager
Project Directorate I-1
Division of Reactor Projects - I/II
Office of Nuclear Reactor Regulation

Docket No. 50-271

Attachments: 1. List of Attendees
2. Agenda
3. Masonry Wall Seismic Evaluation

cc w/atts: See next page

DISTRIBUTION:

HARD COPY
Docket File (w/encls.)
PUBLIC (w/encls.)
PDI-1 R/F (w/encls.)
OGC (w/encls. 1&2)
ACRS (w/encls. 1&2)

EMAIL (w/encls. 1&2)
W. Russell/F. Miraglia
R. Zimmerman
S. Varga
J. Zwolinski
D. Dorman (w/encls.)
S. Little
E. Jordan
D. Dorman
R. Rothman
J. Ma
G. Bagchi
R. Eaton
W. Dean

DOCUMENT NAME: G:\VERMONT\VY032896.MTS

To receive a copy of this document, indicate in the box: "C" = Copy without enclosures "E" = Copy with enclosures "N" = No copy

OFFICE	LA:PDI-1		PM:PDI-1		D:PDI-1					
NAME	SLittle		DDorman:smm		SShankman					
DATE	04/18/96		04/18/96		04/18/96		04/ /96		04/ /96	

OFFICIAL RECORD COPY

The licensee stated that it intended to install modifications to restore the battery racks and the wall to full qualification during the 1996 RFO. The 1996 RFO is scheduled to begin on or about August 24, 1996, and last approximately 29 days.

Daniel H Dorman

Daniel H. Dorman, Project Manager
Project Directorate I-1
Division of Reactor Projects - I/II
Office of Nuclear Reactor Regulation

Docket No. 50-271

Attachments: 1. List of Attendees
2. Agenda
3. Masonry Wall Seismic Evaluation

cc w/atts: See next page

Vermont Yankee Nuclear Power Station

Vermont Yankee Nuclear Power
Corporation
cc:

Regional Administrator, Region I
U. S. Nuclear Regulatory Commission
475 Allendale Road
King of Prussia, PA 19406

R. K. Gad, III
Ropes & Gray
One International Place
Boston, MA 02110-2624

Mr. Richard P. Sedano, Commissioner
Vermont Department of Public Service
120 State Street, 3rd Floor
Montpelier, VT 05602

Public Service Board
State of Vermont
120 State Street
Montpelier, VT 05602

Chairman, Board of Selectmen
Town of Vernon
P.O. Box 116
Vernon, VT 05354-0116

Mr. Jay Thayer, Vice President
Vermont Yankee Nuclear Power
Corporation
Ferry Road
Brattleboro, VT 05301

Mr. Donald A. Reid
Vice President, Operations
Vermont Yankee Nuclear Power
Corporation
Ferry Road
Brattleboro, VT 05301

Mr. Robert J. Wanczyk, Plant Manager
Vermont Yankee Nuclear Power Station
P.O. Box 157, Governor Hunt Road
Vernon, VT 05354

G. Dana Bisbee, Esq.
Deputy Attorney General
33 Capitol Street
Concord, NH 03301-6937

Resident Inspector
Vermont Yankee Nuclear Power Station
U.S. Nuclear Regulatory Commission
P.O. Box 176
Vernon, VT 05354

Chief, Safety Unit
Office of the Attorney General
One Ashburton Place, 19th Floor
Boston, MA 02108

Mr. David Rodham, Director
ATTN: James Muckerheide
Massachusetts Civil Defense Agency
400 Worcester Rd.
P.O. Box 1496
Framingham, MA 01701-0317

Mr. Raymond N. McCandless
Vermont Division of Occupational
and Radiological Health
Administration Building
Montpelier, VT 05602

Mr. J. J. Duffy
Licensing Engineer
Vermont Yankee Nuclear Power
Corporation
580 Main Street
Bolton, MA 01740-1398

LIST OF ATTENDEES

MEETING WITH LICENSEE REPRESENTATIVES FOR

VERMONT YANKEE NUCLEAR POWER STATION

ROCKVILLE, MARYLAND

MARCH 28, 1996

NAME	AFFILIATION	TITLE
Dan Dorman	NRR/Project Directorate I-1	Project Manager
Jim Duffy	Vermont Yankee	Licensing Engineer
Steve Short	EQE	Senior Consultant
Robert Kennedy	SMC	Consultant
Scott Goodwin	Vermont Yankee	Lead Mechanical Eng.
Jay Thayer	Vermont Yankee	VP, Engineering
Stan Miller	Vermont Yankee	Design Eng. Manager
R. Rothman	NRR/DE/ECGB	Asst Branch Chief
J. Ma	NRR/DE/ECGB	Structural Engineer
G. Bagchi	NRR/DE/ECGB	Branch Chief
Ron Eaton	NRR/PD I-1	Sr. Project Manager

ECGB = Civil Engineering and Geosciences Branch

Attachment 1

Agenda

- **Introduction**
- **Problem**
- **Actions Taken**
- **Masonry Wall Evaluation**

Introduction

- **Vermont Yankee / Yankee Atomic**

Jay Thayer - VP Engineering
Stan Miller - Design Engineering Manager
Scott Goodwin - Lead Mechanical Engineer
Jim Duffy - Licensing Engineer

- **Consultants**

Bob Kennedy - RPK Structural Mechanics Consulting
Steve Short - EQE International, Inc.

Problem

- **USI A-46 reviews discover apparent non-conservative inputs to original IEB 80-11 calculation**
    - **Masonry wall used, in part, to provide structural support to main station battery racks**

Actions Taken
3/5/96 through Present

- Detailed review of analysis of record confirms use of non-conservative inputs

- Reanalysis using proper inputs determines calculated stresses exceed acceptance criteria

- Additional reviews performed to define total scope of walls affected; total of two walls defined

Actions Taken (Cont.)

- **Parallel discussion initiated with EQE concerning alternate methods applicable for demonstrating design capability of the walls**

- **EQE feels confident that their method, accounting for arching behavior, will yield acceptable results. EQE commissioned to perform evaluation**

- **EQE performs successive iterations to the calculation to refine initial assumptions based on actual wall geometry**

- **Final results are as contained in EQE Calculation No. 240008-C-001. Spectral capacity = .75g vs. licensed design basis demand = .4g**

Actions Taken (Cont.)

- **At VY request, RPK is commissioned through EQE to perform third party review of the EQE calculation**

- **RPK concurs with the conclusions in the EQE calculations and cites two assumptions which are deemed to be overly conservative. With those two assumptions modified, it is concluded that spectral capacity may be increased from .75g to 1.41g**

Masonry Wall Seismic Evaluation
Vermont Yankee Nuclear Power Station
Control Building, Battery Room

Robert P. Kennedy
RPK Structural Mechanics Consulting
Stephen A. Short
EQE International, Inc.

March 28, 1996

Attachment

Battery Room Wall Seismic Evaluation

- Calculations have been performed to determine whether the wall has sufficient capacity to support attached batteries in a seismic event
  - Demonstrate that the wall is OK for temporary operation
- Upgrade of the wall and batteries is being developed
  - Detach batteries from the wall
  - Strengthen battery support structure
- Methods accounting for arching behavior have been used
  - Not proposed for use in design of new walls
  - Common method for evaluating existing walls
  - Validated against wall test results

Battery Room Wall Seismic Evaluation (cont.)

- Arching behavior is common practice for evaluation of existing unreinforced masonry walls
  - U.S. experience
  - Experience in Canada and England
- A simplified "reserve energy" method employed
  - Validated against time history analyses
- Vermont Yankee wall has high seismic capacity/demand ratio

Arching Evaluation of Unreinforced Masonry Walls

Many investigators have conducted studies of arching action of walls.

- United States
  - Park, 1991 (Reserve energy calcs & Agbabian tests)
  - Angel and Abrams, 1994 (University of Illinois)
  - Hill, 1994 (NSF grant, linear 3 hinge arch calcs vs. tests)
  - Flanagan, et.al., 1994 (Oak Ridge HCTW tests)
  - Oconee nuclear power plant wall tests
- Canada and U.K.
  - Dawe & Seah, 1988 (Canada - tests and yield line arching analyses)
  - Anderson, 1984 (U.K. - comparison of arching theory and tests)

Past Work on Arching of Masonry Walls

- Park, 1991 (Brookhaven National Laboratory)
  - Compared an equivalent linear, reserve energy arching analysis method (similar to the method used for the Vermont Yankee wall) to test results.
  - Comparion of analysis and test results indicates a median safety factor of 1.02 with a coefficient of variation of 0.14.
  - It is concluded that the equivalent linear model reasonably predicts the wall collapse strength.

Past Work on Arching of Masonry Walls (cont.)

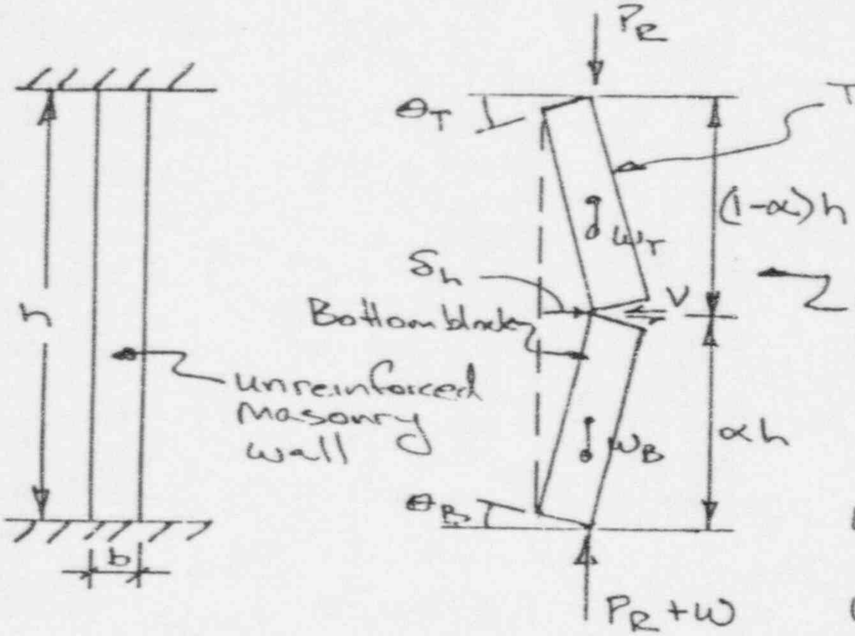
- Dawe & Seah, 1988
  - Demonstrates ratio of arching theory to experimental ultimate load of between 0.94 to 1.14 (mean = 1.02 & COV = 0.06)
- Anderson, 1984
  - 1978 British Standard BS 5628 permits design of unreinforced masonry using arching.
  - Arching theory and BS 5628 equation compared to tests.
    - Test to theory averages 0.94 with COV of 0.17
    - Test to BS 5628 equation averages 1.09 with COV of 0.48
  - Reasonable agreement between tests and arching theory

Equivalent Linear Reserve Energy Methods

- The method for arching evaluation of walls employed for the battery room wall uses an equivalent linear formulation by equating energy of non-linear restoring forces to an equivalent linear wall stiffness
- The reserve energy method has been verified by comparison to both time history analyses and to test results
  - Park, 1991 compares reserve energy calculations to wall test results with good agreement.
  - Wesley, et.al., 1980 7th WCEE and Wesley, et.al., 1984 ASCE Structural Engineering in Nuclear Facilties Conference compares reserve energy calculations to nonlinear time history analyses of walls with good agreement.

Derivation of Wall Acceleration Capacity

- **Arching behavior**



Masonry wall subjected to out-of-plane seismic excitation

W = total wall weight

$= W_T + W_B$

$W_B = \alpha W ; \; W_T = (1-\alpha) W$

Wall cracks and rotates at height αh above base

Crack at location of maximum moment ($V=0$)

Individual block pieces deform as rigid bodies

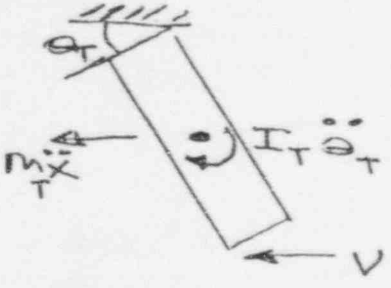
Small angle approximations apply

$$\theta_B = \frac{\delta_h}{\alpha h} \quad \theta_T = \frac{\delta_h}{(1-\alpha)h} = \frac{\alpha}{1-\alpha}\theta_B$$

Derivation of Wall Acceleration Capacity (cont.)

- **Equations of motion**

Top Block

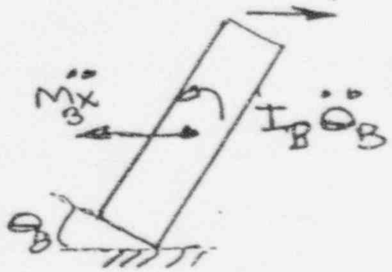


$$I_T\ddot{\theta}_T + \frac{m_T\ddot{x}\,l_T}{2} + k_{\theta_T}\theta_T + V l_T = 0$$

$$I_T = \frac{m_T l_T^2}{3} \qquad m_T = \frac{(1-\alpha)W}{g} \qquad l_T = (1-\alpha)h$$

$$\boxed{\frac{(1-\alpha)^3 W h^2}{3}\ddot{\theta}_T + g k_{\theta_T}\theta_T = -\frac{(1-\alpha^2)Wh\ddot{x}}{2} - (1-\alpha)Vhg}$$

Bottom Block



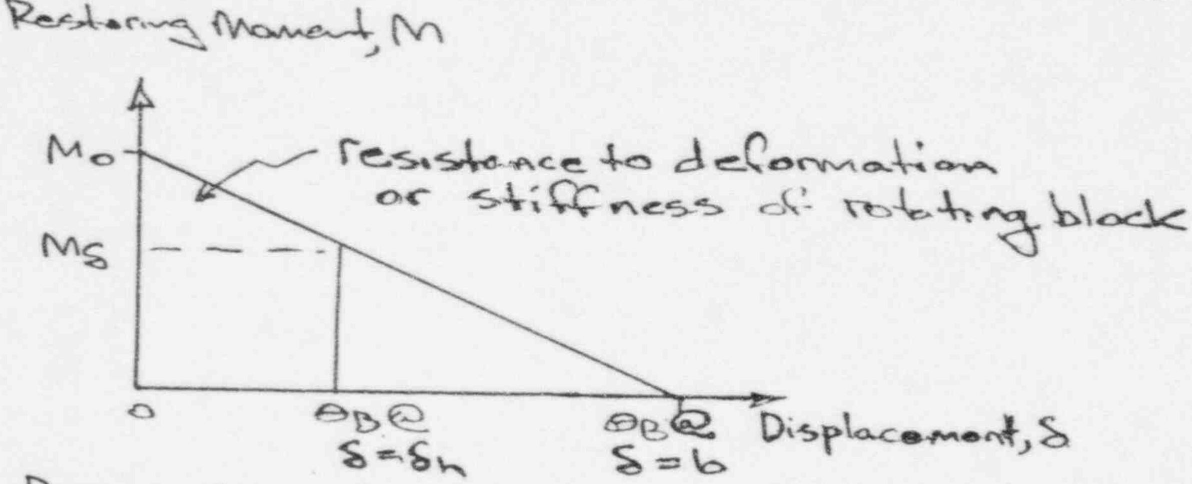
$$I_B\ddot{\theta}_B + \frac{M_B\ddot{x}\,l_B}{2} + k_{\theta_B}\theta_B - V l_B = 0$$

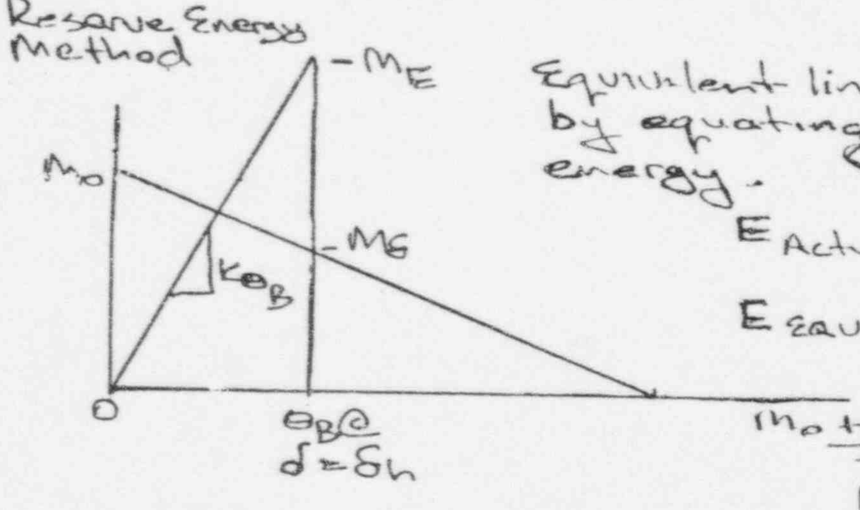
$$I_B = \frac{M_B l_B^2}{3} \qquad M_B = \frac{\alpha W}{g} \qquad l_B = \alpha h$$

$$\boxed{\frac{\alpha^3 W h^2}{3}\ddot{\theta}_B + g k_{\theta_B}\theta_B = -\frac{\alpha^2 Wh\ddot{x}}{2} + \alpha Vhg}$$

Derivation of Wall Acceleration Capacity (çont.)

- **Equivalent linear stiffness by reserve energy method**





Equivalent linear stiffness, k_θ is determined by equating actual energy to equivalent energy.

$$E_{Actual} = \left(\frac{M_o + M_S}{2}\right)\theta_B$$

$$E_{EQUIV} = \frac{1}{2} M_E \theta_B \; ; \; k_{\theta_B} = \frac{M_E}{\theta_B}$$

$$\frac{M_o + M_S}{2}\theta_B = \frac{1}{2} k_{\theta_B} \theta_B^2$$

$$\boxed{k_{\theta_B} = \frac{M_o + M_S}{\theta_B}}$$

Derivation of Wall Acceleration Capacity (cont.)

UNIFORM LOAD

spectral acceleration capacity

$$\frac{SA}{g} = 4(b/h)\,F_p\left(1-\frac{\delta_h}{2b}\right)$$

where F_p is a function of δ_h, α, and P_{RS}

lateral force capacity

$$q = \left(\frac{SA}{g}\right)w = 4w(b/h)\,F_p\left(1-\frac{\delta_h}{2b}\right)$$

which may be simplified to:

$$q = (b/h)\left\{6w\left(1-\delta_h/2b\right) + 2f_p\,\frac{P_{RO}+P_{RS}\left(1-\delta_h/b\right)}{h}\right\}$$

when the reaction force is applied to the edge of the wall, $f_p = 4.03$

effective frequency

$$f_e = \frac{1}{2\pi}\sqrt{\frac{1.5\left(\frac{SA}{g}\right)g}{\delta_h}}$$

Derivation of Wall Acceleration Capacity (cont.)

- **Confining force, P_R**

P_R depends on the upward displacement of the wall during arching, δ_u

$$\delta_u = \delta_h (b/h)\left(\frac{1}{\alpha} + \frac{1}{1-\alpha}\right) \cong f_p\left(\frac{b}{h}\right)\delta_h$$

P_R also depends on the flexibility of the restraining slab and the crushing capacity of the wall, P_C

$$P_C = (nc) f'_m t - P_{Ro} = 0.125 f'_m t - P_{Ro}$$ Anderson, 1984

c is fraction of block thickness that supports confining force P_{RS}

n is an increase factor on f'_M for local crushing

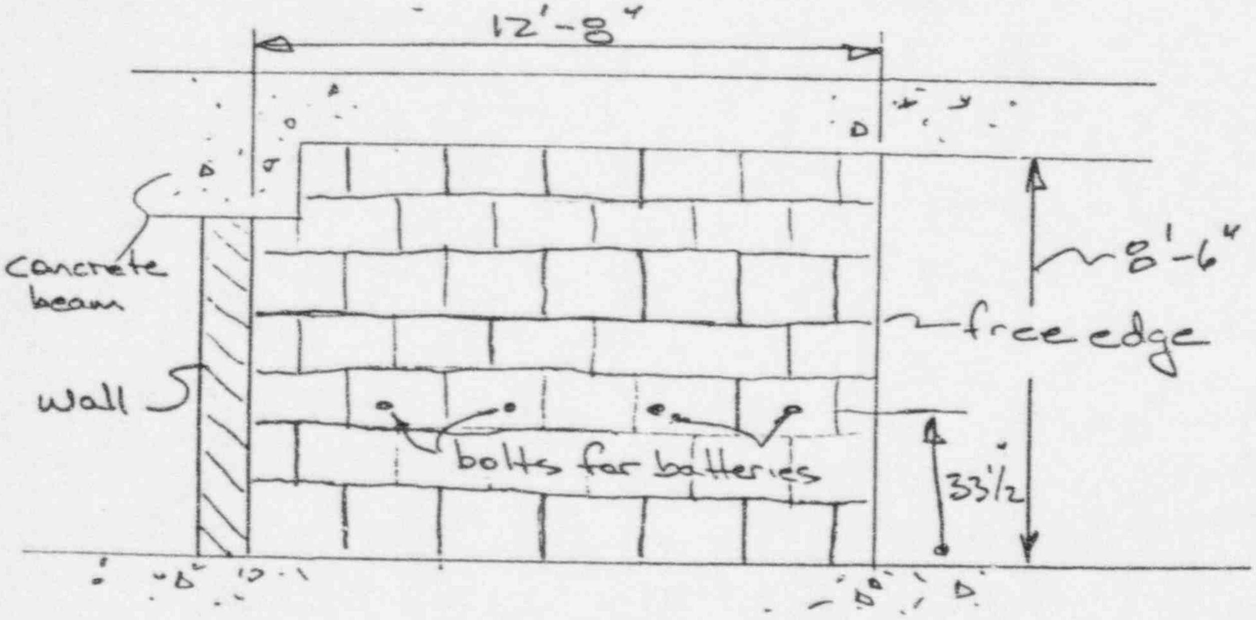
Arching Calculations and Wall Test Results

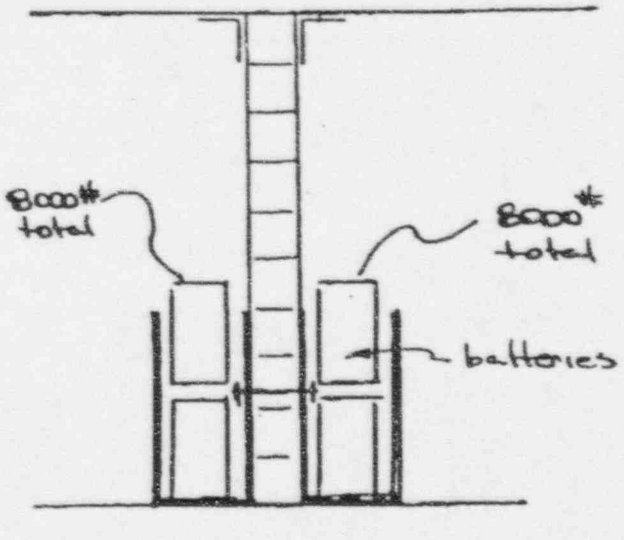
- This arching evaluation method (uniform load) was developed for Oak Ridge buildings
  - Establish criteria for evaluation of existing buildings with unreinforced masonry infill walls (HCTW)
  - Compared with static air bag tests of an actual building wall and of 3 test walls
  - Comparison of predicted capacity and test capacity

Wall	Predicted q_p	Test q_p	Test/Prediction
1	3.94 psi	3.85 psi	0.98
2	4.76 psi	4.74 psi	1.00
3	1.13 psi	1.13 psi	1.04
Building wall	0.86 psi	0.87 psi	1.01
Mean = 1.01		COV = 0.02	

Battery Room Masonry Wall

- At the Vermont Yankee control building battery room, there is an 8" thick by 8.5' high by 12.67' wide unreinforced masonry wall. The wall fits between the floor and ceiling concrete slabs with no gap.
- The wall supports batteries which are connected at 33.5" above the floor.





Battery Room Wall Capacity

- This arching capacity approach has been applied to the battery room wall
- The battery room wall has a free edge such that it is assumed that confining force is provided only at one end of the wall near the beam and cross wall
- The confining force is limited by the flexibility of the floor and ceiling slabs as well as that of beams framing into columns
- The confining force is further limited by the cracking moment of the slab which has minimal top reinforcement
- Evaluated median capacity as well as factored capacity using a strength reduction factor of 2/3

Concentrated Wall Load

- The previously defined arching action equation applies for the case of a uniform load over the wall area
- These batteries are a significant concentrated load, much greater than the wall weight.

For vertically spanning wall with Concentrated inertial load W_B at height h_B $(W_B >> W)$

Crack will form at $\alpha = h_B/h$

Equation of motion is modified to include $W_B \ddot{x}$ at h_B term

Spectral acceleration capacity becomes:

$$\frac{SA}{g} = \frac{4(b/h) F'_p \left(1 - \frac{\delta_h}{2b}\right)}{\left[1 + \frac{2W_B}{W}\right]}$$

Effective frequency becomes:

$$f_e = \frac{1}{2\pi} \sqrt{\left(\frac{W_B + 1.5W}{W_B + W}\right) \frac{\left(\frac{SA}{g}\right) g}{\delta_h}}$$

Battery Room Wall Capacity (cont.)

- Initially it was assumed that the battery weight of 16,000 lbs was distributed uniformly over the wall area (EQE Calculation No. 240008-C-001)
  - <u>Median capacity = 1.13g; Factored capacity = 0.75g</u>
- Another calculation was performed treating the batteries as a concentrated load of 16,000 lbs
  - <u>Median capacity = 1.64g; Factored capacity = 1.09g</u>
- In addition, a calculation was performed treating the batteries as a 12,000 lb concentrated load assuming the remaining 4,000 lb is directly tributary to the floor
  - <u>Median capacity = 2.12g; Factored capacity = 1.41g</u>

Battery Room Wall Capacity/Demand

- The best estimate of the median capacity of the wall is 2.12g. This is a conservative estimate of median as minimum specified masonry and concrete strengths were used.
- Factored capacity is 1.41g including strength reduction factor of 2/3
- Factored capacity to demand is over 3.5 for the 0.4g design basis wall load
- The wall capacity far exceeds the seismic demand

Battery Room Wall Capacity/Demand (cont.)

- The effective frequency of the battery room wall is estimated to be about 6.5 hz
- At this frequency, the spectral acceleration of both the floor and ceiling levels is about 0.5g
- Hence, the factored capacity to demand is over 2.8 considering seismic demand of 0.5g design from dynamic analysis of the building

Conclusion

- There is more than adequate margin for the Vermont Yankee battery room wall to continue in operation for a short period of time with batteries supported from the wall.