TOLEDO EDISON

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Docket No. 50-346

License No. NPF-3

Serial No. 814

May 3, 1982

Director of Nuclear Reactor Regulation
Attention: Mr. John F. Stolz
Operating Reactors Branch No. 4
Division of Operating Reactors
United States Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Mr. Stolz:

This is in response to your letter dated March 8, 1982 (Log No. 918) concerning Masonry Wall Design; IE Bulletin 80-11, Request for Additional Information as it relates to Davis-Besse Nuclear Power Station Unit 1.

On April 26, 1982 a discussion was held between Toledo Edison personnel, Mr. Al DeAgazio, Project Manager NRR, staff reviewers and Bechtel. As a result of this telephone conversation, all concerned parties agreed that Toledo Edison would make a partial submittal of the requested information at this time. The remaining information will be subsequently provided at a meeting at Bechtel, Gaithersburg with the staff reviewers to be scheduled during the week of May 24, 1982.

Very truly yours,

RPC:GAB:rs

Attachment

cc: DB-1 NRC Resident Inspector

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RESPONSE TO NRC QUESTIONS

MASONRY WALL DESIGN

1. Question

Table I (2) refers only to the edge conditions as indicated in the masonry wall drawings. Provide the boundary conditions assumed for the analysis.

Response

For CMU walls supported at the top and bottom edges, vertical strips have been analyzed assuming the top and bottom edges are pinned. This is conservative because the calculated natural frequency of the CMU wall, using this assumption, will be lower than the calculated natural frequency based on fixed or partially fixed connections. The various floor response spectra employed a constant response equal to the peak response on the low frequency side of the peak. This results in determining from the respective floor response curve, the upper bound seismic acceleration to be applied perpendicular to the plane of the CMU wall. In addition to upper bound seismic loads being applied to the CMU wall, the calculated moments used in stress calculations will be greater for the assumption of pinned edges versus the assumption of fixed or partially fixed edges, resulting in conservative stress calculations.

For CMU walls with short horizontal spans, supported on both vertical edges, horizontal strips have been analyzed assuming the vertical edges are pinned. This is conservative based on the above statements.

For CMU walls free at the top, the bottom connections are assumed fixed, with the stresses in the masonry and the connections analyzed accordingly.

2. Question

Indicate how the effects of higher modes were considered in cases where the analysis was based on the "block wall" program, which includes only three modes.

Response

The computer code "BLOCK WALLS" was verified by comparison with a solution considering nine modes. The comparison showed the computer code "BLOCK WALLS" produced a seismic moment due to flexure that was conservative by 1.1 percent versus the 9 mode solution.

3. Question

Indicate whether any of the walls was analyzed as a plate, with special reference to walls having cut-outs.

Response

Information required to answer this question is currently unavailable and will be provided at the meeting scheduled for the week of May 24, 1982 at Bechtel - Gaithersburg.

4. Question

Explain why the Table V (2) factors for operating basis earthquake (OBE) and wind load are 1.0, while the plant FSAR specifies a factor of 1.25 for these loads.

Response

Analysis of CMU walls used working stress criteria for which "SEB Interim Criteria for Safety-Related Masonry Wall Evaluation", July 1981, specifies a factor of 1.0 for both operating basis earthquake and wind. The factor of 1.25 in the FSAR is based on ultimate strength criteria.

5. Question

Indicate how equipment weight was considered in the analysis of the masonry walls. Standard Review Plan (SRP), Section 3.7.2 (7), suggests that the equipment weight should be multiplied by a factor of 1.5 times the peak floor acceleration.

Response

The equipment weight multiplied by a factor of 1.5 times the peak floor acceleration is an equivalent static load method of analysis which may be used in lieu of a dynamic method. All CMU walls which were analyzed used a dynamic method including actual dead weight of the wall plus the dead weight of the equipment.

6. Question

With reference to Section 7.1, Appendix E (2), use the envelope of the floor spectra or provide justification for using the average spectral acceleration.

Response

The evaluations herein demonstrate that the use of the average floor acceleration response spectra to calculate the response of the wall panel is appropriate.

For the purposes of this evaluation, the seismic response of a simply-supported, uniform beam simulating a strip of the wall panel with unit width is considered, as shown in Figure 1:

Use of Average Spectra

The equation of motion of an undamped, simply-supported beam can be written in terms of the total displacement with respect to some fixed reference axis as:

$$- m \frac{\partial^2 U}{\partial t^2} + EI \frac{\partial^4 U}{\partial x^4} = 0 \qquad (1)$$

where m and EI are the mass density and flexural rigidity of the beam. Denote the seismic excitations at the ends of the beam as U_a and U_b. Then the total displacement u(x,t) can be expressed in terms of the two seismic motions and the relative displacement to the seismic motions as:

$$u(x,t) = (x/L)\ U_b + (1 - x/L)\ U_a + r(x,t) \tag{2}$$

where L is the length of the beam. The relation expressed by the above equation is shown in Figure 2. The relative displacement r(x,t) must satisfy the following simply-supported conditions:

$$r(o,t) = r\ (L,t) = 0 \tag{3}$$

$$\left.\frac{\partial^2 r}{\partial x^2}\right|_{x=0} = \left.\frac{\partial r}{\partial x^2}\right|_{x=L} \tag{4}$$

Upon substitution of Equation 2 into Equation 1, the equation of motion in terms of relative displacement r(x,t) can be expressed as:

$$m\frac{\partial^2 r}{\partial t^2} + EI\frac{\partial^4 r}{\partial x^4} = -m(x/L)\ \ddot{U}_b - m(1 - x/L)\ddot{U}_a \tag{5}$$

The eigen-function solutions for the homogeneous equation associated with Equation 5 that satisfy the boundary conditions specified by Equations 3 and 4 are:

$$\sin\frac{n\pi x}{L}, \quad n = 1, 2, 3, \ldots,$$

and the corresponding frequencies of vibration are:

$$\omega_n = n^2\pi^2\sqrt{\frac{EI}{mL^4}} \quad n = 1, 2, 3, \ldots \tag{6}$$

So, the solution of Equation 5 can be expressed as:

$$r(x,t) = \sum_{n=1}^{\infty} a_n(t)\sin\frac{n\pi x}{L} \tag{7}$$

Substitute Equation 7 into Equation 5, and mutiply the latter by $\sin n\pi x/L$ and then integrate it with respect to x over the full length of the beam; the equation of motion can be transformed into modal equations of motion as:

$$\ddot{a}_n + \omega^2 n^a n = \Gamma_n \left(\frac{\ddot{U}_a + \ddot{U}_b}{2} \right) \qquad n = 1, 3, 5, \ldots \tag{8a}$$

and

$$\ddot{a}_n + \omega^2 n^a n = \Gamma_n \left(\frac{\ddot{U}_a - \ddot{U}_b}{2} \right) \qquad n = 2, 4, 6, \ldots \tag{8b}$$

where Γ_n = participation factor

$$= \frac{4}{n\pi} \tag{9}$$

If damping in the form of modal damping ratio is included, Equations 8a and 8b become:

$$\ddot{a}_n + 2\xi_n \omega_n \dot{a}_n + \omega^2 n^a n = \Gamma_n \left(\frac{\ddot{U}_a + \ddot{U}_b}{2} \right) \qquad n = 1, 3, 5, \ldots \tag{10a}$$

and

$$\ddot{a}_n + 2\xi_n \omega_n \dot{a}_n + \omega^2 n^a n = \Gamma_n \left(\frac{\ddot{U}_a - \ddot{U}_b}{2} \right) \qquad n = 2, 4, 6 \ldots \tag{10b}$$

Where ξ_n is the damping ratio of the nth mode.

Equation 10a means that the odd-number modes which are symmetrical about the mid-span of the beam will be excited by the average of the two seismic excitations; while equation 10b means that the even-number modes which are antisymmetrical about the mid-span of the beam will be excited by half of the difference between the two seismic excitations.

Expressing the maximum modal displacement response in Equation 10a and 10b in terms of absolute acceleration response spectra gives:

$$|\partial_n|_{max} \leq |\Upsilon_n| \left[\frac{S_a(\xi_n, \omega_n)}{2\omega^2 n} + \frac{S_b(\xi_n, \omega_n)}{2\omega^2 n} \right]$$

$$\leq \frac{4mL^4}{n^5 \pi^5 EI} \left[\frac{S_a(\xi_n, \omega_n) + S_b(\xi_n, \omega_n)}{2} \right] \quad (11)$$

$$n = 1, 2, 3, \ldots$$

This illustrates that the use of the average of two floor acceleration response spectra to calculate the modal response of a wall panel is appropriate.

7. Question

With reference to Table II (2), indicate possible variations in the value E for masonry, and determine the actual value of E such that the spectral curve provides a conservative estimate for acceleration.

Response

A single value of E was used in the analysis of the CMU walls. Specifically, E was taken equal to 1000 f'_m per the Uniform Building Code, 1970 Edition, Volume 1, Table No. 24-H, page 170 (also refer to ACI 531-79, Table 10.1). The various floor response spectra employed a constant response equal to the peak response on the low frequency side of the peak. The value of E described above coupled with the modified frequency response spectrum results in conservative stress calculations.

8. Question

With reference to page 8 of Reference 2, provide sample calculations to illustrate that single wythe analysis of multiple wythe walls is conservative.

Response

Information required to answer this question is currently unavailable and will be provided at the meeting scheduled for the week of May 24, 1982 at Bechtel - Gaithersburg.

9. Question

It is the NRC's position that the energy balance technique and the arching theory should not be used in the absence of conclusive evidence of their validity as applied to masonry structures. With reference to Table I (2), explain the following points:

a. Provide sample calculations to show the procedure used to determine the ductility ratio of walls and explain the effect of wall boundary conditions on this ratio.

b. Explain why the ductility ratios for several walls are less than unity even though the working stresses have been exceeded.

c. Explain how a ductile mode of failure of the masonry walls can be guaranteed since it depends on several factors, such as the amount and distribution of reinforcements and the anchorage provided.

d. Explain how wall deflections are estimated for specific ductility ratios.

Response

a. The ductility of walls is calculated by the following equations:

$$\mu = 1/2 \left[1 + \left(\frac{Ma}{My} \right)^2 \right]$$

$$My = \frac{Fy\ Icr}{nd}$$

where: μ = ductility ratio

Ma = applied moment, including seismic

Fy = yield stress of reinforcing bar

Icr = cracked moment of inertia

n = modular ratio

d = distance from neutral axis to reinforcing bar

Example: Assume a 12" thick, totally grouted wall

$$My = \frac{40\ k/in\ \ x\ 275\ in\ /ft.}{20\ x\ 6.99\ in.}$$

$$= 78.68\ in\text{-}k/ft.$$

Ma = 109.69 in-k/ft. (Output from "BLOCK WALLS")

$$\mu = 1/2 \left[1 + \left(\frac{109.69}{78.68} \right)^2 \right]$$

$$= 1.47$$

For effects of assumed wall boundary conditions on calculated moments and the resulting effect on the ductility ratio, see the response to Question #1.

b. A ductility ratio less than unity represents a stress in the reinforcing bar between the allowable and yield.

c. Reference 9 indicates that CMU walls with poured-in-place concrete columns and bond beams act as flexible structures, even when the design and construction is poor. This observation was based on actual structures located within 20 miles of the epicenter of an earthquake with a magnitude of 7.5 on the Richter scale. Reference 10 indicates considerable ductility where the reinforcement ratio is 0.15% or greater. All CMU walls analyzed for Davis-Besse Unit 1 have reinforcement ratios which exceed this value. Reference 11 indicates that a reinforced CMU wall is a ductile structure provided a flexural type of failure will occur with tensile yielding of the reinforcing steel. All CMU walls which were analyzed met this criteria for loads applied perpendicular to the plane of the wall.

d. Wall deflections are calculated by the following equation:

$$\Delta_{max.} = \Delta \times \frac{Fy}{f_s} \times \mu \times 2$$

where: Δ = deflection, from "BLOCK WALLS"

fs = stress of reinforcing bar, from "BLOCK WALLS"

2 = factor of safety

10. Question

With reference to Table IV (2), specify the allowable stresses for shear (shear walls and flexural members where reinforcement takes the shear), tension parallel to the bed joint, and tension normal to the bed joint.

Response

No CMU walls were provided to resist building shear or moments due to a seismic event. Therefore, no CMU walls have been evaluated as shear walls. In no case was it necessary to resist shear forces with reinforcement, because the masonry shear stress for each evaluated CMU wall was less than 0.02 f'_m. All CMU walls which were evaluated contain steel tension reinforcement to resist tension forces normal or parallel to the bed joint. Therefore, the assumed allowable masonry tensile stresses normal or parallel to the bed joint was zero for the evaluation performed in response to IE Bulletin 80-11.

11. Question

With reference to Table IV (2), justify the maximum value of 1200 psi specified for allowable stress in axial compression.

Response

The maximum allowable axial compressive stress of 1200 psi is given in the Uniform Building Code, 1970 Edition, Volume 1, Section 2418, page 158, and corresponds to a f'_m of 6000 psi. The values of f'_m established for Davis-Besse Unit 1 are

1500 psi for reinforced, completely grouted hollow or solid units and 1350 psi for reinforced, partially grouted hollow or ungrouted hollow units. The maximum allowable masonry compressive stresses for Davis-Besse Unit 1 are 300 psi and 270 psi, respectively.

12. Question

With reference to the proposed allowables for factored loads in Table IV (2), justify the increase factors of 3.17 for bearing, 1.5 for masonry shear, 1.67 for reinforcement shear, and 1.33 for bond. The SEB criteria (4) propose 2.5 for bearing, 1.3 for masonry shear, and 1.5 for reinforcement shear.

Response

The working stress allowables of Table IV are from the Uniform Building Code, 1970 Edition as referenced in the FSAR. The ultimate stress allowables are based on ACI 531-79, as recommended by the "SEB Interim Criteria for Safety-Related Masonry Wall Evaluation", July 1981 multiplied by an increase factor. The increase factors in the question result from comparing the ultimate stress allowables to the working stress allowables.

The increase factor based on ACI 531-79 for ultimate bearing stress is 2.5 (0.62/0.25) for bearing on full area and 2.5 (0.95/0.375) for bearing on one-third area or less. This is in agreement with the SEB criteria.

The increase factor of 1.5 for masonry shear, 1.67 for reinforcement shear and 1.33 for bond are intended for use with load combinations involving abnormal and/or extreme environmental conditions. Since ACI Code allowable stresses (reference ACI 531-79 Commentary, Chapter 10-1) are generally associated with a factor of safety of 3, the increase factors provide the following factors of safety against failure: 2.0 (3/1.5) for masonry shear, 1.8 (3/1.67) for reinforcement shear and 2.3 (3/1.33) for bond. It is our engineering judgement that these factors of safety are conservative and provide sufficient margin for abnormal and/or extreme conditions.

The only ultimate stress allowable used from Table IV was 0.85 f'_m for masonry compressive stress due to flexure which was checked when the energy balance technique was utilized.

13. Question

With reference to Table IV (2), justify the value for maximum allowable compression for reinforcement since it exceeds the ACI 531-79 maximum of 24,000 psi (6).

Response

The maximum allowable compressive stress for reinforcement is given in the Uniform Building Code, 1970 Edition, Volume 1, Section 2418, page 152. No CMU walls were evaluated utilizing reinforcement to resist compressive loads. This is accepted practice and is conservative.

14. Question

Provide details of proposed wall modifications with drawings, and indicate how these modifications will help to correct the wall deficiencies. Indicate how out-of-plane drift effects due to bracing are considered in the analysis.

Response

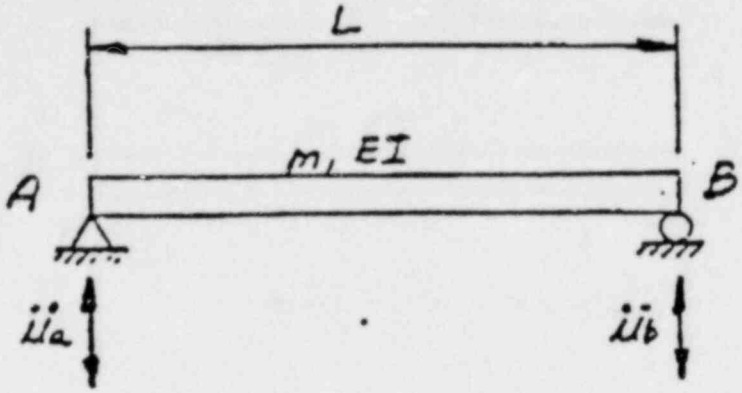
Information required to answer this question is currently unavailable and will be provided at the meeting scheduled for the week of May 24, 1982 at Bechtel - Gaithersburg.

15. Question

Provide a schedule for wall modifications.

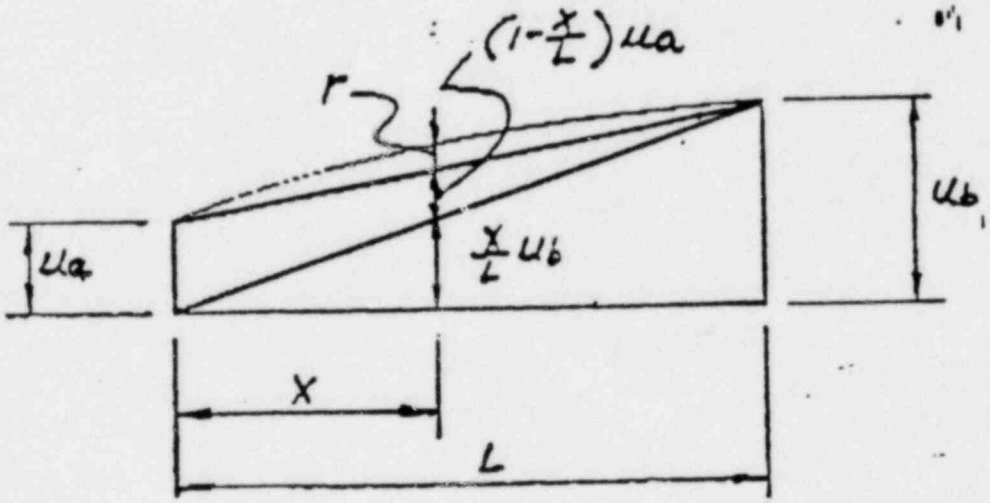
Response

Information required to answer this question is currently unavailable and will be provided at the meeting scheduled for the week of May 24, 1982 at Bechtel - Gaithersburg.



IDEALIZED SIMPLY-SUPPORTED UNIFORM BEAM

FIGURE Nº 1



RELATION BETWEEN SEISMIC EXCITATION AND RELATIVE DISPLACEMENT

FIGURE Nº 2

REFERENCES

1. IE Bulletin 80-11
   "Masonry Wall Design"
   NRC, May 8, 1980

2. R. F. Crouse (Toledo Edison Company)
   Letter with attachments to J. G. Keppler (NRC)
   November 4, 1980

3. R. F. Crouse (Toledo Edison Company)
   Letter with attachments to J. G. Keppler (NRC)
   September 29, 1981

4. Standard Review Plan, Section 3.8.4, Appendix A
   "Interim Criteria for Safety-Related Masonry Wall Evaluation"
   NRC, July 1981

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

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

7. Standard Review Plan, Section 3.7.2
   "Seismic System Analysis"
   NRC, July 1981

8. Uniform Building Code, 1970 Edition, Volume 1

9. Structural Observations of the Kern County Earthquake,
   ASCE Transactions, Paper No. 2777, August 1953,
   H. J. Degenkolb

10. The Influence of Horizontally Placed Reinforcement on the
    Shear Strength and Ductility of Masonry Walls, 6th International World Conference on Earthquake Engineering, 1977,
    Sheppard, et al

11. Reinforced Masonry - Seismic Behavior and Design, Bulletin
    New Zealand Society for Earthquake Engineering, Vol. 5,
    No. 4, December 1972, J.C. Scrivner