Appendix A

Technical Report
on

EVALUATION OF BLOCK MASONRY WALLS AT PALO VERDE NUCLEAR GENERATING STATION

submitted
to

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by

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1- INTRODUCTION

Block masonry walls at Palo Verde Nuclear Generating Station (PVNGS) Units 1,2 and 3 were constructed with lap splices for the vertical reinforcing steel. Splices , which were not staggered, have lengths less than that specified in the ACI 531 masonry code (1) for reinforced masonry construction. The NRC staff and consultants have expressed their concerns regarding the bond stresses at the splices and the margins of safety under SSE and OBE earthquake loads for walls at 74 ft Elevation.

The NRC staff and consultants visited the plant on March 20,1986 and inspected the masonry walls . Several meetings were conducted at the NRC to discuss different aspects of the problem. Two reports dated April 16, 1986 (2) and June 19,1986 (3) were submitted by the licensee regarding masonry wall evaluation at PVNGS.

This report presents a review of the June 19,1986 report regarding the technical evaluation of masonry walls at PVNGS.

2- ANALYTICAL METHODOLOGY

Time history analyses were performed by Bechtel on coupled models that included representations of both the control building structure and the masonry walls. The soil-structure interaction was considered in this study. A lumped mass model of the control building was used to develop

the response spectra. A stick model of 1- ft. strip of the wall was used to analyze the masonry wall at Elevation 74 ft. A single direction T-H record was used to analyze the wall using finite element method adopting a macro-analysis approach (i.e. ,mortar joints were not modelled). A number of assumptions was used in this analysis ; an evaluation of each is presented in the following section.

3- EVALUATION OF ASSUMPTIONS

i) Single direction time history–This represents a realistic approach since the masonry walls in question are nonloadbearing elements for which the out-of-plane behavior dominates their response.

ii) Strip idealization of the wall- The wall behavior is assumed to be one-way in the vertical direction which is a conservative and a realistic assumption because the side boundaries of the walls are free. Also, the wall pattern is a running bond and openings are adequately reinforced which assure continuity in the horizontal direction.

iii) Material properties-A conservative grout strength and average rebar location were used. Wall modulus of elasticity is assumed to be equal to 1000 f'm, where f'm is the prism compressive strength. This formula, which is specified by the current masonry codes (1,4) highly overestimates the elastic modulus and would lead to nonconservative estimate of wall stiffness (5). This is an important factor to be considered in the evaluation since PVNGS wall response is highly

sensitive to the calculated frequency ; see the critical range in the response spectra presented in Fig. 1.

iv) 3-stage moment of inertia- It is assumed that the wall undergoes three stages of cracking :1) uncracked, 2) partially cracked where only the faceshell is cracked (i.e. ,mortar debonding), and 3) fully cracked when the tensile stresses in the extreme fibers of the grout cores reach modulus of rupture of the grout. Test results (6) do not support the Bechtel assumption of 3-stage cracking model. The tests indicate that cracking of the faceshell will occur simultaneously with cracking of the grout and that grouted masonry, as a composite material, has only one cracking moment. The Bechtel approach is neither realistic nor conservative in estimating wall stiffness.

4- ANALYSIS OF RESULTS

The time history analyses coupled with the 3-stage model surprisingly revealed very low bond stresses (110 psi for SSE and 80 psi for OBE at Elevation 74 ft) compared with those from previous simplified analysis presented in the April, 1986 report (2). Bectel concluded that walls at PVNGS
are adequate because calculated bond stresses were below the code allowables (180 psi for SSE and 120 psi for OBE).

The calculated bond stresses are highly sensitive to the estimated wall stiffness. The stiffness determines the wall frequency which in turn

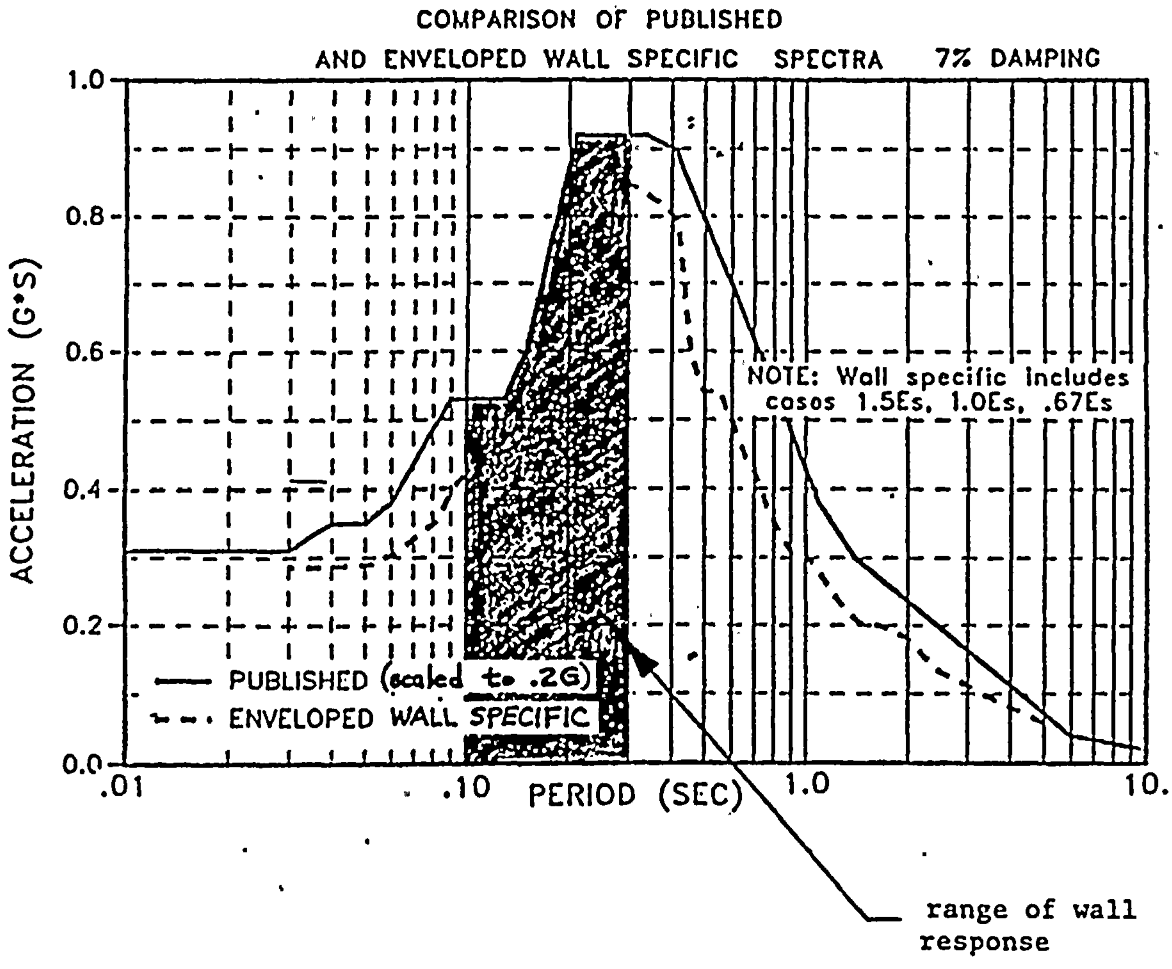

Fig. 1- Floor Spectra at Elevation 74 Ft.

determines the induced loads and the resulted stresses the wall will experience during an earthquake. The small change in wall frequency results in a large change in acceleration due to the fact that the period of PVNGS walls in question falls in the steep portion of the response spectra curve; see Fig. 1.

A proper design method should conservatively account for the sensitivity of the calculated frequency and the inherent variability in estimating the modulus of elasticity and the effective moment of inertia of such a brittle material as masonry and concrete (7).

5- CONCLUSION

Based on the review of the information submitted in June,1986 report (3) and discussions of concerns presented above ,it is concluded that Bechtel design methodology of PVNGS masonry walls regarding the calculation of wall stiffness is not justified. This approach could lead to nonconservative results for bond stresses in lap splices at Elevation 74 ft. Therefore, it is concluded that Bechtel analytical methodolgy presented in June 1986 report is not acceptable.

7- REFERENCES

(1) American Concrete Institute 531 Code, " Building Code Requirements for Concrete Masonry Structures," Detroit, Michigan, 1979.

(2) "Evaluation of PVNGS Masonry Walls," from E.E. Van Brunt, Jr., Arizona Nuclear Power Project ,to G.W. Knighton, NRC, Dated April 16,1986.

(3) " PVNGS Masonry Walls," from E.E. Van Brunt, Jr.. Arizona Nuclear Power Project ,to G.W. Knighton, NRC, dated June 19,1986.

(4) International Conference of Building Officials, UBC Code, Chapter 24, 1985.

(5) Ziab, G., " Modulus of Elasticity of Concrete Block Masonry," M.Sc. Thesis, Department of Civil Engineering, Drexel University, 1986

(6) Drysdale, R. and Hamid, A., " Effect of Grouting on the Flexural Tensile Strength of Concrete Block Masonry," Proceedings of the Masonry Society Journal,Vol. 3, No.2, July-Dec. 1984.

(7) " Variability of Deflections of Simply Supported Reinforced Concrete Beams," Report by ACI Committee 435, ACI Journal, Proceedings 69, January 1972.