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

February 17, 1982

Docket No. 50-206
LS05-82-02-068

Mr. R. Dietch, Vice President
Nuclear Engineering and Operations
Southern California Edison Company
2244 Walnut Grove Avenue
Post Office Box 800
Rosemead, California 91770

Dear Mr. Dietch:

SUBJECT: EVALUATION OF MASONRY WALL NON-LINEAR ANALYSIS UNDER SEP TOPIC III-6, SEISMIC DESIGN CONSIDERATIONS - SAN ONOFRE UNIT 1

We have reviewed the non-linear inelastic time history analysis methodology proposed for use in the evaluation of the San Onofre Nuclear Generating Station Unit 1 (SONGS 1). The information reviewed includes the three reports received from you, and your presentation on the methodology provided to the staff during the meeting of January 20, 1982, held in Bethesda, Maryland.

At this point in time, we can not accept your proposed non-linear inelastic time history analysis methodology as the sole basis for evaluation and qualification of the masonry walls at SONGS Unit 1. Two options for timely completion of the plant specific evaluation are proposed. We believe that the option of using elastic linear analysis (second option) is more desirable and preferred from the standpoint of practicality and cost-effectiveness. The details of our review and the options proposed are contained in the enclosure.

You are requested to submit your response within two weeks of your receipt of this letter as to what option you decide to pursue to resolve the subject issue.

Sincerely,

Walter A. Paulson

Walter A. Paulson, Project Manager
Operating Reactors Branch No. 5
Division of Licensing

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Enclosure:
As stated

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ENCLOSURE

EVALUATION OF NON-LINEAR INELASTIC TIME HISTORY ANALYSIS METHODOLOGY FOR SAN ONOFRE UNIT 1 MASONRY WALL ASSESSMENT

1. Background and Objective

A significant number of safety related masonry walls are utilized in several Category I structures of the San Onofre Nuclear Station, Unit 1 (SONGS 1). As a part of the overall systematic evaluation program for the plant, these safety related masonry walls need to be evaluated to demonstrate their design adequacy and to ensure that the walls will maintain their structural integrity and perform safety functions when subjected to the combined effects of design basis earthquakes, accidents, and other applicable loads.

The licensee has proposed a non-linear inelastic time history analysis methodology for use in the evaluation of SONGS 1 masonry walls. Since the methodology proposed by the licensee is a "first-of-a-kind" analysis approach, the suitability and acceptability of the method needs to be examined.

The objective of this evaluation report is to review and reach a conclusion on the acceptability of the licensee method and to discuss the technical bases of the conclusion. Options and suggested follow-up actions by the licensee to expeditiously complete the masonry wall evaluation task are also provided in this report.

2. Scope of Evaluation

The scope of this evaluation covers only the acceptability, technical bases/adequacies of the licensee's proposed nonlinear inelastic time history analysis methodology. The plant specific evaluation of masonry wall design adequacy and needed dispositions of walls are not included within the present scope of evaluation. Such a plant specific evaluation will be implemented later, after the completion of the present task.

3. Information Reviewed

The following information was reviewed to form the basis for SEB staff conclusions:

(1) "Seismic Evaluation of Reinforced Concrete Masonry Walls, Volume 1: Criteria," Computech Engineering Services, Inc.

(2) "Seismic Evaluation of Reinforced Concrete Masonry Walls, Volume 2: Inelastic Analysis Methodology," Computech Engineering Services, Inc.

(3) "Seismic Evaluation of Reinforced Concrete Masonry Walls, Volume 3: Masonry Wall Evaluation," Computech Engineering Services, Inc.

(4) Meeting between SEB staff and the licensee and its consultants, held on January 20, 1982, at Bethesda, MD.

4. Summary of SEB Staff Conclusion

Based on our detailed review of the information listed in item 3 above and the technical discussions held with the licensee and its consultants, we conclude that the sole use of the licensee's analysis methodology to demonstrate SONGS 1 masonry wall design/construction adequacy is not acceptable. The bases for our conclusion are:

(1) The analysis methodology proposed is based on several assumptions and computational method not thoroughly verified by relevant test data. To

the extent that available test data are utilized to support the methodology, the applicability and relevancy of the data are judged as extremely questionable.

The limited test data presented were obtained based on a static, monotonic, air bag load test, whereas, the real masonry walls need to be qualified for a severe dynamic/cyclic earthquake shakings of the order of 0.67g Housner spectra in conjunction with other applicable loads. This fact constitutes the most severe weakness of the method.

(2) Even if the test data presented were considered as marginally applicable, the scope and size of the available test data are such that no reasonable and sound engineering conclusion can be drawn with respect to the acceptability of the methodology.

(3) Whatever QA/QC procedures were or may have been implemented for the existing SONGS 1 walls, the procedures do not provide reasonable assurance that the as-built walls reflect correctly what is defined or called for in the design drawings/specifications. Some systematic on site inspection effort is considered to be needed to ensure that proper construction, QA/QC, placement and testing of materials were indeed carried out for these walls such that a sophisticated analysis procedure (e.g., licensee's methodology) can be effectively applied.

(4) Our review has also identified the following technical shortcomings, questions and/or comments applicable to the licensee's proposed methodology.

a. During the entire analysis, the masonry face shell is assumed to remain elastic. There is a likelihood that the compressive stress at the face shell may exceed f'm value and the spalling of the face may occur. There is no grout core to stabilize this situation. This aspect needs thorough investigation in terms of the strength of masonry, strain/stress magnitudes at face shell, and actual masonry block behavior during shaking.

b. In the non-linear analysis the concept of modal and Rayleigh damping, which is applicable in the linear analysis, is used. The treatment of damping needs additional justification/verification. In addition, the seven percent value used also needs additional verification. Considering the uncertainity in the treatment and the value of damping, at least a parametric study will be required to address the concerns in this area.

c. The selection of the length of rebar assumed to yield in the analysis is arbitrary. At present, there is no data to provide the basis for such selection. Also, it needs to be verified that the paramater, L_{jt}, related to cracked joint widths is problem independent.

d. The permissible ductility is only mentioned with respect to quantification of maximum permissible strain in reinforcing steel. However, quantifications of the ductility in terms of force/deflection, moment/curvature (analogous to that given in Appendix C of ACI-349) need to be further examined and their significance discussed.

e. It is doubtful that the air bag used in test to load walls provides a uniform pressure on the surface of the wall as intended. It is unclear that the wall be analyzed as a cantilever beam, a compressed beam, or as a slab with different edge conditions.

f. Details of computer codes are not known. Degree and order of accuracy, error propagation, numerical stability, integration schemes and all pertinent verification data for numerical analysis should be provided for assessment of the computer codes. Are there any numerical damping induced to the solution? How does it compare with the system damping?

g. Assessment of the impact of transverse load on in-plane load carrying capacities, and vice versa, is needed.

h. The local and gross effects of attachments on the wall (such as conduit, piping, and equipment) were not properly considered in the analysis. The evaluation of the effect of possible local damages and gross motion of the attachment on the overall analysis of the wall is needed.

5. Suggested Options for Completing the SONGS 1 Masonry Wall Evaluation

The following two options are considered viable for completing the evaluation tasks:

a. Licensee's commitment and implementation of a limited scope test program to provide relevant test data for the validation of the licensee proposed methodology, with a concurrent effort to resolve the technical shortcomings of the method as discussed in item 4 (a through h) above.

b. To perform a routine, time-tested elastic evaluation of the walls based on present SEB criteria (a copy attached) or modification thereof, and implement necessary wall fixes as dictated by the elastic evaluation.

From the standpoint of both timeliness and cost-effectiveness of completing the evaluation as well as practicality consideration, however, we believe that the option b is much more desirable than option a, although, option a may offer advantages, such as, advancing the state-of-the-art in masonry wall analysis and design and utilization of the technical study results obtained to date by the licensee.

The licensee should be advised to consider these options and/or propose other possible option(s). The staff will be ready to review the licensee's option(s), if proposed, on a high priority basis.

Selection of either option by the licensee will necessitate a follow-up staff/licensee meeting, to further define the specific tasks/steps for completion of the evaluation. A future SEB staff on site inspection trip will also be needed to complete the entire evaluation task.

SEB CRITERIA FOR

SAFETY-RELATED MASONRY WALL EVALUATION

JULY 1981

TABLE OF CONTENTS

1. General Requirements

The materials, testing, analysis, design, construction and inspection related to the design and construction of safety-related concrete masonry walls shall conform to the applicable requirements contained in Uniform Building Code - 1979, unless specified otherwise, by the provisions in this criteria.

The use of other standards or codes, such as ACI-531, ATC-3 or NCMA are also acceptable. However, when the provisions of these codes are less conservative than the corresponding provisions of the criteria, their use should be justified on a case-by-case basis.

In new construction, no unreinforced masonry wall will be permitted. For operating plants, existing unreinforced walls will be evaluated by the provisions of this criteria. Plants applying for operating license which have already built unreinforced masonry walls, will be evaluated on a case-by-case basis.

2. Loads and Load Combinations

The loads and load combinations shall include consideration of normal loads, severe environmental loads, extreme environmental loads, and abnormal loads. Specifically, for operating plants the load combinations provided in plant's FSAR shall govern. For operating license applications, the following load combinations shall apply (for definition of load terms, see SRP Section 3.8.4II-3).

(a) Service Load Conditions

(1) $D + L$

(2) $D + L + E$

(3) $D + L + W$

If thermal stresses due to T_o and R_o are present, they should be included in the above combinations, as follows:

(1a) $D + L + T_o + R_o$

(2a) $D + L + T_o + R_o + E$

(3a) $D + L + T_o + R_o + W$

Check load combination for controlling condition for maximum 'L' and for no 'L'.

(b) Extreme Environmental, Abnormal, Abnormal/Servere Environmental and Abnormal/Extreme Environmental Conditions

(4) $D + L + T_o + R_o + E'$

(5) $D + L + T_o + R_o + W_t$

(6) $D + L + T_a + R_a + 1.5\ P_a$

(7) $D + L + T_a + R_a + 1.25\ P_a + 1.0\ (Y_r + Y_j + Y_m) + 1.25\ E$

(8) $D + L + T_a + R_a + 1.0\ P_a + 1.0\ (Y_r + Y_j + Y_m) + 1.0\ E'$

In combinations (6), (7), and (8) the maximum values of P_a, T_a, R_a, Y_j, Y_r, and Y_m, including an appropriate dynamic load factor, should be used unless a time-history analysis is performed to justify otherwise. Combinations (5), (7) and (8) and the corresponding structural acceptance criteria should be satisfied first without the tornado missile load in (5) and without Y_r, Y_j, and Y_m in (7) and (8). When considering these

loads, local section strength capacities may be exceeded under these concentrated loads, provided there will be no loss of function of any safety-related system.

Both cases of L having its full value or being completely absent should be checked.

3. Allowable Stresses

Allowable stresses provided in ACI-531-79, as supplemented by the following modifications/exceptions shall apply.

(a) When wind or seismic loads (OBE) are considered in the loading combinations, no increase in the allowable stresses is permitted.

(b) Use of allowable stresses corresponding to special inspection category shall be substantiated by demonstration of compliance with the inspection requirements of the SEB criteria.

(c) When tension perpendicular to bed joints is used in qualifying the unreinforced masonry walls, the allowable value will be justified by test program or other means pertinent to the plant and loading conditions. For reinforced masonry walls, all the tensile stresses will be resisted by reinforcement.

(d) For load conditions, which represent extreme environmental, abnormal, abnormal/severe environmental, and abnormal/extreme environmental conditions the allowable working stresses may be multiplied by the factors shown in the following table:

TYPE OF STRESS	FACTOR
Axial or Flexural Compression (1)	2.5
Bearing	2.5
Reinforcement stress except shear	2.0 but not to exceed 0.9 fy
Shear reinforcement and/or bolts	1.5
Masonry tension parallel to bed joint	1.5
Shear carried by masonry	1.3
Masonry tension perpendicular to bed joint	
for reinforced masonry	0
for unreinforced masonry (2)	1.3

Notes

(1) When anchor bolts are used, design should prevent facial spalling of masonry unit.

(2) See 3 (c).

4. Design and Analysis Considerations

(a) The analysis should follow established principles of engineering mechanics and take into account sound engineering practices.

(b) Assumptions and modeling techniques used shall give proper considerations to boundary conditions, cracking of sections, if any, and the dynamic behavior of masonry walls.

(c) Damping values to be used for dynamic analysis shall be those for reinforced concrete given in Regulatory Guide 1.61.

(d) In general, for operating plants the seismic analysis and Category I structural requirements of FSAR shall apply. For other plants, corresponding SRP requirements shall apply. The seismic analysis shall account for the variations and uncertainties in mass, materials and other pertinent parameters used.

(e) The analysis should consider both in-plane and out-of-plane loads.

(f) Interstory drift effects should be considered.

(g) In new construction, grout in concrete masonry walls, whenever used, shall be compacted by vibration.

(h) For masonry shear walls, the minimum reinforcement requirements of ACI-531 shall apply.

(i) Special constructions (e.g. multiwythe, composite) or other items not covered by the code shall be reviewed on a case-by-case basis for their acceptance.

(j) Licensees or applicants shall submit QA/QC information, if available, for staff's review.

In the event, QA/QC information is not available, a field survey and a test program reviewed and approved by the staff shall be implemented to ascertain the conformance of masonry construction to design drawings and specifications (e.g. rebar and grouting).

(k) For masonry walls requiring protection from spalling and scabbing due to accident pipe reaction (Y_r), jet impingement (Y_j) and missile impact (Y_m), the requirements similar to those of SRP 3.5.3 shall apply. However, actual review will be conducted on a case-by-case basis.

5. References

(a) Uniform Building Code - 1979 Edition

(b) Building Code Requirements for Concrete Masonry Structures ACI-531 - 79 and Commentary ACI-531R - 79.

(c) Tentative Provisions for the Development of Seismic Regulations for Buildings - Applied Technology Council ATC 3-06.

(d) Specification for the Design and Construction of Load-bearing Concrete Masonry - NCMA August, 1979.

(e) Trojan Nuclear Plant Concrete Masonry Design Criteria Safety Evaluation Report Supplement - November, 1980.

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SE04 Add: Gary Staley
S/11 Eileen McKenna

Sincerely,

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DSU USE (EX)-08

Walter A. Paulson, Project Manager
Operating Reactors Branch No. 5
Division of Licensing

Enclosure:
As stated

*See previous concurrence

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As stated

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ENCLOSURE

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1. Background and Objective

A significant number of safety related masonry walls are utilized in several Category I structures of the San Onofre Nuclear Station, Unit 1 (SONGS 1). As a part of the overall systematic evaluation program for the plant, these safety related masonry walls need to be evaluated to demonstrate their design adequacy and to ensure that the walls will maintain their structural integrity and perform safety functions when subjected to the combined effects of design basis earthquakes, accidents, and other applicable loads.

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The objective of this evaluation report is to review and reach a conclusion on the acceptability of the licensee method and to discuss the technical bases of the conclusion. Options and suggested follow-up actions by the licensee to expeditiously complete the masonry wall evaluation task are also provided in this report.

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the extent that available test data are utilized to support the methodology, the applicability and relevancy of the data are judged as extremely questionable.

The limited test data presented were obtained based on a static, monotonic, air bag load test, whereas, the real masonry walls need to be qualified for a severe dynamic/cyclic earthquake shakings of the order of 0.67g Housner spectra in conjunction with other applicable loads. This fact constitutes the most severe weakness of the method.

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(4) Our review has also identified the following technical shortcomings, questions and/or comments applicable to the licensee's proposed methodology.

a. During the entire analysis, the masonry face shell is assumed to remain elastic. There is a likelihood that the compressive stress at the face shell may exceed f'm value and the spalling of the face may occur. There is no grout core to stabilize this situation. This aspect needs thorough investigation in terms of the strength of masonry, strain/stress magnitudes at face shell, and actual masonry block behavior during shaking.

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f. Details of computer codes are not known. Degree and order of accuracy, error propagation, numerical stability, integration schemes and all pertinent verification data for numerical analysis should be provided for assessment of the computer codes. Are there any numerical damping induced to the solution? How does it compare with the system damping?

g. Assessment of the impact of transverse load on in-plane load carrying capacities, and vice versa, is needed.

h. The local and gross effects of attachments on the wall (such as conduit, piping, and equipment) were not properly considered in the analysis. The evaluation of the effect of possible local damages and gross motion of the attachment on the overall analysis of the wall is needed.

5. Suggested Options for Completing the SONGS 1 Masonry Wall Evaluation

The following two options are considered viable for completing the evaluation tasks:

a. Licensee's commitment and implementation of a limited scope test program to provide relevant test data for the validation of the licensee proposed methodology, with a concurrent effort to resolve the technical shortcomings of the method as discussed in item 4 (a through h) above.

b. To perform a routine, time-tested elastic evaluation of the walls based on present SEB criteria (a copy attached) or modification thereof, and implement necessary wall fixes as dictated by the elastic evaluation.

From the standpoint of both timeliness and cost-effectiveness of completing the evaluation as well as practicality consideration, however, we believe that the option b is much more desirable than option a, although, option a may offer advantages, such as, advancing the state-of-the-art in masonry wall analysis and design and utilization of the technical study results obtained to date by the licensee.

The licensee should be advised to consider these options and/or propose other possible option(s). The staff will be ready to review the licensee's option(s), if proposed, on a high priority basis.

Selection of either option by the licensee will necessitate a follow-up staff/licensee meeting, to further define the specific tasks/steps for completion of the evaluation. A future SEB staff on site inspection trip will also be needed to complete the entire evaluation task.

SEB CRITERIA FOR

SAFETY-RELATED MASONRY WALL EVALUATION

JULY 1981

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The loads and load combinations shall include consideration of normal loads, severe environmental loads, extreme environmental loads, and abnormal loads. Specifically, for operating plants the load combinations provided in plant's FSAR shall govern. For operating license applications, the following load combinations shall apply (for definition of load terms, see SRP Section 3.8.4II-3).

(a) Service Load Conditions

(1) $D + L$

(2) $D + L + E$

(3) $D + L + W$

If thermal stresses due to T_o and R_o are present, they should be included in the above combinations, as follows:

(1a) $D + L + T_o + R_o$

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(3a) $D + L + T_o + R_o + W$

Check load combination for controlling condition for maximum 'L' and for no 'L'.

(b) Extreme Environmental, Abnormal, Abnormal/Servere Environmental and Abnormal/Extreme Environmental Conditions

(4) $D + L + T_o + R_o + E$

(5) $D + L + T_o + R_o + W_t$

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(8) $D + L + T_a + R_a + 1.0\ P_a + 1.0\ (Y_r + Y_j + Y_m) + 1.0\ E'$

In combinations (6), (7), and (8) the maximum values of P_a, T_a, R_a, Y_j, Y_r, and Y_m, including an appropriate dynamic load factor, should be used unless a time-history analysis is performed to justify otherwise. Combinations (5), (7) and (8) and the corresponding structural acceptance criteria should be satisfied first without the tornado missile load in (5) and without Y_r, Y_j, and Y_m in (7) and (8). When considering these

loads, local section strength capacities may be exceeded under these concentrated loads, provided there will be no loss of function of any safety-related system.

Both cases of L having its full value or being completely absent should be checked.

3. Allowable Stresses

Allowable stresses provided in ACI-531-79, as supplemented by the following modifications/exceptions shall apply.

(a) When wind or seismic loads (OBE) are considered in the loading combinations, no increase in the allowable stresses is permitted.

(b) Use of allowable stresses corresponding to special inspection category shall be substantiated by demonstration of compliance with the inspection requirements of the SEB criteria.

(c) When tension perpendicular to bed joints is used in qualifying the unreinforced masonry walls, the allowable value will be justified by test program or other means pertinent to the plant and loading conditions. For reinforced masonry walls, all the tensile stresses will be resisted by reinforcement.

(d) For load conditions, which represent extreme environmental, abnormal, abnormal/severe environmental, and abnormal/extreme environmental conditions the allowable working stresses may be multiplied by the factors shown in the following table:

TYPE OF STRESS	FACTOR
Axial or Flexural Compression (1)	2.5
Bearing	2.5
Reinforcement stress except shear	2.0 but not to exceed 0.9 fy
Shear reinforcement and/or bolts	1.5
Masonry tension parallel to bed joint	1.5
Shear carried by masonry	1.3
Masonry tension perpendicular to bed joint	
for reinforced masonry	0
for unreinforced masonry (2)	1.3

Notes

(1) When anchor bolts are used, design should prevent facial spalling of masonry unit.

(2) See 3 (c).

4. Design and Analysis Considerations

(a) The analysis should follow established principles of engineering mechanics and take into account sound engineering practices.

(b) Assumptions and modeling techniques used shall give proper considerations to boundary conditions, cracking of sections, if any, and the dynamic behavior of masonry walls.

(c) Damping values to be used for dynamic analysis shall be those for reinforced concrete given in Regulatory Guide 1.61.

(d) In general, for operating plants the seismic analysis and Category I structural requirements of FSAR shall apply. For other plants, corresponding SRP requirements shall apply. The seismic analysis shall account for the variations and uncertainties in mass, materials and other pertinent parameters used.

(e) The analysis should consider both in-plane and out-of-plane loads.

(f) Interstory drift effects should be considered.

(g) In new construction, grout in concrete masonry walls, whenever used, shall be compacted by vibration.

(h) For masonry shear walls, the minimum reinforcement requirements of ACI-531 shall apply.

(i) Special constructions (e.g. multiwythe, composite) or other items not covered by the code shall be reviewed on a case-by-case basis for their acceptance.

(j) Licensees or applicants shall submit QA/QC information, if available, for staff's review.

In the event, QA/QC information is not available, a field survey and a test program reviewed and approved by the staff shall be implemented to ascertain the conformance of masonry construction to design drawings and specifications (e.g. rebar and grouting).

(k) For masonry walls requiring protection from spalling and scabbing due to accident pipe reaction (Y_r), jet impingement (Y_j) and missile impact (Y_m), the requirements similar to those of SRP 3.5.3 shall apply. However, actual review will be conducted on a case-by-case basis.

5. References

(a) Uniform Building Code - 1979 Edition

(b) Building Code Requirements for Concrete Masonry Structures ACI-531 - 79 and Commentary ACI-531R - 79.

(c) Tentative Provisions for the Development of Seismic Regulations for Buildings - Applied Technology Council ATC 3-06.

(d) Specification for the Design and Construction of Load-bearing Concrete Masonry - NCMA August, 1979.

(e) Trojan Nuclear Plant Concrete Masonry Design Criteria Safety Evaluation Report Supplement - November, 1980.