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

January 15, 1981

Docket No. 50-70

Mr. R. W. Darmitzel, Manager
Irradiation Processing Product Section
Vallecitos Nuclear Center
General Electric Company
P. O. Box 460
Pleasanton, California 94566

Dear Mr. Darmitzel:

We have completed our review of your December 3, 1980 "Analysis of the Subgrade Rupture Mechanism at the General Electric Test Reactor". We conclude that the potential load combinations resulting from surface offset and vibratory ground motion acting on the GETR are limited as you have proposed.

Our evaluation is contained in Enclosure 1 and is issued as Appendix B to our October 27, 1980 draft safety evaluation. Furthermore, we have revised page C-8 of our October 27, 1980 safety evaluation to recognize the additional soil analyses performed. The revised page C-8 is attached as Enclosure 2. As revised, our October 27, 1980 safety evaluation is no longer designated as having draft status but is designated as final. With issuance of this letter and its enclosures, the staff's safety evaluation regarding issues (1) and (2) of the October 24, 1977 Order to Show Cause is deemed complete and states the staff's finalized position. The documents stating and supporting the staff's finalized position are, in addition to this letter and its enclosures, our letters of May 23 and October 27, 1980, and their enclosures.

The enclosed supplements to our safety evaluation are being submitted to the Advisory Committee on Reactor Safeguards, documenting completion of the one outstanding issue discussed in their letter of November 12, 1980, and the Atomic Safety and Licensing Board assigned to this proceeding.

You are again requested to propose Technical Specifications and to provide a description of your pre-operational test programs as requested in our letter of October 27, 1980.

Sincerely,

Thomas M. Novak, Assistant Director
for Operating Reactors
Division of Licensing

Enclosures:
1. Appendix B
2. Revised Page C-8

cc w/encl:
See next page

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Appendix B

Evaluation of Soil Properties and Pressures and Analysis of the Subgrade Rupture Mechanism at the General Electric Test Reactor

INTRODUCTION

This report is an evaluation by the NRC staff (staff) of the results of analyses and investigations presented by the General Electric Company (GE or licensee) to evaluate the soil properties and pressures at the foundation subgrade interface beneath the GETR and to determine the effects of combined vibratory motion, due to an earthquake and surface rupture offset caused by the postulated Verona fault. This evaluation is based on our review of references given at the end of this report.

SUBSURFACE PROFILE AND SOIL PROPERTIES

General Electric and their consultants have made extensive studies to evaluate the soil properties of the subgrade beneath the reactor. Subsurface conditions in the vicinity of the GETR were interpreted from borings, trenches, and geologic mapping of the area. The investigations revealed that the base of the GETR foundation mat, which is located about 20 feet below grade, is underlain by very dense clayey sand and gravel with occasional layers of very dense sandy and/or gravelly clay to a depth of 70 feet (Ref. 1). For a description of any changes in the soil profile below a depth of 70 feet from the ground surface, the licensee sought indirect geologic evidence in the Livermore Formation (bedrock in this region) below that depth. There is a hard, cemented stratum known as the middle conglomerate unit of the Livermore Gravels, which crops out in hills on the west and south of the site. Projection of this stratum beneath the GETR places it at a depth of 200 feet or more, which is below the level considered as subgrade in the fault plane analysis (Ref. 2).

Standard Penetration Tests performed for GE (Ref. 1) on the materials underlying the GETR foundation mat show blow counts of from 50 to 100 blows/foot penetration, affirming the very dense nature of these soils. Groundwater levels at GETR were shown to vary from 20 feet to 28 feet below plant grade (Ref. 2). Laboratory testing was conducted to ascertain soil parameters for design (Ref. 1, 3 and 4). For purposes of fault plane analysis (Ref. 2) soils beneath GETR were assigned by GE to have drained strength parameters of $c' = 0$ and $Ø' = 36°$ and an undrained shear strength of 4000 psf for soils fully saturated. Based on the staff's evaluation of these data and published literature (e.g., Ref. 5) the selected strength parameters are considered reasonable bounding values for the analysis of fault plane behavior.

EVALUATION OF GE'S ANALYSES

1. BEARING CAPACITY ANALYSIS

In June 1980, GE proposed an analytical model to determine the load limits on the foundation due to the combined loading case comprised of a ground acceleration vibratory motion and a surface rupture offset (i.e., vertical slip) of one meter (Ref. 6). The surface rupture offset was represented analytically as an "unsupported length" of the reactor foundation slab. Engineering Decision Analysis Company (EDAC), which developed the above analytical model, determined an ultimate bearing capacity of 20 ksf for the subgrade beneath the reactor based on their interpretation of the soil properties as investigated to that date (Ref. 6).

Using 20 ksf as the ultimate bearing capacity of the soil, EDAC performed analyses for several cases of unsupported lengths. Figure C-1 in Section IIC of the SER dated October 27, 1980, shows a plot of the horizontal ground accelerations (at which incipient local yielding[1/] of the soil occurs) as a function of unsupported lengths.

The staff reviewed the EDAC report and concluded that the value of ultimate bearing capacity of the soil beneath GETR may be greater than the 20 ksf proposed by the licensee. This conclusion was reached because the undrained strength values chosen by GE were the lowest tested strengths and because overburden soils (surcharge), that would contribute to the bearing capacity, were not considered. A higher value of the bearing capacity would likely result in a larger unsupported cantilever length of the GETR foundation mat than that analyzed by GE. The staff's conclusion was discussed with the licensee and GE subsequently revised their method of analyzing the subgrade rupture mechanism (Ref. 2) as discussed below.

2. FAULT PLANE ANALYSIS

The revised analysis proposed by GE consists of a comparison of the static stability of two-dimensional soil wedges formed by thrust fault planes meeting the reactor foundation at different locations. As described in Reference 2, the hypothetical thrust fault is visualized as a passive Rankine wedge being pushed by a major principal stress, P_p.

[1/] "Incipient local yielding" was defined by EDAC to mean the loading combination that produces bearing pressure at the edge of the supporting soil equal to the ultimate bearing capacity.

For soil strength parameters c' = 0, and $\emptyset$ = 36° the preferred failure surface (defined as the plane requiring a minimum value of P_p) is inclined at an angle = 45 - ϕ/2 when there is no surcharge. With a surcharge load S, the optimum failure plane may vary, depending on the magnitude and distribution of the surcharge. By trial and error the most probable failure plane corresponding to the minimum value of P_p was obtained by GE for the low water table (drained) case. The locations of the failure planes were varied for an assumed wedge depth of 70 feet below the reactor foundation slab. The results of analyses by GE showed that, for the 21 feet of surcharge at the GETR (Ref. 6), the preferred failure plane passes through the edge of the slab. Therefore GE argues that a thrust fault plane will be deflected away from the base of the reactor slab because of the weight of the GETR and the surcharge. GE also performed calculations using assumed undrained strength parameters of c' = 4000 psf and $\emptyset$' = 0° that would be appropriate for very rapid loading of a saturated subgrade for the high water table condition. In this case GE also found that the preferred failure planes (those requiring minimum passive pressure) did not fall beneath the reactor or within the zone that may create a cantilever span of the reactor mat. (Ref. 2)

The staff reviewed the licensee's revised analysis and concurs with GE's findings that the previously hypothesized cantilever condition should not occur. As a check on the licensee's work, the staff performed additional calculations for an assumed wedge depth of 100 feet using similar soil conditions and found the above findings to be correct for the 21 feet surcharge load. The staff noted that this result was dependent on the presence of the 21 feet high surcharge within about 170 feet of the reactor building. If , for any reason, a significant part of this surcharge were excavated a reevaluation would be necessary. The staff also analyzed the the three-dimensional aspects of the failure plane deflection around the GETR and found that the conclusion based on a two-dimensional analysis remains valid.

In addition to the theoretical calculations discussed above, the staff reviewed the literature to ascertain whether there was additional support for the assumption that an offset would deflect away from deeply buried, heavy structures. An example of this type of behavior in similar soil deposits was observed in the 1972 Managua earthquake in Nicaragua (Ref. 7). Surface faulting occurred on a trace of the fault that passed under the Banco Central Building, a large deeply buried heavy structure. Near the building, the rupture deviated from the active trace, and the building's foundation survived intact. This observational experience gives the staff additional confidence in the theoretical calculations.

CONCLUSION

Figure C-1 in Section II-C of the October 27, 1980 SER figuratively presents the maximum effects from the specified Verona fault design basis event, for which GETR must be designed, based on the licensee's Bearing Capacity Analysis. Although the staff does not concur with the Bearing Capacity Analysis, further analysis by the licensee, the Fault Plane Analysis, demonstrates that a cantilever of the GETR foundation should not occur.

The staff concurs with the Fault Plane Analysis and therefore concludes that the "incipient local yielding" and "limiting load combinations" curves of Figure C-1, which are used in comparison with the inputs to the licensee's structural evaluations, postulate a greater loading on the foundation mat than that predicted by the fault plane analysis. The use of the curves of Figure C-1 is acceptable since it results in placing a conservative limit on the load combinations from the specified design basis event on the Verona Fault.

REFERENCES

1. Shannon and Wilson, 1973, "Investigation of Foundation Conditions G.E. Test Reactor" for URS - John A. Blume and Associates.

2. Earth Sciences Associates, December 1980, Analyses of the Subgrade Rupture Mechanism at the General Electric Test Reactor submitted by the General Electric Company, Pleasanton, California, to Mr. Darrell G. Eisenhut, Director, Division of Operating Reactors, NRC.

3. Dames and Moore, 1960, "Foundation Investigation, Proposed Boiling Water Reactor, Vallecitos Atomic Laboratory, California, February 1978: Report to General Electric, Co., Vallecitos, California.

4. Earth Sciences Associates (August 1980) GETR Stability Analysis, report for General Electric Company, Vallecitos Nuclear Center, Pleasanton, California.

5. Lambe, T.W. and Whitman, R.V., "Soil Mechanics", John Wiley & Sons, Inc., New York, New York, 1969.

6. Engineering Decision Analysis Company, Inc., June 1980, Expanded Description of Soil Pressure Analyses, Supplement No. 1 to "Additional Investigations to Determine the Effects of Combined Vibratory Motions and Surface Rupture Offset Due to an Earthquake on the Postulated Verona Fault."

7. L. Cluff, K. Weaver and M. Niccum, Zoning for Surface Fault Rupture, Managua, Nicaragua, Sixth World Conference on Earthquake Engineering, New Delhi, India, January 1977.

Analyses were performed to determine representative and conservative input parameters to be used which would be consistent with the seismic design criteria defined by the Verona fault hazards. Bearing capacity analyses were evaluated to determine the physical load limits on the combined load case comprised of a ground acceleration vibratory motion and a surface rupture offset, the latter represented analytically as an unsupported cantilevered length of the reactor building. Based on these analyses GE proposed physical limits on the combined loading of vibratory motion and unsupported length of the reactor building (Figure C-1). The staff however did not find the bearing capacity analyses acceptable. Further geotechnical engineering analyses, fault plane analyses, demonstrate that the postulated "unsupported cantilever length" is not expected to develop for the combined load case comprised of a ground acceleration and a surface rupture offset because the fault plane will be deflected away from the base of the GETR foundation mat. Therefore, Figure C-1 provides a conservative representation of the limiting load combinations resulting from the specified Verona fault design basis event. Our evaluation supporting this conclusion is attached as Appendix B.

Analyses were performed to assure that the facility can withstand the load combinations defined above. The capacity of the facility was determined based on evaluations for various sets of load combinations selected to conservatively represent the input parameters defined in Figure C-1. These included evaluations for the following combined input parameter cases:

a) Ground acceleration = 0.75 g
   Unsupported length = 0 ft.

b) Ground acceleration = 0.0 g
   Unsupported length = 20 ft.

c) Ground acceleration = 0.30 g
   Unsupported length = 17 ft.

These analyses reasonably bound the limiting load combinations representing the hazard defined by our seismic criteria.

In addition to the investigation performed to verify the adequacy of the GETR with respect to our specific design criteria, a post-offset analysis using an input acceleration of 0.8 g was performed to demonstrate that the facility could resist a major ground motion which might occur subsequent to a surface offset event. It was conservatively assumed that only the safety related portion of the core structure could be relied on to resist the input acceleration. It was assumed that the remainder of the structure, including all concrete slabs and walls exterior to the core structure, had lost their structural resisting capacity due to the surface rupture offset effects; however, the total mass for these assumed failed portions were included in the model. Nonlinearities due to potential uplift at the foundation slab-soil interface, as well as at the interface of the interior concrete structure and the foundation slab were considered.