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EXTREME EXTERNAL PHENOMENA
SUBCOMMITTEE
JANUARY 29-30, 1981
INGLEWOOD, CA

The ACRS Subcommittee on Extreme External Phenomena held a two-day meeting on January 29-30, 1981 at the Airport Park Hotel, 600 Avenue of Champions, Inglewood, California. The purpose of this meeting was to review matters relating to seismic scram, the seismic safety margins research program (SSMRP), and the seismic qualification of auxiliary feedwater systems. Notice of this meeting was published in the Federal Register on January 15, 1981. A copy of this notice is included as Attachment A. A list of attendees is included as Attachment B and the schedule for the meeting is included as Attachment C. Selected handouts from this meeting are included as Attachment D. The complete set of handouts is in the ACRS files. No written statements or requests for time to make oral statements were received from members of the public. The principal attendees at this meeting were:

D. Okrent, Subcommittee Chairman
C. P. Siess, Subcommittee member
M. Bender, Subcommittee member
J. C. Mark, Subcommittee member
P. Shewmon, Subcommittee member
H. Etherington, Consultant
D. Ward, Subcommittee member
S. Saunders, Consultant
M. White, Consultant
Z. Zudans, Consultant
G. Thompson, Consultant
J. Maxwell, Consultant
R. Savio, ACRS Staff
R. Richardson, NRC
D. Dong, LLNL
G. Cummings, LLNL
J. Wells, LLNL
D. Bernreuter, LLNL
M. Bohn, LLNL
J. Johnson, SMA
A. Cornell, MIT
T. Y. Chuang, LLNL
J. Knight, NRC
R. Gupta, NRC
P. Smith, LLNL
S. Bush, BDL

The meeting was begun at 8:30 am on Thursday, January 29, 1981 and was adjourned at 6:35 pm on that date. The meeting was reconvened at 8:30 am on Friday, January 30, 1981 and was adjourned at 3:45 pm on that date. The entire meeting was held in open session.

INTRODUCTION

Dr. Okrent opened the meeting with a short introduction in which he summarized the purpose and the goals for the Subcommittee meeting.

SEISMIC SCRAM - J. RICHARDSON, NRC

Mr. Richardson summarized the current status of the NRC investigations on the advisability of the seismic scram. The NRC sponsored study at LLNL had investigated low-level seismic scrams and had concluded that safety benefits of low-level scrams were marginal at best. The NRC plans to examine high-level seismic scram work via work sponsored at LLNL. The results of this work are expected to be available by the end of FY 81. High level seismic scrams (approximately 2/3 the equivalent of the SS) are used by the Japanese. The scrams have not proved to be operational inconvenience. The NRC Staff has discussed the use of high-level seismic scrams with the Japanese but has been unable to uncover the regulatory philosophy that the Japanese use in deploying such scram devices.

SSMRP INTRODUCTION - J. RICHARDSON, NRC

Mr. Richardson summarized the status of the SSMRP research. He indicated that the program objectives were to develop methods of estimating the conservatism (or nonconservarism) inherent in the seismic design methods specified in the Standards Review Plan and to develop, as required, improved safety requirements and methods for safety assessment. The SSMRP work is organized in three phases. The results of Phase I work has been completed. This part of the program was directed towards developing the methodology, using the probabilistic methods to evaluate the Zion plant, and to performing some sensitivity studies to identify the most critical aspects of the input/analysis methods. The final report on Phase I is expected by March 1981. The Phase II portion of this work will deal with the improvement and validation of the methodology and the completion of the sensitivity studies. The probabilities of release which is associated with various seismic induced accident scenarios will be calculated in the Phase II portion of the work. The Phase III portion of the work will be recommended changes to the Standard Review Plan. Completion of the SSMRP work is expected in mid 1984. A listing of the major milestones in the Phase I portion of the work is given on page 1 of Attachment D. There was some discussion as to the use of the SSMRP work in the licensing process and as to the ultimate program goals. The Phase I work has produced a series of computer codes which could be used in the licensing evaluations. The analysis of the implications of the Zion study is not yet completed. It is expected that this will give an improved licensing perspective to the adequacy of the currently employed seismic design methods. The SSMRP techniques are currently being applied to the analysis of the nonseismic qualified auxiliary feedwater systems in San Onofre 1.

OVERVIEW OF THE SSMRP PROGRAM - R. DONG, LLNL

Mr. Dong summarized the status of the SSMRP work. The summary of the managerial responsibilities for various aspects of the SSMRP program are given on page 2 of Attachment B. A summary of the computational procedures used in this work is given on page 3 of Attachment D. The major codes which have been developed are the SMACS, BE/EMS, and SEISIM codes. The Phase I work is completed. The objectives of the Phase I work are believed to have been met and a probabilistic computational procedure has been constructed using, for the most part, state-of-the-art methodology. The computational procedure has been demonstrated by the application to the Zion plant. Event trees for selected initiating events were constructed for the Zion studies. These were for the full range of LOCA events, the Transient I and Transient II sequences, and the reactor pressure vessel rupture event. Fault trees were constructed for the auxiliary feedwater system, the service water system the residual heat removal system, the safety injection system, the reactor coolant loop system, and the electrical power system. Thirty time histories were used in the seismic input for six acceleration ranges (.15-.30g, .30 to .45g, .45 to .60g, .60 to .75g, .75 to .90g, and .90g and above). The HAZARD code was used to generate response spectra. The fragility data used was obtained from the available experimental data, the design information from the Zion plant, and a survey of subjective expert opinion. The structures considered in the analysis were the containment building, the internals of the containment building, the auxiliary-turbine building and the crib house. Log-normal fragility curves were used. The random and modeling uncertainties were not separated in this analysis. In the soil-structure interaction review the FLUSH and CLASSIX I and one-dimensional linear and nonlinear techniques were compared. The analysis of the major structural response included structural analysis techniques review, and assessment of dampening magnitudes, and assessment of the uncertainties in the estimated response frequencies and dampening. In the piping analysis the pipe support was assumed to be rigid and unable to fail. A simplified SMACS sensitivity analysis on subsystem response was performed within the Phase I work. Much of the work is considered as being plant specific to the Zion plant. The development of the seismic input, the fragility treatment, the event trees, the HAZARD, SMACS, and SEISIM codes will, however, have generic applications.

Mr. Dong summarized the current assessment of the uncertainties in the seismic design process. Mr. Dong stated that the Zion work had only been recently completed and the results had not been fully evaluated at this time. However, on the basis of the current assessment of this work, the major uncertainties in the calculated response are, in decreasing order, a) the determination of pipe movements, b) the determination of piping acceleration and c) the determination of building acceleration. The major contributors to the uncertainty in the estimation of the probability of release and system failure are judged to be, in this order, a) systems not treated in the fault trees, b) the determination of responses, c) the determination of fragilities, d) the incomplete treatment of the full scope of initiating events, and e) the determination of the seismic input. The major contributors to the seismic input uncertainty are, in this order, a) the ground motion model, b) local site effects, c) the determination of the largest expected earthquake, and d) the proper zonation of earthquake zones. In the soil-structure interaction analysis the largest uncertainties, in this order, are a) the definition of the free field ground motion, b) the modeling of soil properties, and c) the adequacy of the analysis techniques. The major uncertainty in the modeling structures was judged to be the uncertainty in the basic structural modeling. The dampening uncertainty was judged not to be important as was thought at the beginning of the work. The major contributors to subsystem response uncertainty are the modeling of support behavior and the estimation of appropriate dampenings. The fragility analysis contains many significant contributors to the overall uncertainty. The principal contributors are the fragility of electrical components (particularly relays and breakers), instrumentation (sensors and associated electronics), the diesel generator accessories, piping, the treatment of valve fragility data, the spring operated safety relief valve, and the fragility of cable tray assemblies.

It is expected that the insight into the process that was gained from the Zion analysis will make possible the simplification of the future analysis. The use of expert opinion to augment the available seismic data and the evaluation of the uncertainties in the seismic hazard curves is considered as one of the major results of the SSMRP work. The codes that were generated by Phase I of the SSMRP work will permit rigorous seismic risk calculations to be performed with reasonable expenditures of computer time. Major steps are considered to have been made in the evaluation of state-of-the-art soils-structure interaction methods and in the construction of a fragility data base.

SYSTEMS ANALYSIS - C. CUMMINGS/J. WELLS, LLNL

Mr. Cummings and Mr. Wells summarized the results from the systems analysis segment of the Phase I SSMRP work. The SEISIM computer code had been developed as the computational tool for this part of the analysis. The code is used in the event and fault tree development for the systems modeling. The code was developed and used in the Zion analysis. Event trees were developed for reactor vessel rupture, a full range of LOCA events, the T1 and T2 transients and containment failure. Random failures were treated in a manner similar to what was used in the WASH-1400. Common mode failures, as identified, were reviewed for each fault tree and modeled as appropriate. The calculated release category probabilities are summarized on page 4 of Attachment D.

SEISMIC INPUT - D. BERNREUTER, LLNL

Mr. Bernreuter discussed the development of the probabilistic description of the earthquake hazard and the Zion plant site. The result is given on page 5 of Attachment D. This was developed utilizing the available earthquake hazard data, coupled with use of a systematic survey of expert opinion. It was noted that there were significant differences among experts as to the appropriate seismic zonation of the Eastern U.S. The significance of the uncertainty in the seismic zonation is regionally dependent and, for the Zion site, causes the ground acceleration to vary in the range of 15 to 25 percent. Different ground motion models were found to lead to large variations in the peak ground acceleration and the spectro shape of the earthquake response. The other certainty associated with the ground motion model was judged to be an important parameter. It was significant variation among the experts with regard to the largest earthquake that could occur in each seismic zone. This variation was generally two to three magnitude units and leads to significant variations in the estimation of the seismic hazard at the Zion site.

FRAGILITIES - M. BOHN, LLNL

Mr. Bohn summarized the SSMRP development of a fragility data base. Structural component analysis, the available data base, and the systematic survey of expert opinion were used to develop the data base. Failure for structures was defined in the analysis to be when the elastic deformation of the structure interferred with the operation of safety related equipment. For most of the cases examined considerable margin existed before collapse. Commercial data, military data obtained in missile site hardening test programs, and data obtained from the testing of nuclear plant components were used in the component data base. The results of this work were reviewed by a panel of fragility experts. The review was directed toward an appraisal of a basis method and the data base used. The systematic survey of expert opinion utilized in this work was extensive. Four hundred experts were identified of which 250 agreed to participate. One hundred and fifty actually completed the questionnaires which were assembled and sent out by LLNL.

STATISTICAL RESPONSE(SMACS) - J. JOHNSON, SMA

Mr. Johnson described the results of the SMACS application to the Zion evaluation. The seismic input, the soil structure interaction effects, the structural models, and the subsystem models are input into the SMACS code. System responses are calculated for each set of inputs. The results of this analysis are completed and are being evaluated by the SSMRP.

SENIOR RESEARCH REVIEW GROUP - A. CORNELL,MIT/S. BUSH, BNL

A Senior Research Review Group had been appointed to independently review the SSMRP work. The review group consisted of A. Cornell (MIT), S. Bush (BNL), W. Hayes (USGS), and N. Newmark (Univ of IL). Mr. Bush and Mr. Cornell were present at the meeting and reported to the Subcommittee on the progress of the SSMRP work. Mr. Hayes was unable to attend and reported by way of a written statement which was read into the record. Mr. Bush, Mr. Cornell, and Mr. Hayes generally felt that the work was progressing and was successful. Continuation of this work was supported. It was noted that the fragility data used was useful in making relative comparisons of plant systems and probably could not be taken as representing absolute failure points. The need for addressing functional reliability in the fragility base and for examining the effect of the relative rigidity of the pipe systems was stressed. The meeting was adjourned at 6:35 pm on this date and was reconvened at 8:30 am on Friday, January 30, 1981.

SSMRP APPLICATIONS TO LICENSING - J. RICHARDSON, NRC

Mr. Richardson discussed what he believed were the useful licensing applications of the Phase I of the SSMRP work. Mr. Richardson stated that the Phase I work would aid in focusing the licensing safety reviews on the most important issues and in focusing research and development efforts in the most productive areas. He indicated that he believed that the results would aid in stabilizing the licensing safety evaluations in that the margin could now be better defined and would be useful in evaluating seismic safety improvements for a given plant. He noted that the seismic input element of the SSMRP will play a significant role in the SEP evaluation. The calculational methods developed in the SSMRP will be used in an assessment of the PWR auxiliary structure interaction can be a useful tool in resolving some of the controversy in this area. The computer codes developed in the SSMRP work (SMACS, SEISIM, ARAMA) can be used for seismic design margin analysis. Subcommittee members recommended that an increased effort would be made to orientate the SSMRP work towards an early input into the licensing product and close coordination should be maintained with the cognizant licensing personnel.

SOIL STRUCTURE INTERACTION - J. JOHNSON, SMA

Mr. Johnson indicated that there were several objectives in the soil-structure interaction portion of the SSMRP work. They were a) to identify and assess a relative importance of the various facets of soil structures interaction; b) to review existing methods under development for performing soil structure interaction analysis and to estimate their accuracy; c) to identify the sources of uncertainty in the soil-structure interaction process; d) to recommend benchmark analysis and test problems to be used in the verification of the soil-structure i interaction analysis procedures; and e) to recommend procedures for the Phase II portion of the SSMRP work. The state-of-the-art analysis for soil-structure interaction was discussed. The two methods which are available are the direct method and the substructure method. Complex three-dimensional configurations require the substructure approach. The LLNL recommendations for improving the state-of-the-art are; a) the performance of research directed towards the better definition of free field motion; b) further evaluation of the nonlinear aspects of soil behavior; c) the development of improved benchmark problems; d) an expanded use and analysis of the existing full scale field data.

MAJOR STRUCTURAL RESPONSE - J. JOHNSON, SMA

Mr. Johnson described the structural response analysis before the Zion plant. Four modeling configurations were used. A schematic of the Zion structures and the four modelings of the structural geometry are shown on pages 6-10 of Attachment D. Summaries of some of the results are presented on pages 11-12 of Attachment D. The estimated dampening values were compared to the Reg. Guide 1.61 specified values. These results are summarized on page 13 of Attachment D.

SUBSYSTEM RESPONSE - T. Y. CHUANG, LLNL

Mr. Chuang summarized the work done under the subsystem response task of the SSMRP work. The primary objective of this work was to compute response parameters given the input environment for those components and systems identified as important in the fault tree analysis. The systems which were treated in the Zion analysis were 1) the auxiliary feedwater system; 2) the service water system; 3) the residual heat removal system; 4) the safety injection system; 5) the component cooling water system; 6) the containment spray system; 7) main steam and main feedwater systems; and 8) the reactor coolant system. Linear elastic analysis and the multiple support time history method were used. The uncertainty contributions in the dynamic modeling of the piping systems were found to contribute significantly to the overall uncertainties.

AUXILIARY FEEDWATER SYSTEM SEISMIC STUDY - T. Y. CHUANG, LLNL

Mr. Chuang described the proposed application of the SSMRP methodology to the nonseismic qualified auxiliary feedwater system issue. The post-TMI examination of PWR auxiliary feedwater systems revealed that there were 10 plants in which the auxiliary feedwater systems were not seismically qualified to current standards. The SSMRP methods will be applied to the analysis of the San Onofre 1 auxiliary feedwater system. If this is successful the technique will be used to evaluate other plants in this class.

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NOTE: Additional information can be obtained from the NRC Public Document Room, 1717 H Street, NW, Washington, D.C. 20555 or at cost from the Alderson Reporting Company, Inc, 400 Virginia Avenue, S.W., Washington, D.C. 20024.

Attachments A - C will be included in Certified Copy of minutes on file in Public Document Room and ACRS files

Attachments A, B, C

MAJOR EVENTS OF PHASE I

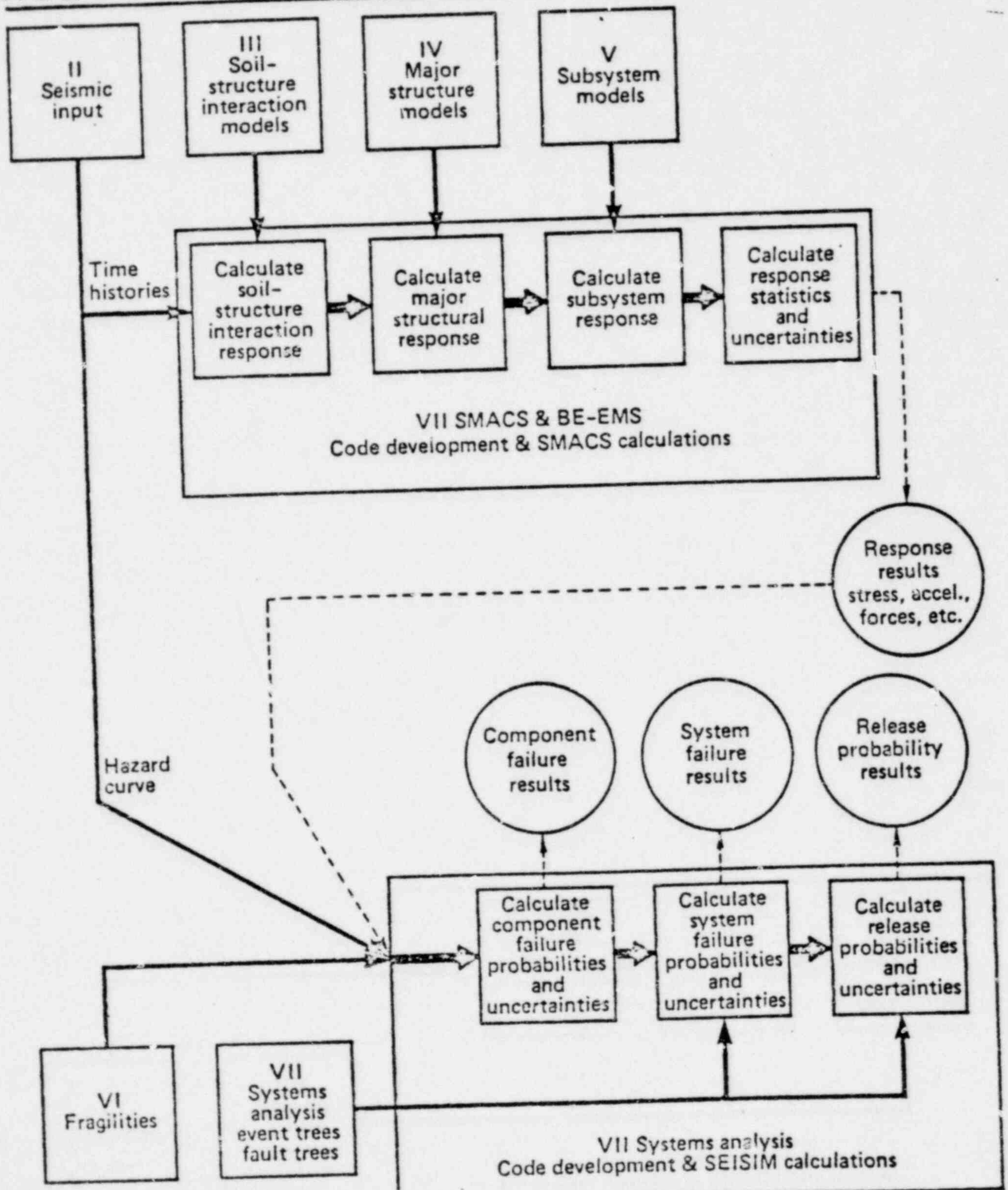
NOVEMBER 1977	INITIAL CONCEPTS FOR SSMRP
FEBRUARY 1978	PROBRAM PLANNING BEGINS
JULY 1978	AUTHORIZATION TO BEGIN MAJOR TECHNICAL WORK (50% SUBCONTRACTED)
AUGUST 1978	SELECTION OF ZION PLANT
MAY 1979	DECISION ON APPROACH TO SSMRP PROBABILISTIC COMPUTATIONAL PROCEDURE
DECEMBER 1979	SSMRP PHASE I SCHEDULE EXTENSION
APRIL 1980	LOAD COMBINATIONS BECOMES A SEPARATE PROGRAM
JULY 1980	SEISMIC AND SMACS CODES RUNNING
JANUARY 1981	COMPLETION OF PHASE I ANALYSES
MARCH 1981	PHASE I FINAL REPORT

THE SSMRP ENCOMPASSES A DIVERSITY OF TECHNICAL DISCIPLINES

		NRC	LLNL
Program Manager		J.E. Richardson	P.D. Smith
Deputy Program Manager		C.W. Burger	R.G. Dong
Projects:			
I	Plant/Site Selection and Data Collection	G. Bagchi	T.Y. Chuang
II	Seismic Input	R.J. Brazee	D.L. Bernreuter
III	Soil-Structure Interaction	J. Costello	J.J. Johnson
IV	Major Structural Response	C.W. Burger	J.J. Johnson
V	Subsystem Response	J.J. Burns	T.Y. Chuang
VI	Fragilities	J.J. Burns	M.P. Bohn
VII	Systems Analysis	J.J. Burns	G.E. Cummings/ J.E. Wells
VIII	SMACS and BE-EMS	C.W. Burger	J.J. Johnson

(3)

A FLOW CHART OF THE PHASE I PROBABILISTIC COMPUTATIONAL PROCEDURE IDENTIFIES THE ROLE OF EACH PROJECT



W

POOR ORIGINAL

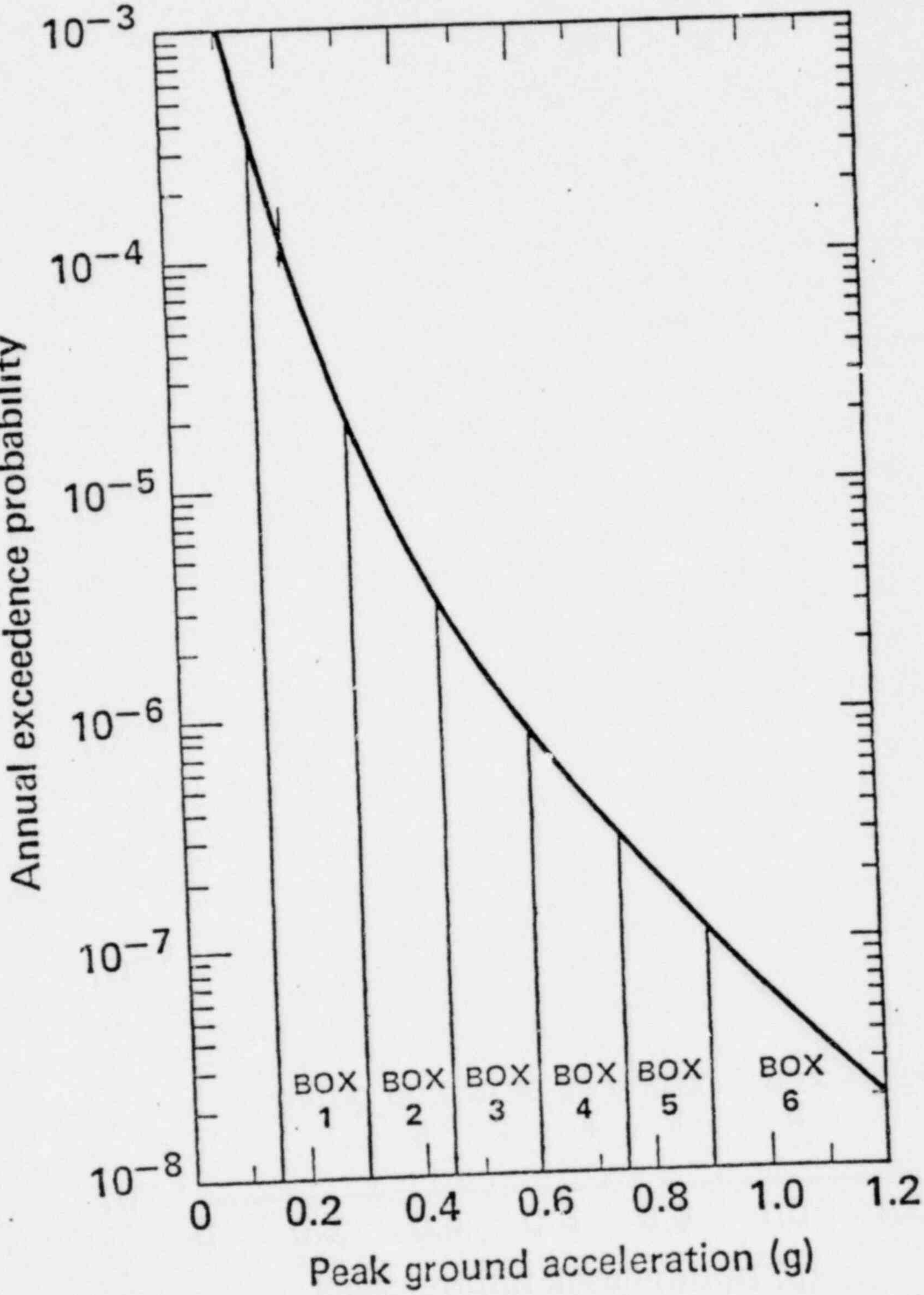
RELEASE CATEGORY PROBABILITIES WERE CALCULATED IN SEISIM

Release category	Calculated probability (1)	Calculated Probability (2)
1	2.8E-09	1.7E-10
2	2.5E-09	8.6E-10
3	9.2E-09	3.8E-08
4	4.0E-09	6.6E-09
5	6.1E-08	4.4E-07
6	2.1E-08	1.4E-10
7	4.3E-07	3.1E-06

(1) USING SEISIM CALCULATED INITIATING EVENT PROBABILITIES

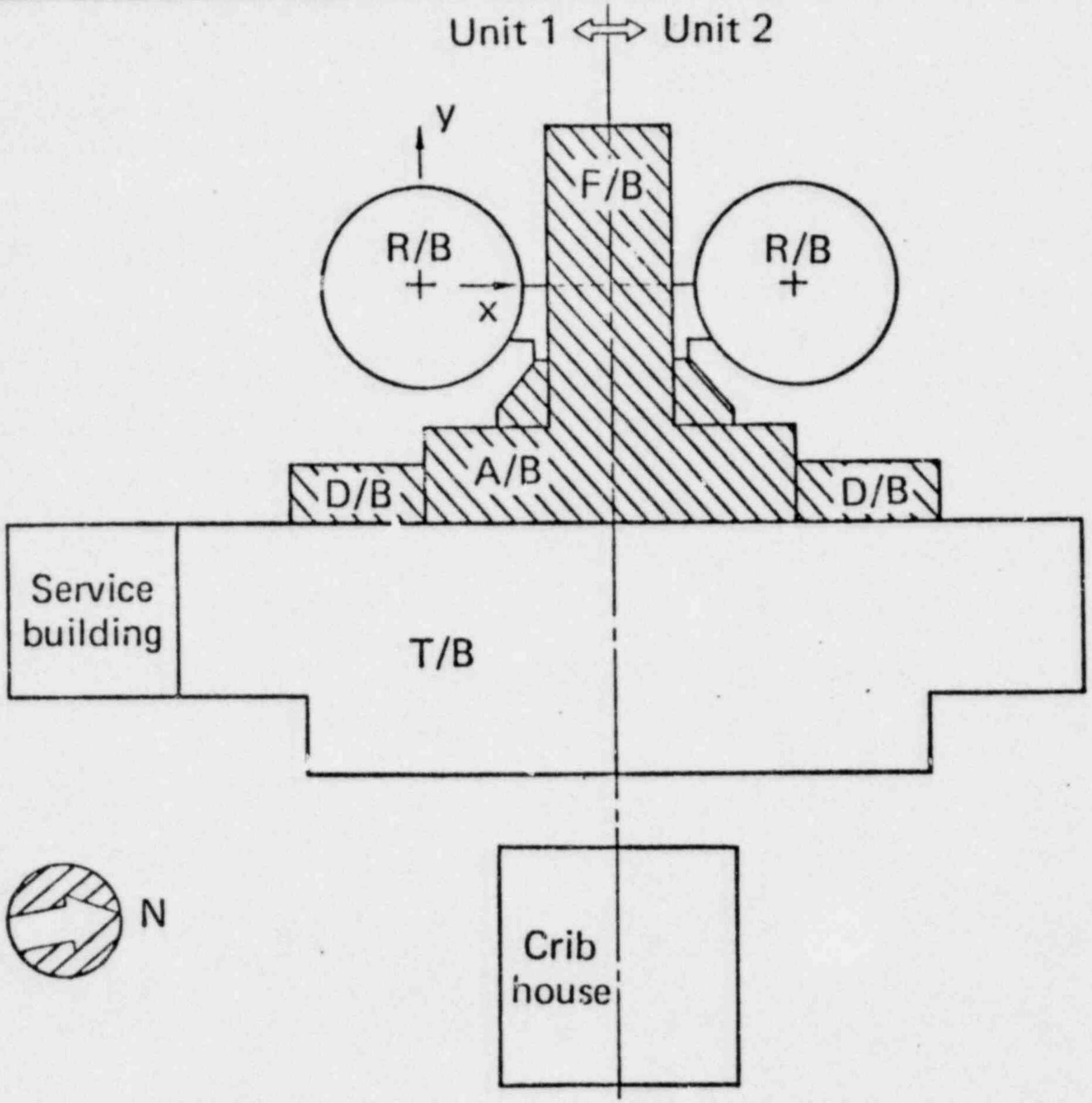
(2) USING DIABLO CANYON STUDY INITIATING EVENT PROBABILITIES

THE MAIN OBJECTIVES OF PROJECT II, PHASE I, ARE: (1) DEVELOP THE PROBABILISTIC EARTHQUAKE HAZARD AT THE ZION NUCLEAR PLANT SITE



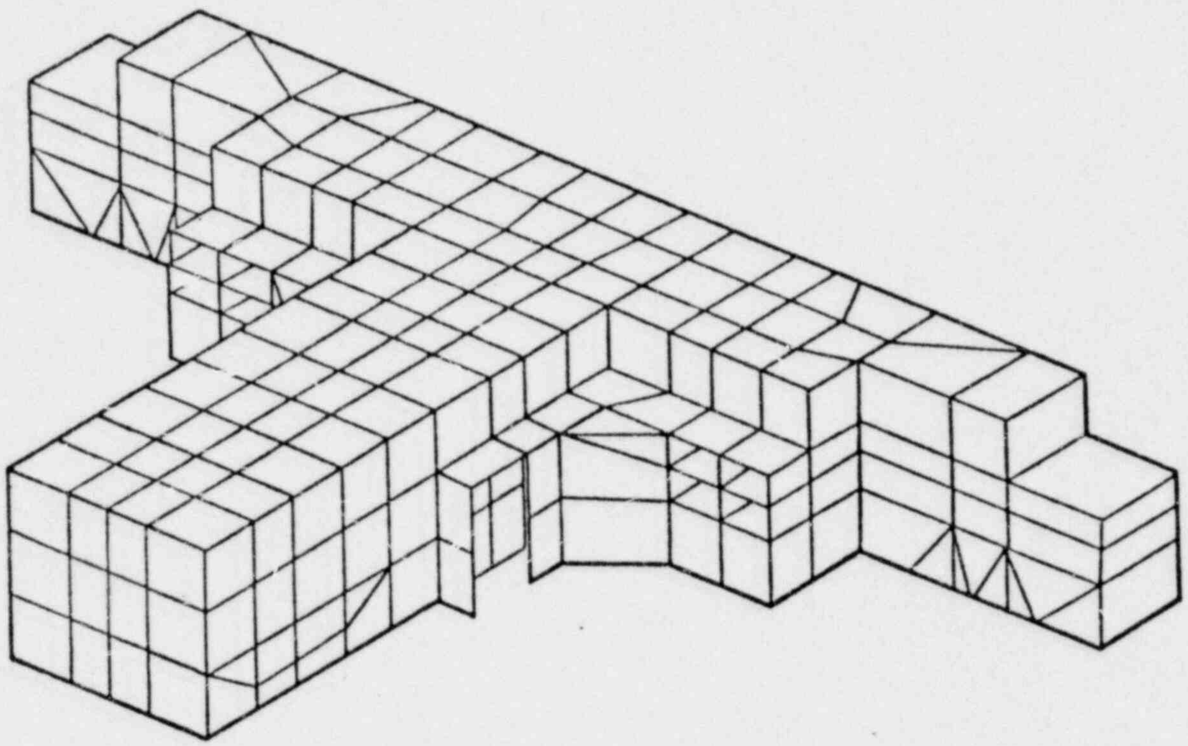
9

A TYPICAL NUCLEAR POWER PLANT BUILDING WAS THE SUBJECT OF THE STUDY



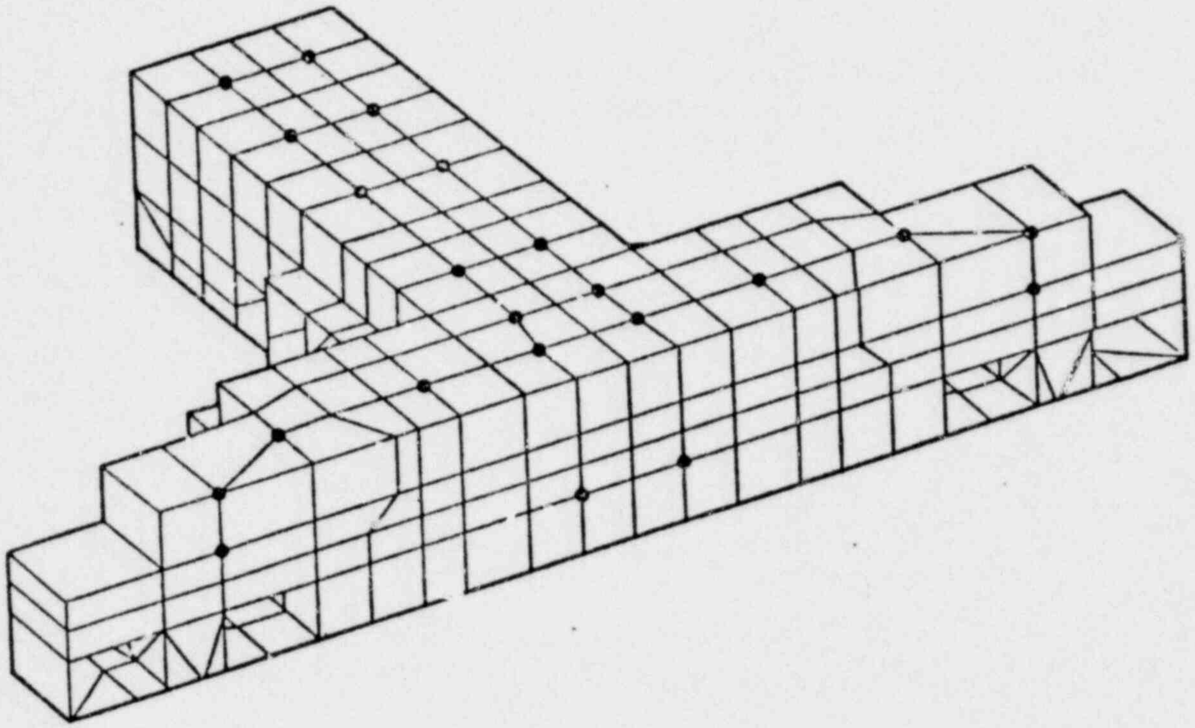
- Specific details obtained from Zion Station Nuclear Plant
- Reinforced concrete – shear wall structure
- Model truncated at grade
- Single plane of symmetry
- Discontinuous internal floor slabs

MODEL 1 REPRESENTS A "BEST ESTIMATE" MODEL OF THE STRUCTURE AND SERVED AS THE BASIS OF COMPARISON



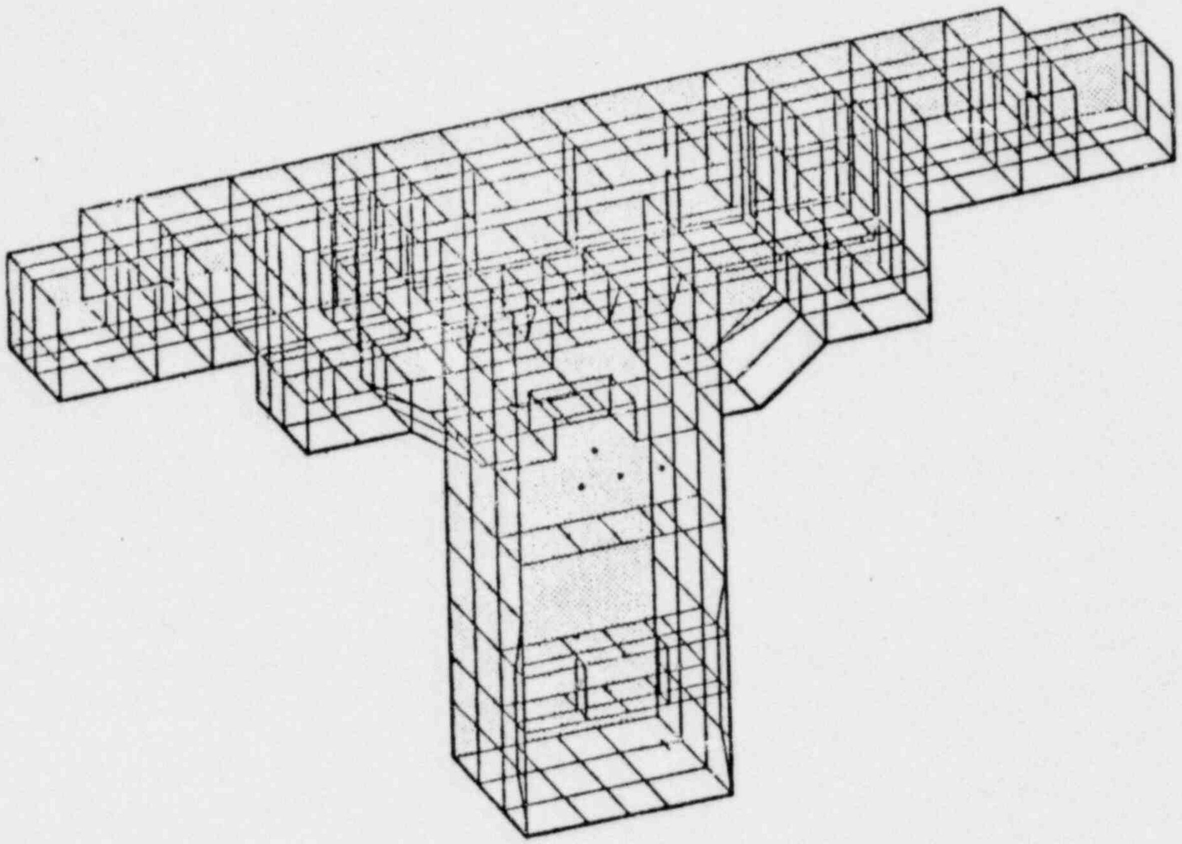
- Plate elements used to model shear walls and floor slabs
- 2490 dynamic DOF
- 122 modes (33 Hz cutoff)

MODEL 2 USED THE SAME DISCRETIZATION AS MODEL 1 BUT EMPLOYED MASS LUMPING TO REDUCE THE DYNAMIC DOF



- 255 dynamic DOF
- 125 modes

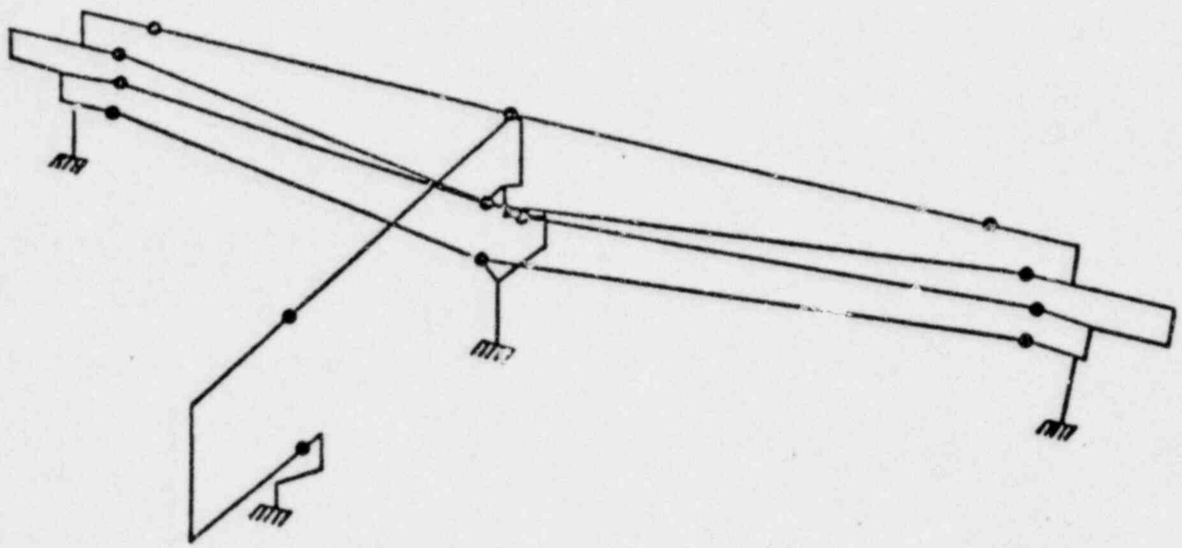
MODEL 3 INCORPORATES THE RIGID FLOOR ASSUMPTION THROUGH A MASTER/SLAVE APPROACH



- Each floor slab defined by a single master node at C.G.
- Other slab nodes rigidly slaved to master
- Shear walls modeled with plate elements
- 132 dynamic DOF
- 32 modes

10

MODEL 4 WAS CONSTRUCTED USING STANDARD MODELING GUIDELINES OF THE NUCLEAR INDUSTRY

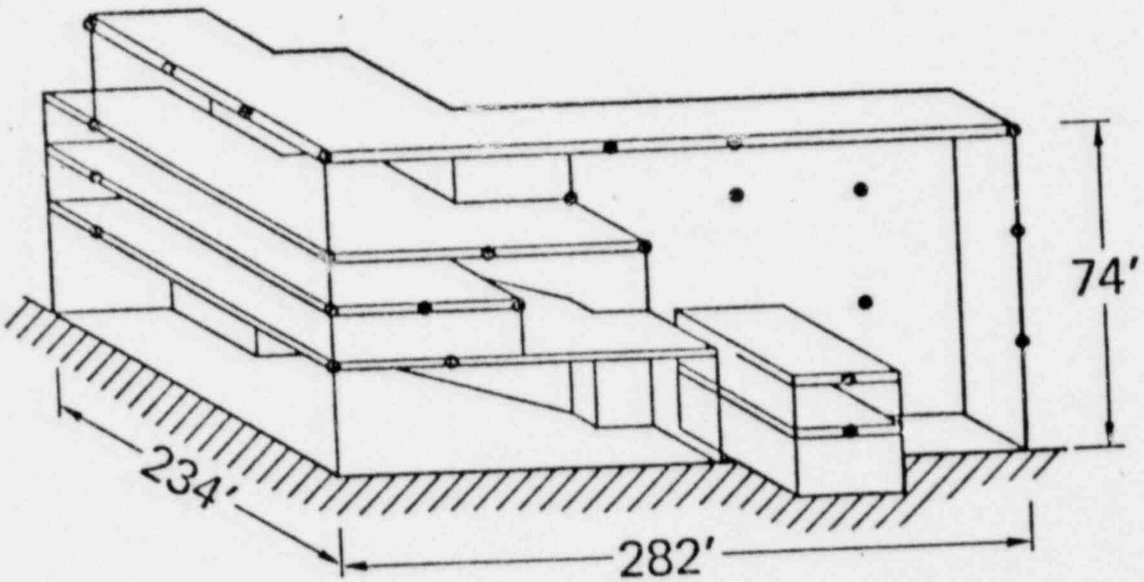


- Floor slabs defined by node at C.G.
- All shear walls between adjacent slabs modeled with a singe beam
- 80 dynamic DOF
- 29 modes

IMAGE EVALUATION
TEST TARGET (MT-3)

6″

RESPONSE POINTS IN THE MODELS WERE SELECTED TO EVALUATE BOTH GROSS STRUCTURAL BEHAVIOR AND LOCAL RESPONSE



- Overall structure behavior dictated by gross stiffness of floor/wall system
- In parts of structure, response governed by local flexibility of wall panels

A COMPARISON OF MASS AND INERTIA VALUES SHOWED GOOD AGREEMENT BETWEEN THE MODELS

	MASS	I_{EW}	I_{NS}	I_{VERT}
MODEL 1	3.08×10^{6}	3.64×10^{10}	4.63×10^{10}	6.97×10^{10}
MODEL 2	3.06×10^{6}	3.38×10^{10}	4.68×10^{10}	6.66×10^{10}
MODEL 3	3.08×10^{6}	3.39×10^{10}	4.16×10^{10}	7.07×10^{10}
MEAN	3.09×10^{6}	3.45×10^{10}	4.50×10^{10}	7.25×10^{10}
COV	.013	.037	.052	.10

IN ANOTHER STUDY, WE FOUND THAT ZION DAMPING VALUES CAN BE MUCH LOWER THAN R.G. 1.61 (NUREG/CR-1661)

ESTIMATED DAMPING LEVELS FOR SEISMIC CATEGORY I STRUCTURES FOR VARYING FREE FIELD GROUND ACCELERATION LEVELS

STRUCTURE	MEDIAN DAMPING (% OF CRITICAL) 3	5	7	10	R.G. 1.61 SSE VALUES (%)
REACTOR BUILDING					
CONTAINMENT VESSEL	0.65G	1G	1.3G		5
CONCRETE INTERNALS	2.7G	4G		5.5G	7
AUXILIARY BUILDING	0.35G	0.5G		0.7G	7
CRIB HOUSE	0.35G	0.5G		0.7G	7

NOTE: DAMPING VALUES CORRESPOND TO SEISMIC RESPONSE STRESS LEVELS ASSUMING NO COINCIDENT LOCA