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7 Abstract

A seismic evaluation of the 221-B canyon structure was performed as part of an ongoing safety review associated with continued operation of B-Plant. The objective of this report is to provide the documentation necessary to demonstrate that the canyon structure complies with the Hanford Facilities Design Criteria, SDC-4.1, Rev. 11. Compliance with SDC-4.1 seismic requirements assures that the structural capacity of the canyon building will not be exceeded (i.e. no collapse) during a Design Basis Earthquake (DBE).

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B PLANT CANYON STRUCTURE SEISMIC EVALUATION

SEPTEMBER 1989

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The analysis work described in this report was a team effort involving several analysts from the Structural Analysis Group. Specific contributions included L. G. Price: BIAX2 section capacity analyses, M. A. Scott: canyon structure design details and code concerns, G. R. Wagenblast: Soil/Structure Interaction and elastic analyses and B. V. Winkel: Nonlinear modeling and analysis. The work was supervised by T. J. Conrads, Structural Analysis Group Manager. Some analysis strategy consulting was performed by Professors S. A. Mahin and J. P. Moehle of the UC-Berkeley Civil Engineering Department.

EXECUTIVE SUMMARY

The seismic evaluation of the 221-B canyon structure is part of an ongoing safety review associated with continued operation of B Plant. The objective of the seismic evaluation was to examine the feasibility of demonstrating adequacy of the canyon structure to current DOE facility seismic requirements. If seismic adequacy could not be demonstrated for the existing facility, specific fixes were to be identified which would result in compliance with the seismic requirements.

The first step in the seismic evaluation was to perform a detailed nondestructive examination of the structural elements of the 45-year-old reinforced concrete facility. "Pulse echo", "ground-penetrating radar" and visual techniques were used to evaluate the in-place stength and condition of the concrete and location and condition of the reinforcing steel. It was concluded that the aging structural elements were in "excellent" condition.

The B Plant canyon structure departs from conventional reinforced concrete design in the sense that the walls and roof are relatively massive and lightly reinforced. Conventional linear seismic analyses resulted in significant overstress in local regions. Increasingly rigorous options were then pursued to remove the conservatisms associated with the conventional evaluation approach. The final analysis approach was an inelastic time history analysis. Results of the time history analysis resolved the overstress problems of the linear analysis and demonstrated conformance to current DOE seismic requirements. Therefore, structural modifications to demonstrate seismic adequacy of the canyon facility are not necessary.

ENGINEERING ANALYSIS SOFTWARE REPORT FORM

SOFTWARE APPLICATION

ANSYS, Rev. 4.3A, Cray X-MP/24
ANSYS, PC-Linear, Rev. 4.3A 2, IBM-AT
FLUSH, cft 5/23/88, Cray X-MP/24
BIAX2

SOFTWARE LOG #

SA/BVW/9-28-89
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SA/GRW/9-89b
SA/LGP/9-89

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ANALYST'S MANAGER

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DATE PERFORMED

Jan. - Sept. 1989

DESCRIPTION OF ANALYSIS:

Two-Dimensional static and dynamic analyses of B Plant Canyon structure. Static Linear & Nonlinear runs made (KAN = 0). Also, response spectra runs (Kan = 2) and Nonlinear time history runs (KAN = 4) were made. Elements used included 2-D beam (STIF3), 2-D spar (STIF1), 3-D mass (STIF21), superelement (STIF50,substructure), interface element (STIF12), and tapered beam (STIF44). Soil/structure analyses were made with the FLUSH code and reinforced concrete section capacities were predicted with the BIAX2 code.

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SIGNATURE OF ANALYSTS _____ DATE 10-10-89

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B PLANT CANYON STRUCTURE SEISMIC EVALUATION

1.0 INTRODUCTION

1.1 OBJECTIVES

The initial objective of the seismic evaluation of the B Plant canyon structure (Building 221-B) was to establish the feasibility of demonstrating that the unmodified structure could meet current Department of Energy (DOE) seismic standards. If demonstrating seismic adequacy was not feasible, the fallback objective was to identify potential fixes which would permit seismic qualification of the canyon structure with modifications.

As the evaluation progressed, it became obvious that the initial objective could not be met with conventional linear seismic analysis methods. Preliminary nonlinear analyses provided positive indications that a more rigorous approach, involving inelastic modeling, would be successful in demonstrating the seismic adequacy of the canyon structure. The rigorous nonlinear option was pursued and is documented in Section 8.0. The objective of this report is to provide the documentation necessary to demonstrate canyon structure compliance with the Hanford Facilities Design Criteria, SDC-4.1, Rev. 11 (WHC 1989).

Compliance with SDC-4.1 seismic requirements assures that the structural capacity of the canyon building will not be exceeded (i.e. no collapse) during a Design Basis Earthquake (DBE). However, through-wall cracking in the confinement boundary, is not precluded. Confinement boundary leakage is not quantitatively addressed in this report.

1.2 PROBLEM DESCRIPTION

The B Plant canyon structure was designed and constructed during World War II. Since no design calculation documents have been found, it is not clear if the canyon building was designed for earthquake loading of any magnitude. Subsequent structural evaluations performed to relatively recent seismic standards, indicated several locations of local overstress and a low probability of demonstrating adequacy with conventional methods.

B Plant seismic adequacy is being addressed in order to develop a safety position for B Plant usage as a pretreatment facility for the Hanford Waste Vitrification Plant (HWVP). The current definition of the Design Basis Earthquake (DBE) and associated allowable stresses for Hanford facilities is found in SDC-4.1 (WHC 1989). Analysis guidelines and structural adequacy criteria are discussed in Section 1.4 of this report.

1.3 CANYON STRUCTURE DESIGN FEATURES

The basic structural design features of the canyon building are shown in Figure 1-1. A discussion of the structural design, with respect to seismic concerns, follows below.

The canyon building design significantly departs from conventional reinforced concrete design in that the wall and roof sections are very thick (3′ to 8.5′) and lightly reinforced (less than 0.5% steel). Even the more heavily reinforced sections do not meet current ACI minimum flexural steel requirements (ACI 1987). This lack of reinforcing steel is partially compensated for in the strength and stability contributed by the massive sections. For example, the bending strength of the walls is significantly increased by dead weight "prestressing" and the overturning resistance of the thick walls adds to the structural stability.

Another design feature affecting seismic capacity is the seven foot thick wall separating each of the process cells. These cell divider walls act as "shear walls" and offer considerable stiffness and strength to the lower half of the building. Primarily because of these cell walls, the signficant seismic stresses all occur above the deck level.

A design trait which is not shown in Figure 1-1 is the division of the canyon into 40 foot segments with an "expansion joint" separating each segment. These expansion joints are equipped with shear keys which forces the 40 foot segments to move together during a seismic event. Also not shown in Figure 1-1 are adjacent structures, including exterior stairwells on every other 40 foot segment. In the seismic analysis, no credit was taken for the additional strength provided by these adjacent structures.

Note in Figure 1-1, that a bridge crane spans the full width of the canyon below the roof. For seismic analysis purposes, the crane dead weight (300,000 lb.) was assumed to be concentrated at the crane rails in a minimum cross section segment of the canyon structure.

1.4 SEISMIC EVALUATION CRITERIA

The basic criteria document specifying facility loads for natural phenomena at the Hanford reservation is SDC-4.1 (WHC 1989). Section B.3.a.(3) of SDC-4.1 provides the current definition of the Hanford Design Basis Earthquake (DBE), which is discussed in Section 5.0. For the canyon structure, the appropriate load combinations and allowable stresses are given in Section H.2 of SDC-4.1.

SDC-4.1 was recently revised to reflect recent changes in the Department of Energy (DOE) General Design Criteria 6430.1A (DOE 1989) and associated guidelines document UCRL-15910 (Kennedy et al. 1989). A brief discussion of these documents, as they relate to the B Plant canyon structure seismic evaluation, is provided below.

221-B CANYON BUILDING

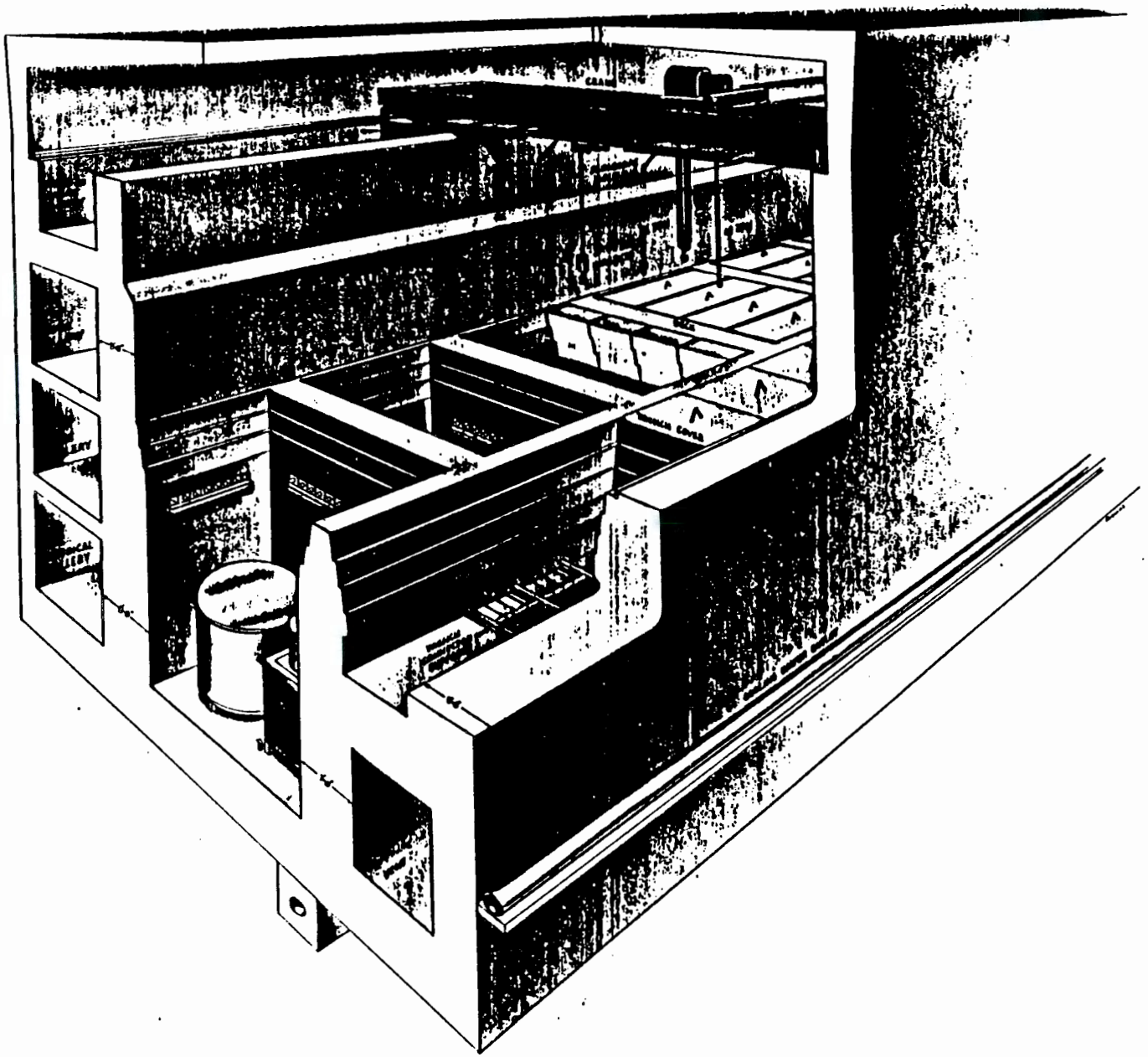

Figure 1-1. Cutaway view of the B Plant Canyon Structure.

Seismic requirements for DOE facilities are addressed in Sections 0111-2.7.2 and 0111-99.0.4 of DOE 6430.1A. DOE 6430.1A provides general direction and refers to UCRL-15910 for more detailed seismic loading and analysis guidance. Specific sections of UCRL-15910 requirements pertinent to the canyon structure seismic analysis follows below.

Section 2.2.1 of UCRL-15910 addresses "facility-use categories" which requires that a facility be placed into one of four hazard level categories. At the present time, B Plant is categorised as a "high hazard" facility. The seismic evaluation described in this report is all based upon the high hazard category following the UCRL-15910 Section 4.2.3 guidelines. A summary of this Section is provided in the next paragraph.

As a minimum, UCRL-15910 specifies that an elastic dynamic analysis be performed resulting in the development of demand/capacity ratios for the facility. The facility capacity is developed from "code ultimate or yield values". If the demand/capacity ratios are below unity for the entire structure, the facility is seismically adequate. If the elastically calculated demand/capacity ratios exceed unity, inelastic analyses may be performed, allowing for a redistribution of the local peak demands. A "direct integration time history analysis explicitlly modeling inelastic behavior of individual elements of the facility" is an acceptable approach. This approach was utilized for the canyon structure as described in Section 8.0.

Section 4.4.5 of UCRL-15910 addresses special considerations for existing facilities. This section emphasizes the need for establishing the as-built condition of the facility. It specifically states that the "in-place strength of the materials" should be determined. The approach taken in meeting this requirement for the canyon structure is addressed in Section 4.1 of this report. Section 4.1 of UCRL-15910 also lists alternatives when an existing facility does not meet the seismic requirements of a new facility.

1.5 EVALUATION PROCEDURE

Preliminary analyses of the canyon structure indicated that an elastic analysis alone is insufficient to demonstrate seismic adequacy. Knowing that nonlinear analyses would be necessary, the following procedure was used in the final seismic evaluation:

(1) Current As-Built Assesment

A detailed assessment of the current building structural condition was made using nondestructive testing techniques. Specific information provided by this assessment included concrete strength, rebar location confirmation, location of cracks and unbonded construction joints, and concrete stiffness (elastic modulus).

(2) Elastic Analyses

Using the latest information on the current building structural status, elastic analyses were performed using response spectrum techniques.

Approximate nonlinear analyses were performed at this stage by locally reducing stiffnesses at overstressed locations indicated by the linear analysis. Iterative elastic analyses were performed to obtain a preliminary inelastic response and estimate the dynamic seismic capacity.

(3) Nonlinear Static Capacity Analyses

A nonlinear finite element model was then developed in order to perform an inelastic analysis of the canyon building. Additional estimates of the seismic capacity of the canyon structure were obtained by statically incrementing lateral accelerations until the building collapsed. This static capacity analysis provided additional preliminary assessments of the dynamic capacity and gave some insight as to the likely dynamic failure modes.

(4) Nonlinear Time History Analyses

The final step in the seismic evaluation was to perform a direct integration time history analysis using the inelastic model developed in Step (3). Using the peak values obtained from the time history analysis, an assessment of the building seismic adequacy was obtained. Estimates of the building capacity were also obtained by performing time history runs on a scaled up time history loading.

2.0 SUMMARY OF RESULTS

The seismic evaluation began by performing a nondestructive evaluation (NDE) of the structural elements of the 45-year-old canyon building. The NDE assessment indicated that the current condition of the concrete is "excellent" with a nominal strength of about 5900 psi. Relatively minor surface shrinkage cracks were detected in the concrete as anticipated. Several unbonded construction joints were identified. Reinforcing bar locations were found to coincide with the drawings and there was no evidence of rebar degradation by corrosion.

The second step in the seismic evaluation was to perform a soil/structure interaction (SSI) of the canyon structure and the adjacent soil. The Design Basis Earthquake (DBE) specified in SDC-4.1 provided the basic ground motion definition at the ground surface away from existing structures. The SSI evaluation modeled the structure and surrounding soil to determine the motion of the structure as it interacts with the soil. Uncertainties in the soil properties were accounted for as specified by UCRL-15910 (Kennedy et al. 1989). The output of the SSI evaluation was an upper bound of the seismic motion of the canyon structure foundation to be applied to a detail model of the canyon building.

Initial elastic analyses indicated that there were several locations of local overstress and that an elastic analysis was insufficient to demonstrate seismic adequacy. As various nonlinear options were pursued it was noted that the overstressed areas coincided with the "precracked" construction joints. This observation led to the decision to develop a nonlinear finite element model with the nonlinearites limited to the construction joints. The resulting modeling approach is analogous to the "plastic hinge" concept used in limit analysis. The details of the nonlinear model development are given in Section 8.1.

Before performing an inelastic time history analysis, efforts were made to develop a feel for the collapse capacity and failure modes. The first effort was an extension of the elastic response spectrum method. Elastic iterations were made utilizing "secant stiffness" values at overstress regions. The second method was a "static capacity" analysis to determine the horizontal acceleration required to collapse the structure. Both of these approaches estimated a postive margin against collapse for the specified DBE.

The inelastic time history analysis results are summarized in Section 8.3.3 with details provided in Appendix D. The time history results indicated that nonlinear "gapping" occurred in several locations, but plastic yielding in the rebar was limited to the crane level construction joints, as indicated in Figure 2-1. The predicted peak plastic strain was less than 2%. The expected minimum ultimate strain for the Grade 40 rebar is 12%, indicating a significant margin against rebar failure. The occurrence of gapping and yielding at construction joints indicates the probability of an increase in confinement leakage. However, as indicated in Section 1.1, leakage concerns are beyond the scope of this report.

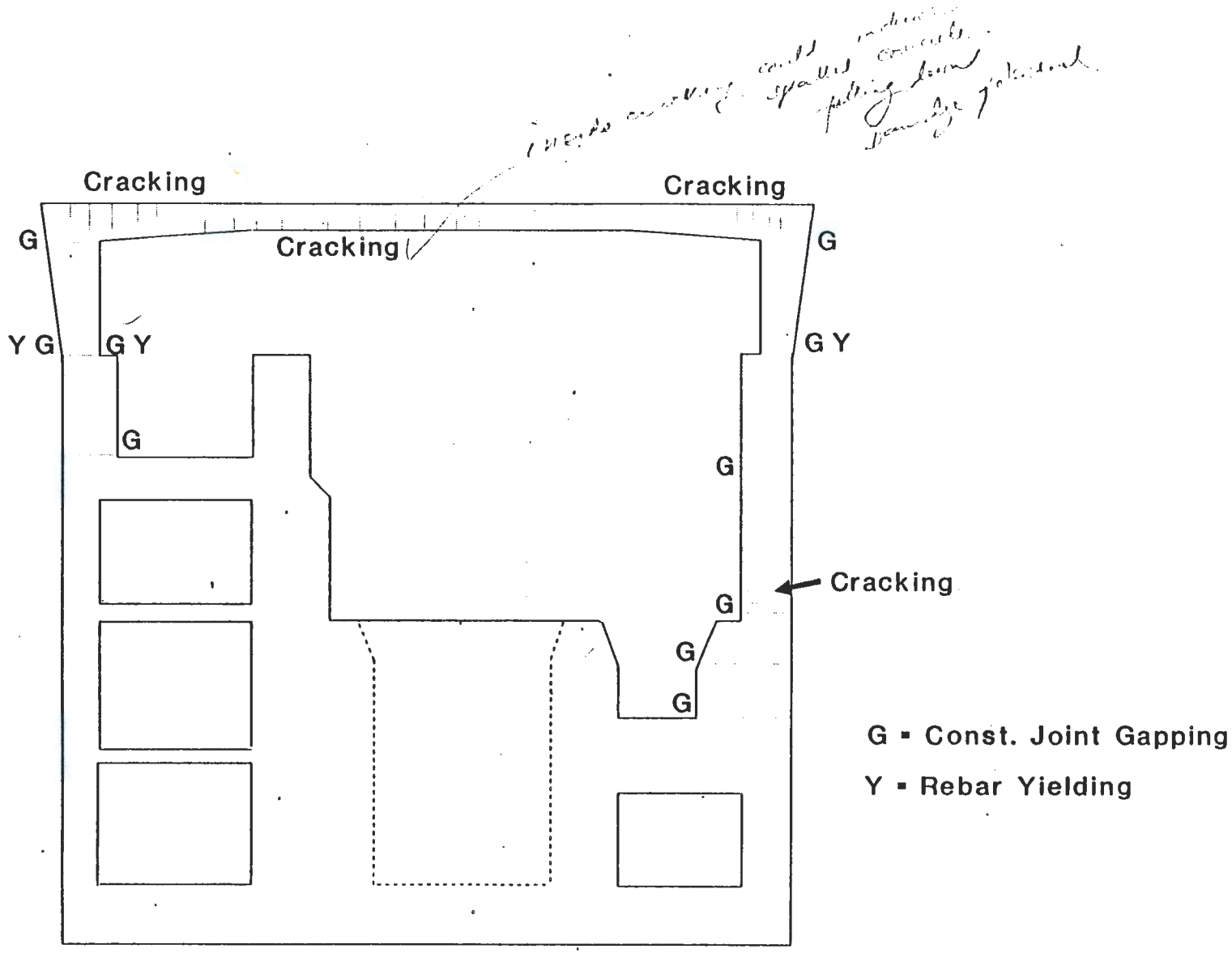

Figure 2-1. Qualitative Description of DBE damage.

Using the peak bending moments predicted by the time history analysis, demand/capacity curves were generated for the canyon walls and roof. These demand/capacity comparisons indicated that the bending moments predicted by the inelastic time history analysis are within the structural capacities as defined by UCRL-15910 (Kennedy et al. 1989).

Figure 2-1 indicates regions where concrete cracking was predicted. Cracking regions were indicated when the predicted peak bending moments exceeded the gross section cracking strength. Since moment reversals are not predicted in these regions, the cracks may not pass through the entire section. However, since the concrete compression zones are small, some through-wall cracking is likely.

Time history analyses beyond the 0.2g DBE event were also performed in order to estimate the seismic capacity of the canyon structure. A 0.4g earthquake analysis was performed by simply doubling the 0.2g acceleration time history. The 0.4g analysis supported the earlier estimates that the collapse capacity was approximately twice the 0.2g DBE magnitude, giving a collapse margin of about 100%.

3.0 CONCLUSIONS

Based upon the results of the inelastic time history analysis, it was concluded that the canyon structure complies with the seismic requirements specified in SDC-4.1 (WHC 1989). Therefore, no structural modifications are necessary to demonstrate seismic adequacy of the canyon building. It was also concluded that the time history results demonstrate compliance to the UCRL-15910 guidelines, as discussed below.

Section 4.4.5 of UCRL-15910 addresses special considerations for evaluating existing facilities. It specifically states that the as-built condition of the existing facility be assessed to determine in-place material strengths and deviations from the drawings. This guideline was addressed with a nondestructive evaluation (Section 4.1) to determine concrete strengths and to verify rebar placement. It was concluded from this evaluation that the basic structural elements (reinforcing steel and concrete) were in "excellent" condition.

Section 4.2.3 of UCRL-15910 outlines the steps recommended to seismically evaluate moderate and high hazard facilities. For an elastic analysis, it specifies that the seismic "demands" be less than the "capacities" for all elements of the facility. Elastic analyses indicated that some local capacities are exceeded leading to the conclusion that an inelastic analysis was necessary as permitted by UCRL-15910. No specific limits are mentioned when a inelastic analysis is performed. For the canyon structure, it was found that the redistributed demand values, from the inelastic analysis, were within the element capacities. This led to the conclusion that inelastic analysis adequately demonstrated compliance with the UCRL-15910 guidelines.

Although not required by UCRL-15910, seismic analyses beyond the 0.2g DBE event were also performed in order to estimate the seismic capacity of the canyon structure. It was concluded that an earthquake magnitude of approximately 0.4g is required to produce a general structural collapse. Thus, the canyon structure collapse margin for the specified 0.2g DBE is approximately 100%.

4.0 CANYON BUILDING STRUCTURAL DETAILS

4.1 CANYON STRUCTURE NDE

In accordance with the guideline given in Section 4.4.5 of UCRL-15910, an assessment of the "as-built condition of the existing facility" was initiated with a nondestructive evaluation (NDE) of the canyon structure. Specific objectives of the NDE were to (1) estimate the current strength and stiffness (i.e. Young's Modulus) of the structural concrete (2) determine the extent of concrete cracking (3) confirm the specified locations and condition (e.g. corrosion) of the steel reinforcing. The bulk of the NDE effort was performed in August of 1988 by R. Muenow and Associates. Due to some NDE/drawing descrepencies, some visual confirmation of roof rebar was necessary in November 1989. The Muenow report and follow-on roof rebar work are provided in Appendix A. A summary of the results is provided below.

4.1.1 North and South Canyon Walls

- The concrete in the north and south walls is in good to excellent condition. The nominal concrete compressive strength and modulus of elasticity for these walls are 5980 psi and 4.86 X 10^6 psi, respectively. These walls show minimal concrete degradation and cracking. The relatively few visible cracks (horizontal and diagonal) on the exteriors have maximum depths of 6 to 9 inches. These appear to be shrinkage cracks which developed during the initial concrete cure. They have progressed little, if any, since.

- Pulse echo NDT with the 90° transducer vertically down the walls from the roof confirms that unbonded construction joints exist at several levels in the north and south walls and are described in detail below.

- The construction joint at the crane rail level (elevation 737.25) is unbonded in both walls.

- Generally intermittent, weakly bonded construction joints are located in the north wall at the pipe gallery floor, the top and under sides of the crane gallery floor slab, and the wall to roof slab juncture.

- Generally intermittent, weakly bonded construction joints are located in the south wall at the floor and top of the hot pipe trench, 3 to 4 ft. above the canyon deck level, and the wall to roof slab juncture.

- The construction joints at the base of these walls with the foundation slab are generally well bonded, based on pulse echo 45° transducer NDT in the electrical gallery on the north wall.

- There are vertical reinforcement layers on both the interior and exterior surfaces of the north wall over the full height.

- The vertical reinforcement bars in the north wall are continuous (unspliced) through the construction joint at the pipe gallery floor level. The vertical reinforcement is spliced at the other north wall construction joints (exception, in section 16 vertical reinforcement splices were not detected in the crane gallery floor slab area).

- The radar NDT shows layers of vertical reinforcement on the exterior and interior surfaces of the south wall. The exterior layer was confirmed to extend down to at least the Hot Pipe Trench floor level. The interior layer could not be detected below the canyon deck level.

- The vertical reinforcement bars in the south wall are spliced at the construction joins at the crane rail level and wall to roof slab juncture (exception, in section 18 splices were also detected 3 to 4 ft. above the canyon deck level). Overlapping vertical dowels are detected near the Hot Pipe Trench floor level.

- No evidence of reinforcement steel corrosion was found in the north and south walls.

4.1.2 Roof

- The concrete in the roof slab was found to be in good to excellent condition. The nominal concrete compressive strength and modulus of elasticity were estimated to be 5340 psi and 4.71 X 10^6 psi, respectively. Cracking and degradation were not detected in the reinforced concrete roof slab.

- Apparently due to the existence of a previously unknown layer of roof insulation, the roof NDE erronously reported a north-south rebar configuration different than that specified on the drawings. To resolve this descrepency, small portions of the roof surface concrete were removed and the rebar was visually inspected. The visual inspection confirmed the rebar configuration specified by the drawing.

- Top and bottom layers of east-west reinforcement were detected which show agreement with the design drawings. No evidence of reinforcing steel corrosion was found in the roof slab.

4.1.3 Galleries

- The concrete in the gallery shielding wall is in good to excellent condition. The nominal concrete compressive strength and modulus of elasticity is 6000 psi and 4.87 X 10^6 psi, respectively. Cracking and degradation were not detected in the concrete gallery shielding wall.

- Generally intermittent, bonded construction joints were detected in the shielding wall at the base in the electrical gallery, the pipe gallery floor level, and the operating gallery floor level. Design drawings also show a shielding wall construction joint at the crane gallery floor level, but this area is not readily accessible for a NDT confirmation.

- The radar NDT was only able to detect reinforcing steel on the front face (gallery side) of the 7 ft. to 9 ft. thick shielding wall. Vertical reinforcement bars 24 in. on center were detected in the operating gallery shielding wall. These bars are unspliced at the operating gallery floor level. Therefore, it is likely that they are continuous down to the pipe gallery floor level. In the electrical gallery, vertical dowels 24 in. on centers anchoring the base of the shielding wall to the base slab were detected.

- Radar NDT for the Operating and Electrical gallery floor slabs detected north-south reinforcement steel layers which closely agree with the design drawings. The top layers of wire fabric detected in these slabs are not shown on the drawing (Note: Concrete core drilling in the electrical gallery floor slab, subsequent to the NDT, for installing compressor anchors did encounter 1/4 inch diameter wire fabric).

- No evidence of reinforcing steel corrosion was found in the gallery shielding wall, and the floor slabs.

4.2 STRUCTURAL MATERIAL PROPERTIES

4.2.1 Concrete Properties

As indicated in Appendix A, concrete strength estimates varied from 4800 to 6500 psi. The minimum strength estimate of 4800 psi was assumed in the canyon structure analysis. Appendix A also presents estimates of the Young's Modulus for the canyon structure concrete. Values range from 4.39 to 4.95 million psi. A conservative value of 4 million was used in the seismic analyses.

4.2.2 Reinforcing Steel Properties

A review of the canyon structure documentation produced no rebar material specification. Based upon a review of other older Hanford facility construction specifications, the most likely rebar used in B Plant was a Grade 40 rebar. Therefore, a minimum yield strength of 40 ksi was assumed in the seismic analysis. The conservatism of this assumption was recently confirmed in part by testing a segment of rebar obtained from some earlier coring activities. Two small specimens were tested, with both specimens indicating yield strengths of about 50 ksi. For the BIAX2 calculations (Appendix D1), an ultimate strength value of 63 ksi was assumed. A typical low carbon steel value for Young's Modulus of 29 million psi was assumed.

4.3 Drawing List

The majority of the important structural details of the canyon structure are found in Drawing No. W-69566. Additional details can be found in the basic

drawing list provided in Table 4-1. A more complete drawing list is found on Drawing No. W-70064.

Table 4-1. B Plant Canyon Structure Basic Drawing List

Drawing No.	Rev. No.	Drawing Title
W-69330	60	Concrete Front Outside Stairs
W-69332	1	Concrete Covers
W-69334	81	Sections 1 & 2, Concrete Plans and Details
W-69333	85	Sections 1 & 2, Concrete Sections & Details
W-69565	86	Standard Sections, Concrete Plans
W-69566	64	Building 221 T-U-B Standard Sections Concrete Sections and Details
W-70064	13	Structural Key Plan

5.0 DESIGN BASIS EARTHQUAKE (DBE) DESCRIPTION

5.1 RESPONSE SPECTRUM DEFINITION

The current definition of the Design Basis Earthquake (DBE) for Hanford Non-Reactor structures is specified in Section B.3.a.(3) of SDC 4.1 (WHC 1989). The specified spectra curves are shown in Figure 3 of SDC 4.1 which is reproduced here as Figure 5-1.

Section B.3.b of SDC 4.1 specifies that for non-reactor facilities the percentage of critical damping used in DBE analyses shall conform to UCRL-15910, unless otherwise justified. UCRL-15910 recommends a damping value of 10% for bolted steel and reinforced concrete. Generally, the dominant damping parameter in reinforced concrete structures is hysteresis in the concrete. For the lightly reinforced, massive walls in the B Plant canyon structure, the total hysteresis activity in the concrete is expected to be significantly less than for a conventionally reinforced concrete structure. Therefore, based upon a literature review and discussions with UC-Berkeley civil engineering professors, a relatively conservative 5% damping was assumed for all of the canyon structure DBE analyses.

5.2 TIME HISTORY DEFINITION

Ten second time histories were generated for the SDC-4.1 spectra by URS Corporation (URS Consultants 1989). Three independent time histories were developed for the north-south, east-west and vertical directions. In accordance with Section 4.4.1 of UCRL-15910 (Kennedy et al. 1989), the east-west and vertical peak accelerations are 80% and 60%, respectively, of the north-south peak of 0.2g. The time histories of interest for the B Plant canyon structure analysis are the north-south (transverse to the canyon axis) and vertical directions which are reproduced here as Figures 5-2 and 5-3.

The initial input for the generated time histories was the El Centro earthquake for the north-south time history and the 1952 Taft for the vertical time history. The acceptance criteria for the final time histories was as follows: (1) The associated computed spectrum could not dip more than 5% below the SDC-4.1 specified spectrum. (2) The average of the ratios of the generated spectrum to the required response spectrum, in the 0.5 to 40 hz frequency range, must exceed 1.0. (3) Power Spectral Density (PSD) plots were generated for each time history to demonstrate that the PSD behavior was reasonable. (4) Cross-correlation coefficients for the independently generated time histories were checked to assure that they are weakly correlated (less than 10% correlation).

The time histories shown in Figures 5-2 and 5-3 were developed for the seismic analysis of a different structure (i.e. not B Plant) using the SDC-4.1 7% damping curve. To evaluate the adequacy of these time histories for the 5% spectrum, the above criteria were applied. It was found that the computed

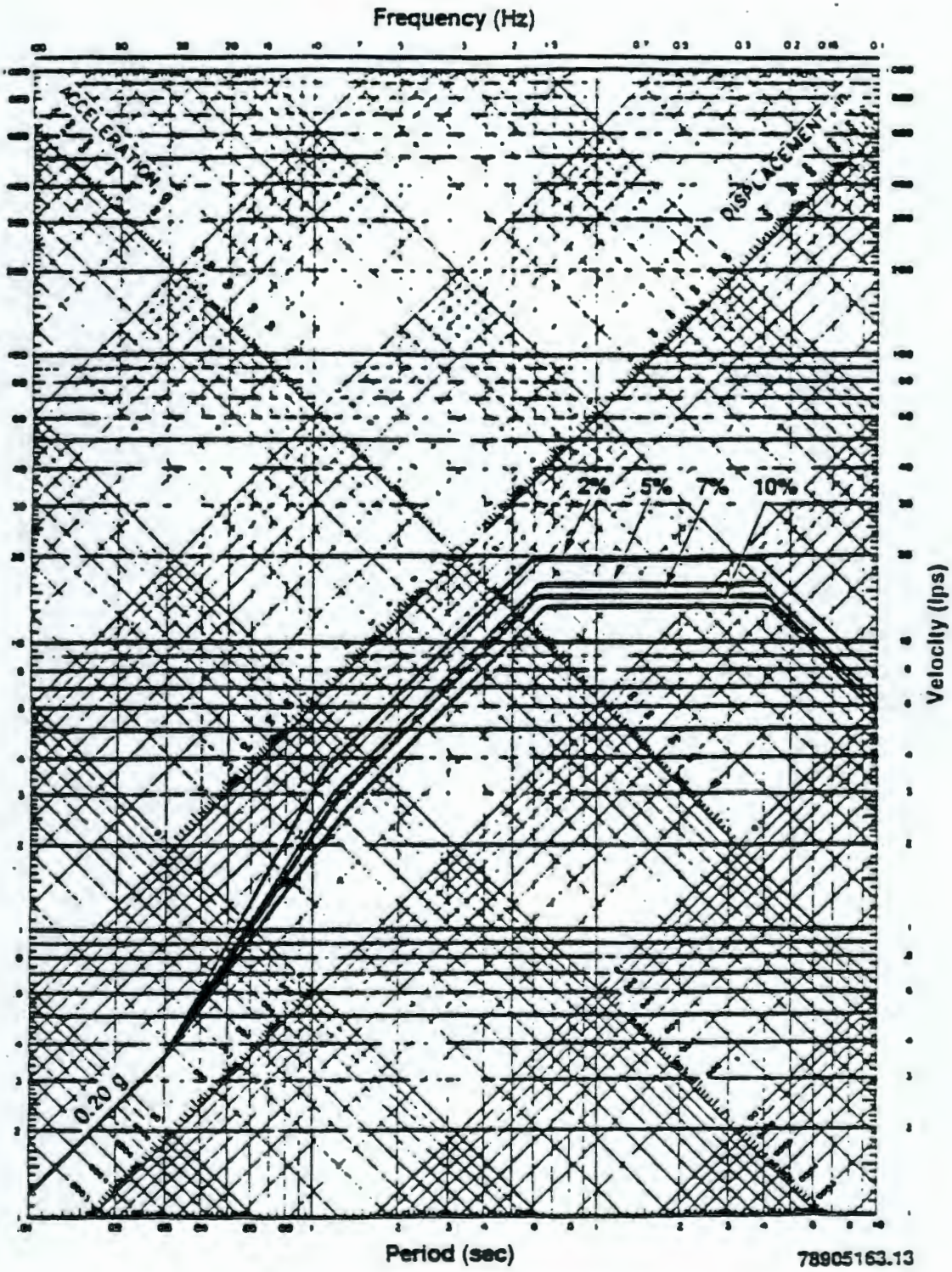

Figure 5-1 RESPONSE SPECTRA - NON-REACTOR SAFETY CLASS 1 for 2, 5, 7, AND 10% CRITICAL DAMPING, 0.20g

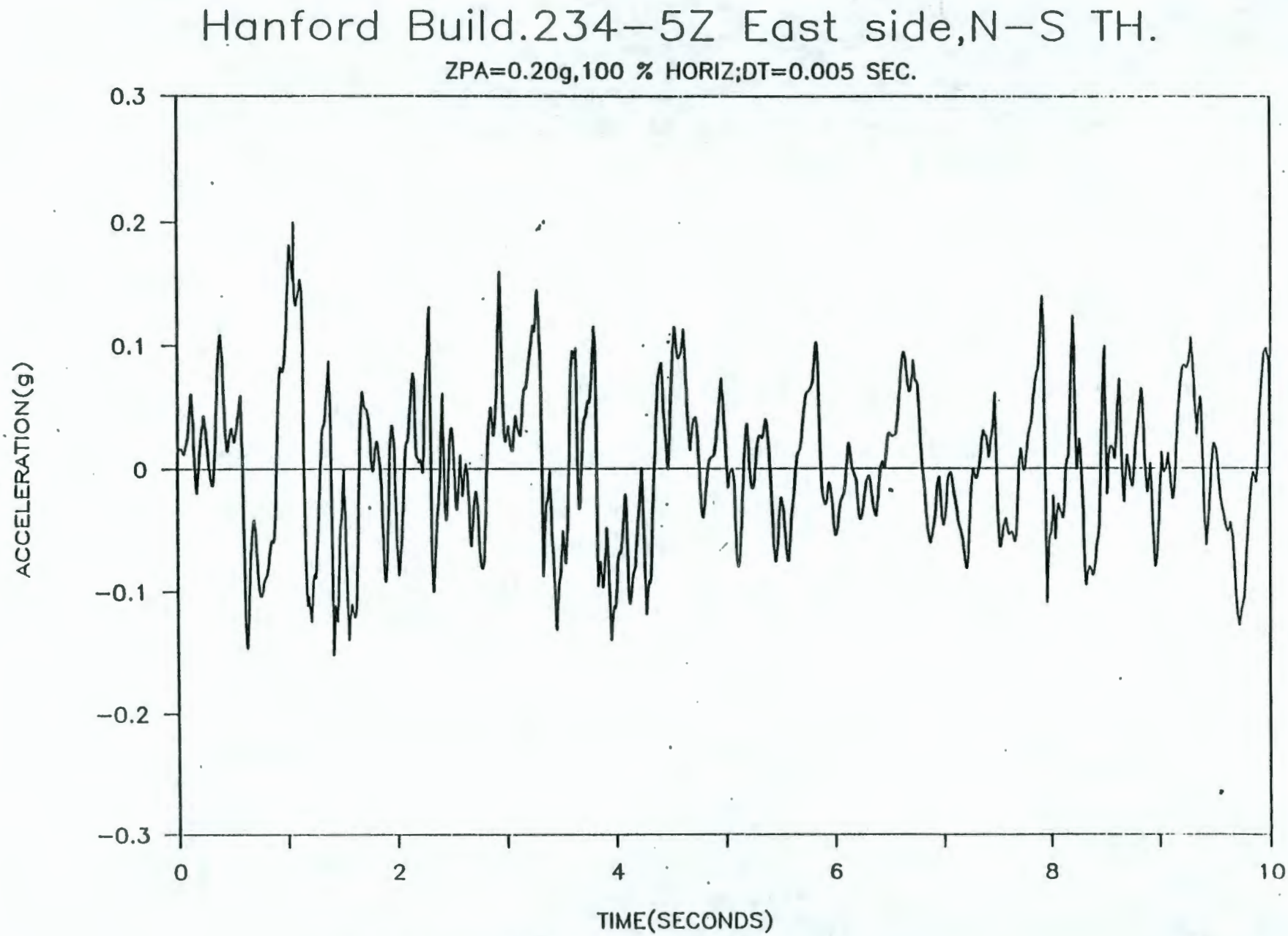

Figure 5-2. North-South 0.2g Time History.

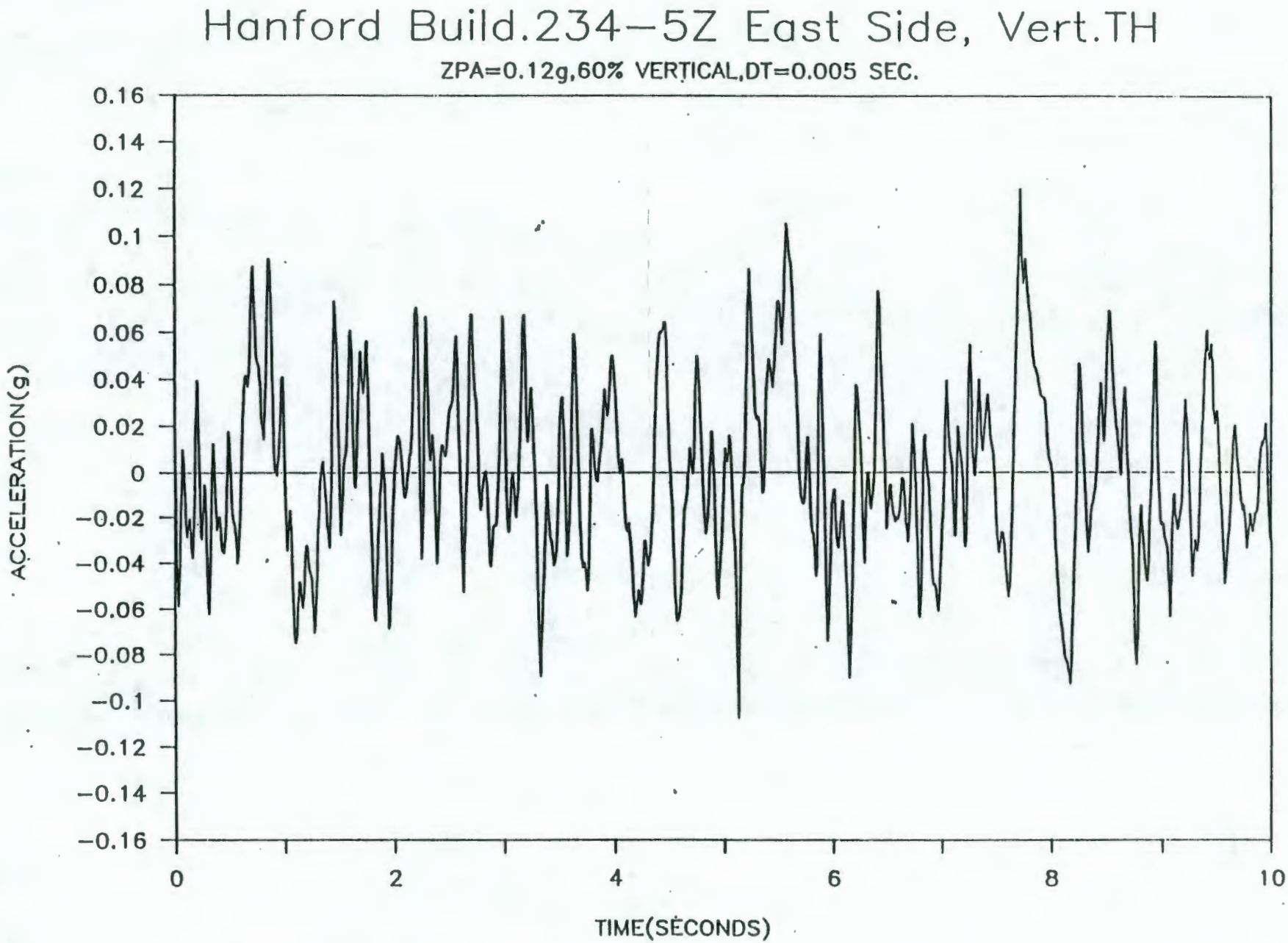

Figure 5-3. 0.12g Vertical Time History.

spectrum dipped slightly more than the 5% criteria at one frequency for the north-south time history as shown in Figure 5-4. However, the average ratio requirement (generated to required spectrum) of 1.0 is met and the time histories were judged to be adequate for 5% damping applications. This judgement was influenced by the fact that the ASCE Standard for seismic analysis (ASCE 1986) allows 10% dips to occur, if the average ratio requirement is met.

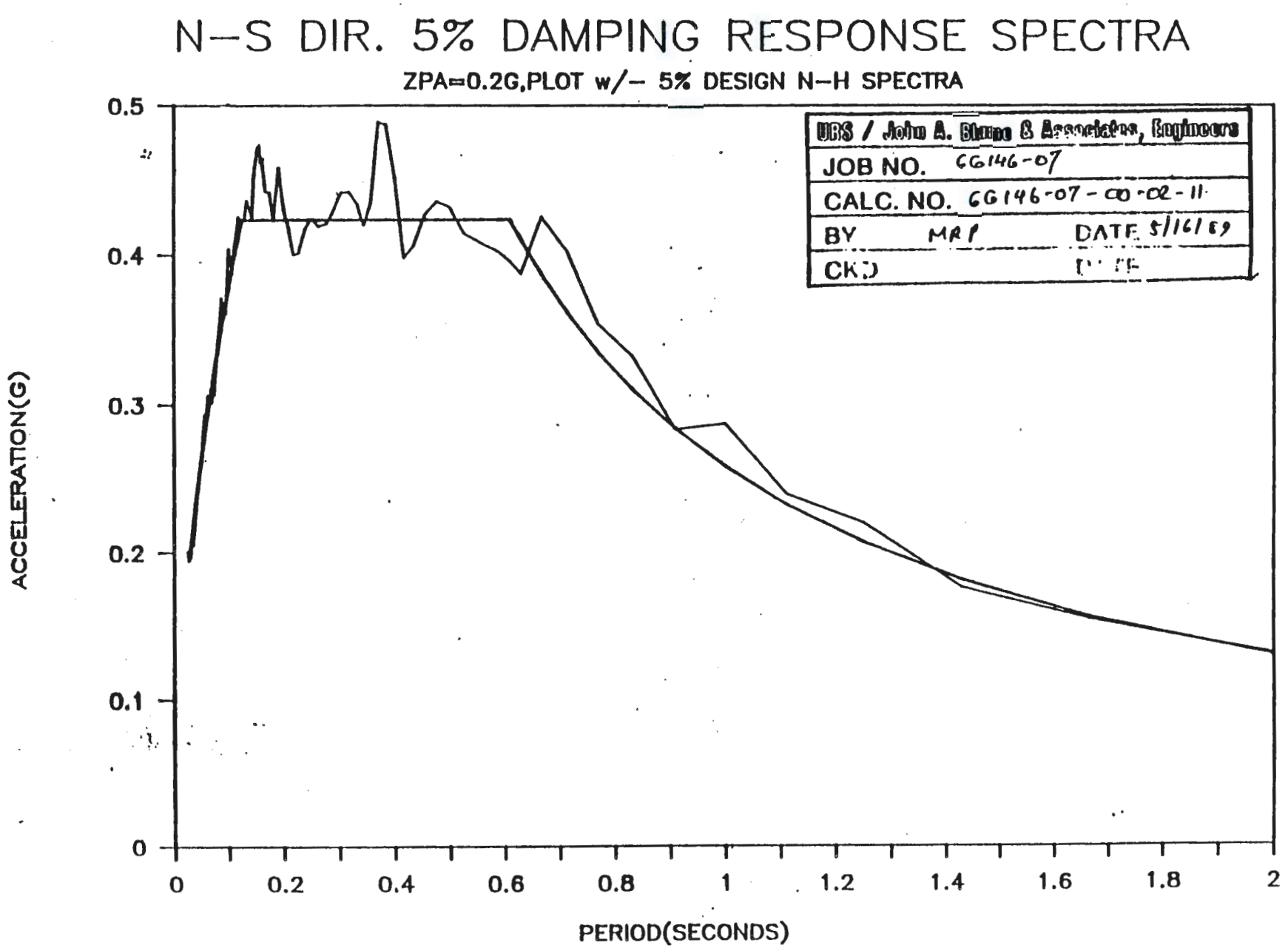

Figure 5-4. Comparison of Computed and Required (SDC-4.1) 5% Response Spectrum.

6.0 SSI EVALUATION

6.1 INTRODUCTION

The Design Basis Earthquake (DBE) for the Hanford Site is defined in SDC 4.1 (WHC 1989) and summarized in section 5.0 of this report. The input design response spectra (Figure 5-1) and the generated time history define the surface ground motion at the site remote from any structures. However, as the incoming vibratory motion in the ground encounters a massive foundation implanted in the soil, wave scattering combined with soil deformation produces motions in the base slab that differ from those defined at the same elevation in the free-field. This difference between the base-slab motion and the free-field motion can be described as the effect of soil-structure interaction (SSI). For an embedded structure, the base-slab motion may be significantly less than the design ground motion at the soil surface.

One method for evaluating SSI is the finite element technique, where the soil mass is separated into finite two-dimensional elements. The structure is also detailed using an appropriate combination of finite elements. A finite element method frequently used in SSI analysis of nuclear power plant structures has been coded into FLUSH, a computer program developed at the University of California, Berkeley (Lysmer et al. 1975). FLUSH is a two-dimensional, finite element program which uses the complex response analytical procedure to solve the equations of motion of the soil-structure system in the frequency domain.

Deconvolution is the method used to compute sub surface ground motion from a given motion at the surface in the free field.

6.2 SOIL COLUMN STUDY

In FLUSH, the nonlinearity in the soil material is approximately accounted for by iterating on the soil properties. The "low strain" soil properties selected for the B Canyon SSI were extracted from the SSI analysis of the nearby Purex facility analysis (URS 1981). The soil model extends to a depth of 161 feet and is characterized by the properties shown in Figure 6-1.

The maximum height of the soil layers selected for the FLUSH model were established using the criteria in the FLUSH users manual:

$$h_m = V_s/(5f_m)$$

where: h_m = maximum height of the soil layers

V_s = shear wave velocity in the layer

f_m = highest frequency in the analysis (30 hz assumed).

The maximum width of the soil elements beneath the structure was established using recommendations specified by the American Society of Civil

Layer	Spacing	Density (KCF)	Poissons Ratio	Low-Strain Shear Modulus (KSF)
1				
2	4@4' = 16'	0.11	0.20	1111
3				
4				
5	1@6' = 6'	0.12	0.24	4513
6				
7	3@10' = 30'			
8				
9				
10	5@10' = 50'	0.12	0.29	5731
11				
12				
13				
14				
15	6@10' = 60'	0.125	0.36	18780
16				
17				
18				
19				

FIGURE 6-1 Soil Profile for Soil Column Study

Engineers (ASCE 1986), which states that at least eight horizontal divisions be used within the width of the structure foundation.

6.3 STRUCTURAL MODEL

The structural portion of the model used a combination of beam and solid elements to represent the canyon structure north-south cross section. Beam elements were used for the walls, roof and floor slabs. Solid elements were used for the 6 foot foundation slab and to account for the shear wall contribution of the 7 foot thick walls between the process cells. An effective shear modulus of 0.35 times the concrete shear modulus was used in the shear walls to account for the fact that the solid portion of the cells is 35% of the total volume. The E/W dimension was assumed to be infinite since the canyon structure is very long in that direction. The finite element model used in the FLUSH evaluation is shown in Figure 6-2. A typical FLUSH input file is provided in Appendix B.

The canyon structure has a 300,000 lb. bridge crane which moves in the E/W direction and can be located anywhere along its length. The crane bridge is supported on the east-west rails by end trucks, each truck having four wheels. The outermost wheels on each end truck are spaced 16 feet apart. The weight of the unloaded crane to be resisted by each one foot length of canyon cross section was conservatively taken as 1/16 of 300,000 pounds or 18750 pounds, 9400 pounds on each rail. The weight of the canyon cell cover blocks were determined and included in the model as concentrated mass points.

6.3.1 Damping

The selection of appropriate damping values to be used for structural seismic analyses is generally extracted from an imposed industry standard such as NRC Reg Guide 1.61. For non-reactor structures located on the Hanford DOE site, the imposed standard, SDC-4.1 (WHC 1989) specifies that damping values should be taken from UCRL 15910 (Kennedy 1989), which specifies a value of 10% for reinforced concrete. The 10% damping was judged to be too high for the relatively thick-walled, lightly-reinforced construction of the canyon structure.

A literature search was performed to evaluate industry precedence used in seismic analyses of structures similar to the canyon building. Some precedence was found in the seismic analysis of concrete dams. Dreher (Dreher 1981) reports that damping values ranging from 2 to 10 percent have been experimentally extracted from tests on dams, with the higher levels reported for "higher levels of exitation". This provides some evidence that relatively high damping is possible for lightly reinforced concrete structures.

Following the literature review, several discussions were held with various experienced seismic analysts including civil engineering faculty members at UC/Berkeley. There was general agreement that for the predicted near-capacity load levels for the canyon structure, a 5% damping value is reasonable.

The dominant damping mechanism in conventional reinforced concrete structures is generally material hysteresis in the concrete in compression. Preliminary estimates of the DBE response of the canyon structure indicate that the structure will be loaded near the structural capacity. However, due to the lightly reinforced nature of the structure, the compressive concrete stresses are expected to be relatively low. Therefore, the higher damping specified by UCRL 15910 for DBE analyses of reinforced concrete structures does not appear to be appropriate for the canyon structure. A 5% damping in the structural portion of the FLUSH model was assumed for all analyses.

6.3.2 Construction Joint Details

The canyon structure is known to have several unbonded construction joints created during the pouring sequence. The reduced moment capacity at these locations increases the structural flexibility and produces corresponding reductions in the natural frequency. To account for the effects of the construction joints, a simplified ANSYS model, suitable for easy conversion to FLUSH, was prepared. To simulate the construction joints, a short (6 in. long) element was modeled at the joint locations.

Modal analyses of this simplified model using a variety of values of moment-of-inertia for the six inch long joint segments were performed and compared to the results from the response spectrum evaluations of the detailed ANSYS model having linear rotational springs (see Section 7). The moment-of-inertia properties from the simplified ANSYS model that resulted in the best approximation of the fundamental frequency of the detailed ANSYS model were used in the FLUSH model.

6.4 FLUSH ANALYSIS

UCRL-15910 (Kennedy et al. 1989) requires that soil property uncertainties be accounted for in SSI analyses. Three soil modulus conditions are recommended: (1) "best estimate" shear moduli corresponding to the iteratively calculated seismic strain for each soil layer, (2) lower bound shear moduli values corresponding to 50% of the best estimate values calculated in (1), and (3) upper bound moduli taken as 90% of the best estimate "low strain" values. The best estimated low strain moduli were taken from the PUREX facility evaluation as discussed in Section 6.2. The reduction factors for higher strains were taken from the Seed and Idriss (Seed et al. 1970) recommendations for sand.

The nonlinearity in the soil stiffness as a function of strain level was accounted for in FLUSH by iterating on the shear moduli and damping values for each of the soil layers until the solution converged. The shear moduli corresponding to the calculated seismic strain for each soil layer were then used by the FLUSH program in computing the "best estimate" response spectra and time history at selected points. Upper and lower bound spectra were obtained by varying the soil properties as indicated in the previous paragraph.

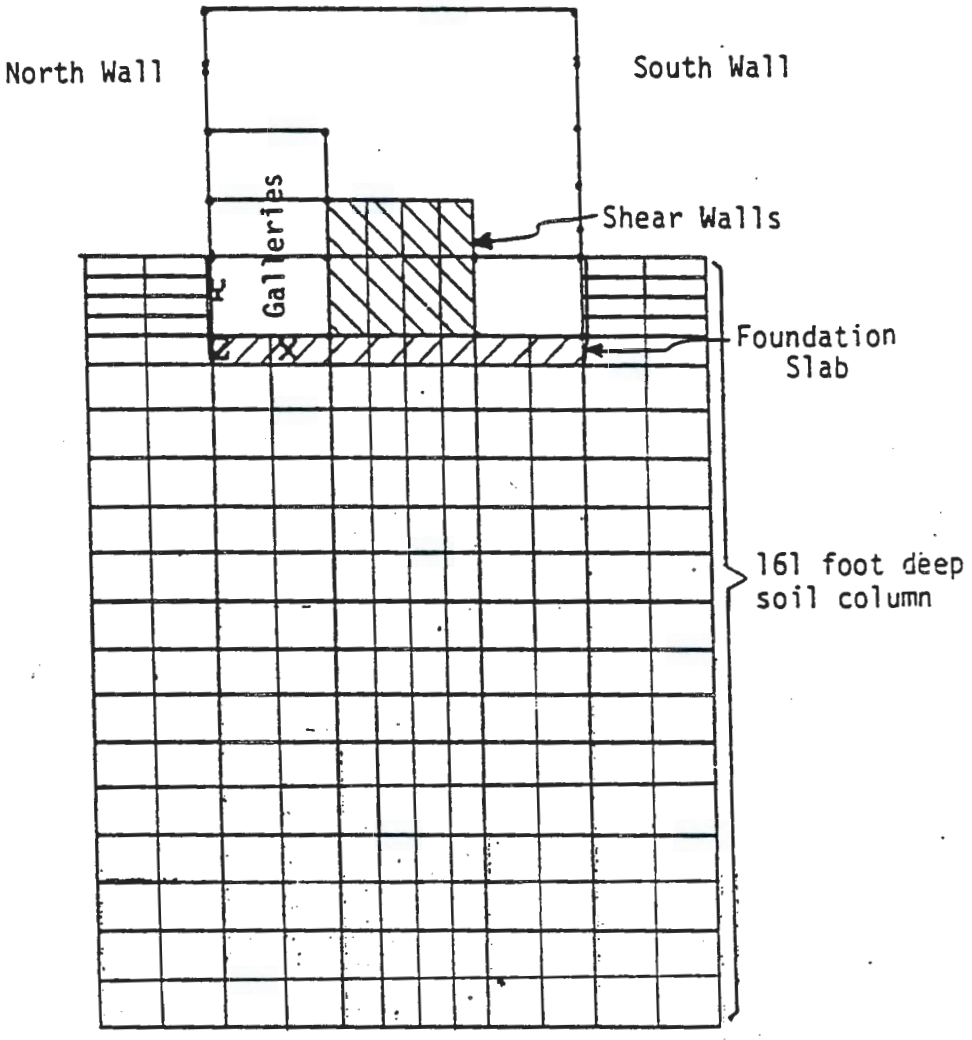

Figure 6-2. Canyon N/S FLOSH Finite Element Model.

6.5 SSI RESULTS

The objective of the SSI analysis was to provide DBE base-slab motion of the canyon structure to be used in a detailed structural model analysis. Motion predictions were produced in both a response spectrum and time history format. Response spectrum curves were generated at the center and edge of the base-slab, at several interior wall and floor locations, and in the soil at the surface and at the foundation depth. The center and edge predictions were almost identical. Therefore, only the center results are reported.

The input motion at the soil surface was a time history. An iterative free field analysis of the soil column was performed and the surface spectrum was generated and compared to the SDC-4.1 input spectrum. The regenerated spectrum was found to correspond adequately to the input spectrum, which provided some verification of the soil column model adequacy (Figure 6-3).

The resulting response spectra for the three bounding soil moduli evaluation conditions are shown along with the SDC-4.1 free-field input in Figure 6-4. At all frequencies, the response of the lower bound soil condition resulted in larger, more conservative, accelerations. The foundation time histories corresponding to the upper bound spectrum are shown in Figures 5-2 and 5-3.

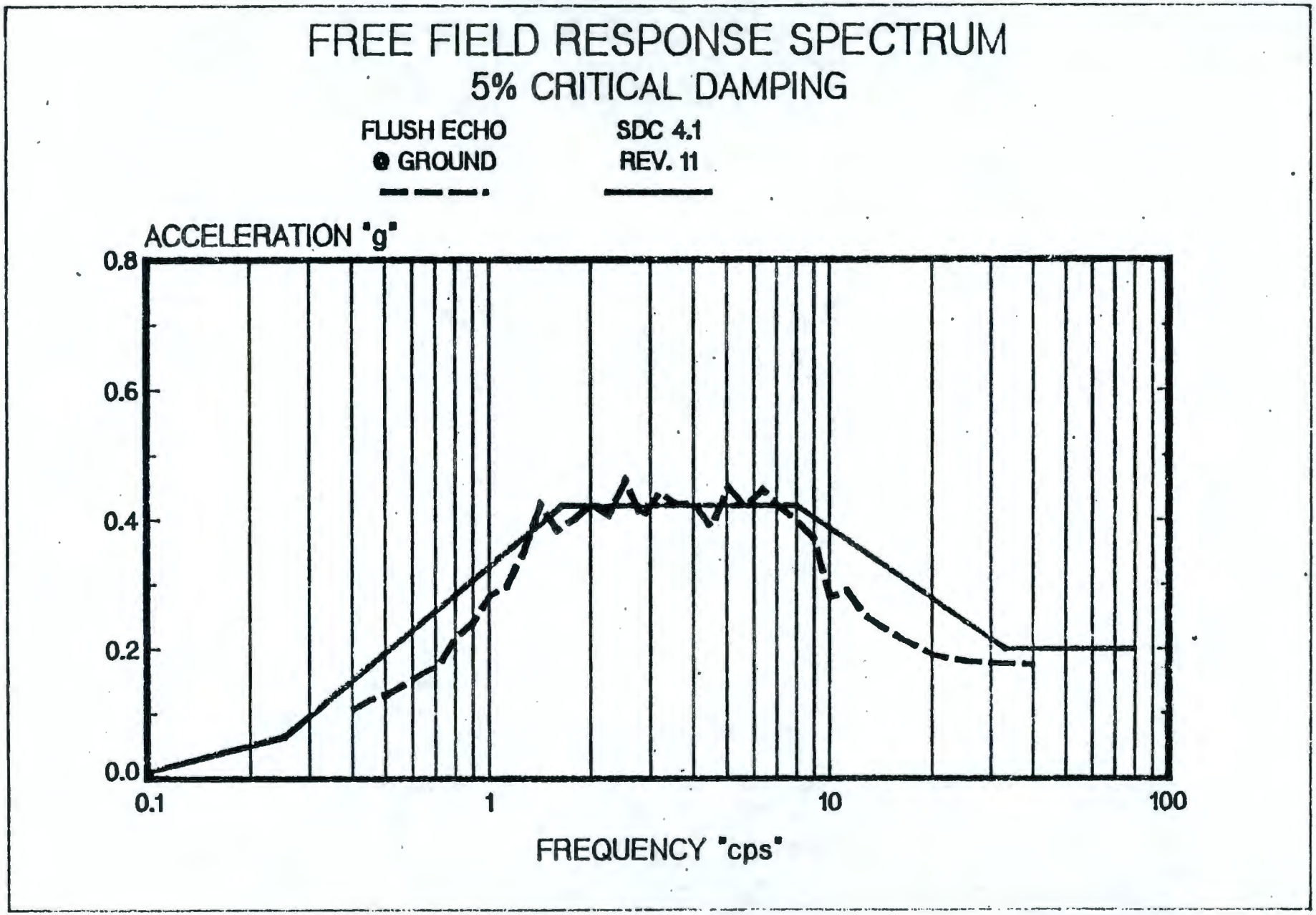

Figure 6-3. Free Field Response Spectrum.

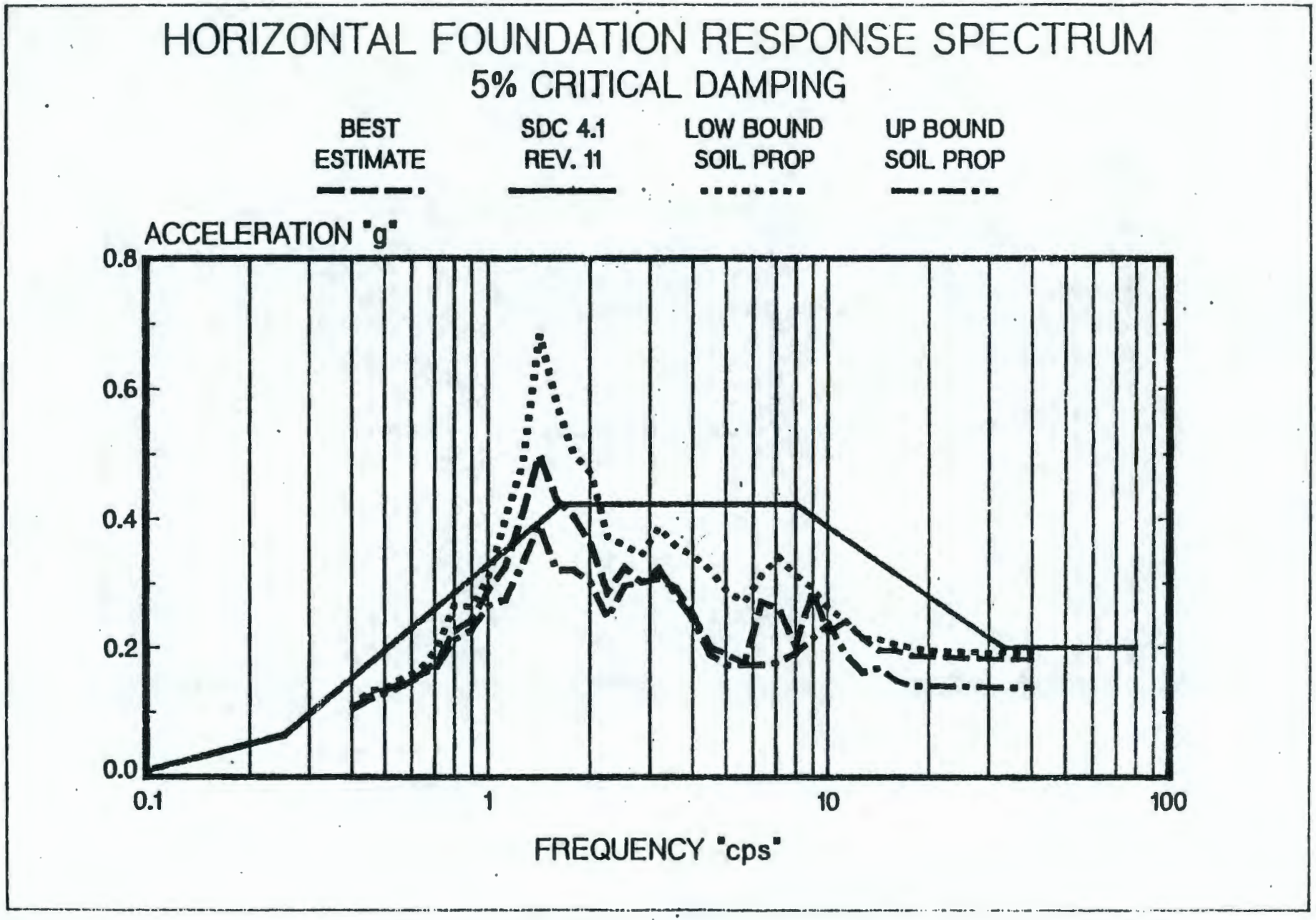

Figure 6-4. Canyon Structure Foundation Response Spectra.

7.0 LINEAR ANALYSIS

Past seismic evaluations of the B-Plant Canyon design have resulted in predictions of cracking of the concrete and overstress of the reinforcing steel. The presence of the unbonded "precracked" construction joints predetermines the locations of reinforcing steel overstress.

In order to approximate the response of the structure having unbonded construction joints, a detailed linear finite element evaluation was performed. Comparisons to the non-linear capacity of the unbonded construction joints were made for three loading conditions. Gravity loads, 0.2g Design Basis Earthquake loads, and double DBE earthquake loads of 0.4g were imposed on the structure in order to determine the dynamic response and potential collapse loads.

The structural model used a combination of beam and solid elements to represent the canyon structure. Gross section beam elements were used for the walls, roof and floor slabs. Solid elements were used for the foundation slab and for the shear walls between the process cells. Rigid link beam elements were used in the area common to the intersecting walls and floors. Nine linear springs were included in the model at the locations of the known unbonded construction joints, three on the north wall above the crane gallery floor and six on the south wall above the bottom of the pipe trench. The linear model is shown in Figure 7-1. A typical computer run input file is provided in Appendix C.

7.1 CONSTRUCTION JOINT STIFFNESS DETERMINATION

A study was performed to determine the overall effects on the structural model due to variations in rotational stiffness of the springs at the construction joints.

Modal analyses were made using varying spring stiffnesses in order to duplicate the results from the modal evaluation of the model having rigid construction joints. Spring stiffnesses for the model were estimated from hand calculations to be 198EI/L where I is the gross stiffness of the uncracked concrete section and L is the distance to the adjacent construction joint. The hand calculated stiffnesses of the joints ranged from 3.1E11 to 8.1E12 inch pounds per radian (ippr). A uniform spring stiffness of 0.1E13 ippr was used in the evaluation. Modal evaluations using these and stiffer spring rates produced results equivalent to the rigid joint evaluation.

The actual moment-rotation relationship for each unbonded construction joint is non-linear as it is a function of the dead weight restoring moment, the moment yield capacity, and the ultimate moment capacity. Based upon the construction joint model development discussed in Section 5.1, the moment-rotation curves shown in Figures 7-2 through 7-10 were created.

7.2 GRAVITY ANALYSIS RESULTS

The static gravity evaluation consisted of subjecting the model to a 1.0 g vertical acceleration. The gravity induced moments produced gapping at seven of the nine construction joints, resulting in elastic loading of the reinforcing steel. That is, the "dead weight restoring moment" (Figures 7.2 to 7.10) were exceed at the seven joints. The crane level and the roof level joints in both

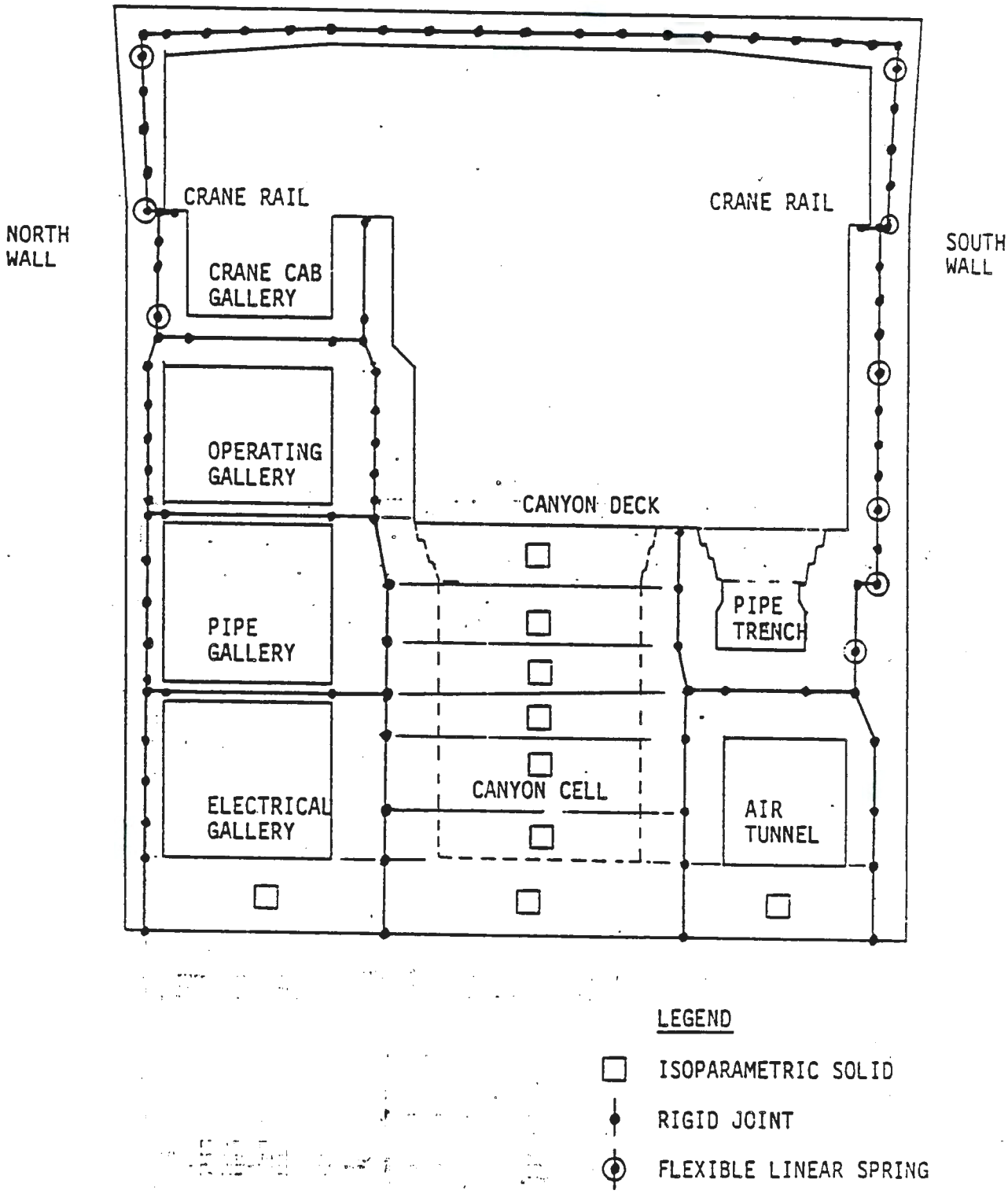

Figure 7-1. Elastic Analysis ANSYS model.

walls have moments resulting in tension in the reinforcing steel on the outside wall surface. The joints below the canyon deck level have moments resulting in tension in the reinforcing steel on the inside wall surface. The reinforcing steel does not reach yield stress at any of those joints for the dead weight loading. The construction joints in the south wall between the crane level and the canyon deck have gravity induced moments that are safely below their dead weight restoring moment capacity. Therefore, the reinforcing steel in these joints remain in compression from gravity loads alone.

7.3 RESPONSE SPECTRUM ANALYSIS

The dynamic evaluation consisted of subjecting the model to a horizontal acceleration response spectrum, combining the dynamic results with the gravity results, and comparing the calculated moments for the linear springs to the moment capacity of the construction joints. The vertical DBE component was ignored to simplify the iterative procedure discussed below.

7.3.1 Nonlinear "Secant" Evaluation Methodology

The determination of an equivalent "secant" linear spring rate for the stiffness of the construction joint springs was used to approximate the non-linear response. The analysis technique used in this approximate non-linear analysis was to iterate on a linear "secant" stiffness for each of the springs until the calculated moments and joint rotations for all springs conformed to the construction joint non-linear property curves. The term "secant" stiffness comes from the geometry definition of a straight line (the linear stiffness) intersecting a curve (the moment-rotation capacity) at two points (the origin and the calculated moment-rotation).

7.3.2 Design Basis Earthquake Results

Due to the nonsymetrical cross-section of the canyon, the structure has a different stiffness (flexibility) in the north horizontal direction than in the south horizontal direction. Subsequently, separate dynamic modal evaluations are required to obtain both the north and south horizontal responses. Only the north direction response was obtained. The model was analyzed for seismic motions causing roof displacements to the north. The model was subjected to the foundation response spectrum developed from the soil structure interaction evaluation of the 0.2g Design Basis Earthquake in Section 6. The resulting construction joint moments are shown in Figures 7-2 to 7-10.

The results of this approximate non-linear analysis indicate that the structure can safely withstand the 0.2g earthquake. The combined gravity and seismic moments are less than the yield moments in all but the crane level joint in the north wall.

7.3.3. Increased Magnitude Earthquake Results

The canyon model was then subjected to an earthquake load of 0.4g or twice the 0.2g DBE in order to estimate a collapse load or a safety margin against collapse. The results are also shown in Figures 7-2 to 7-10. As indicated in the figures, the 0.4g event is predicted to produce moments in excess of the yield moment in six of the construction joints. At three locations (the crane level joints and the north wall/roof intersection), the predicted moments are approaching the ultimate capacity of the joints, indicating the structure is near a general collapse. Therefore, based upon an approximate stepwise linear approach, the seismic capacity of the canyon structure is in the neighborhood of a 0.4g DBE event.

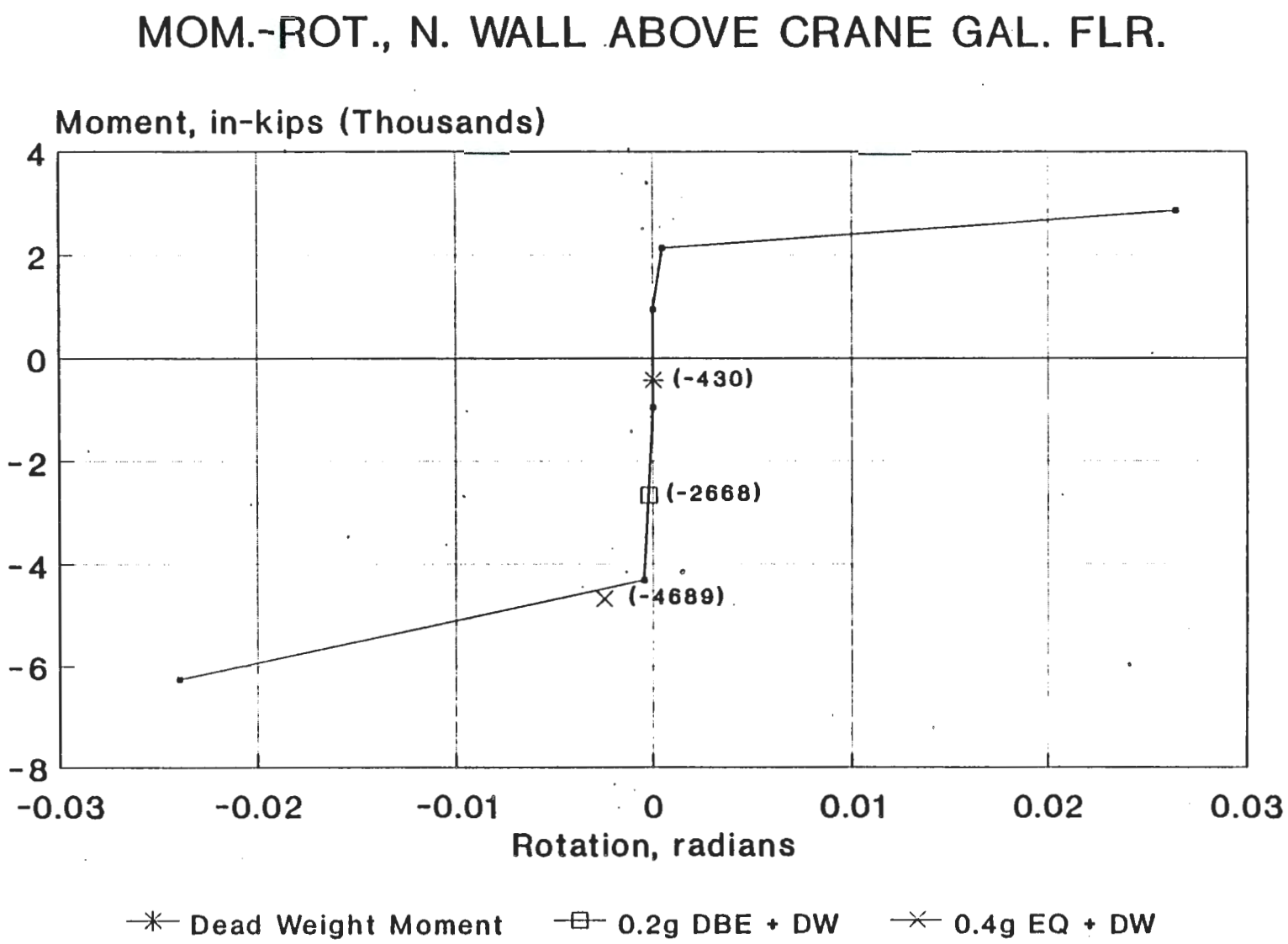

Figure 7-2. N. Wall, Crane Gal. Flr., Mom/Rot Properties

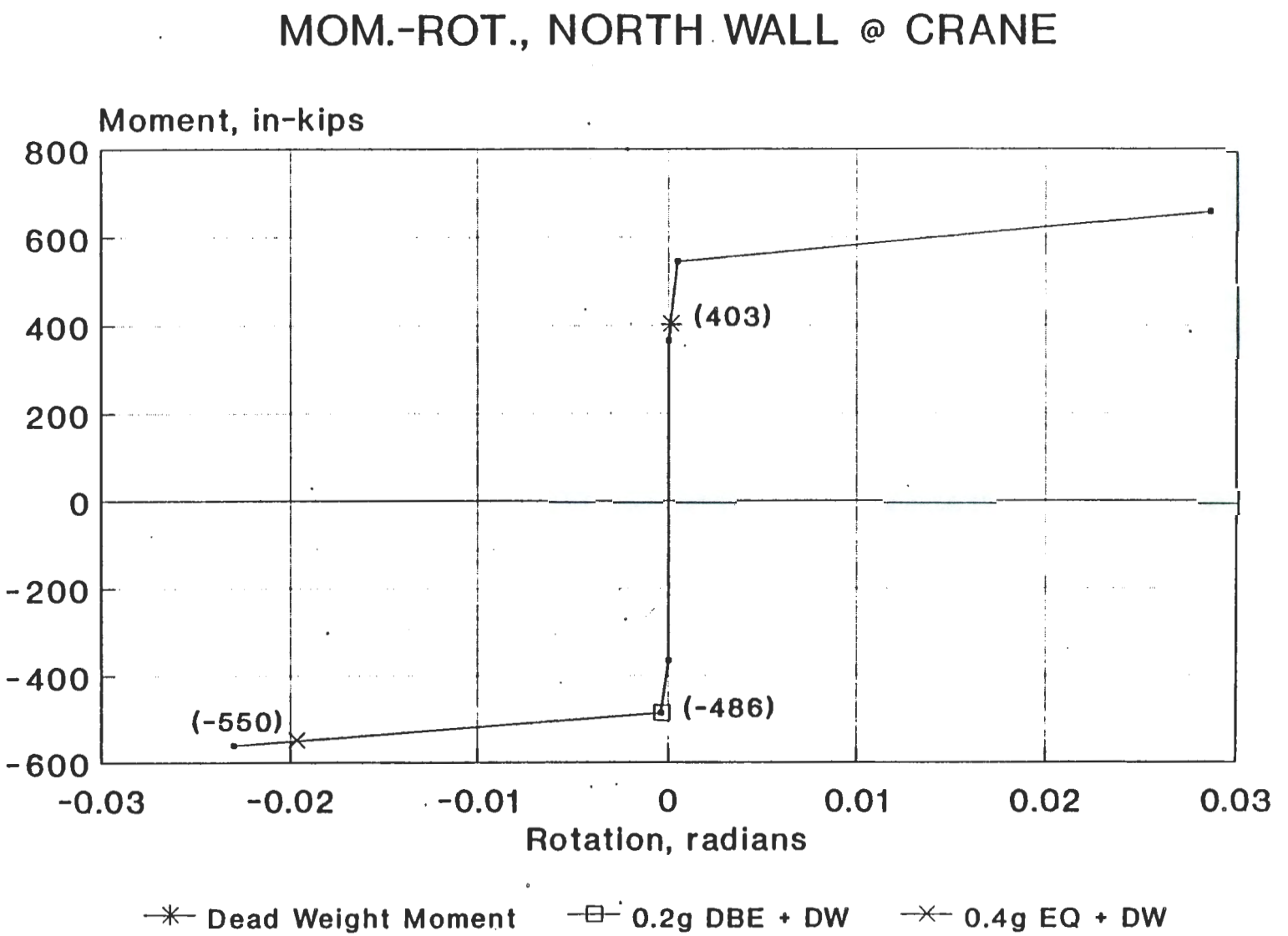

Figure 7-3. N. Wall @ Crane, Mom/Rot Properties

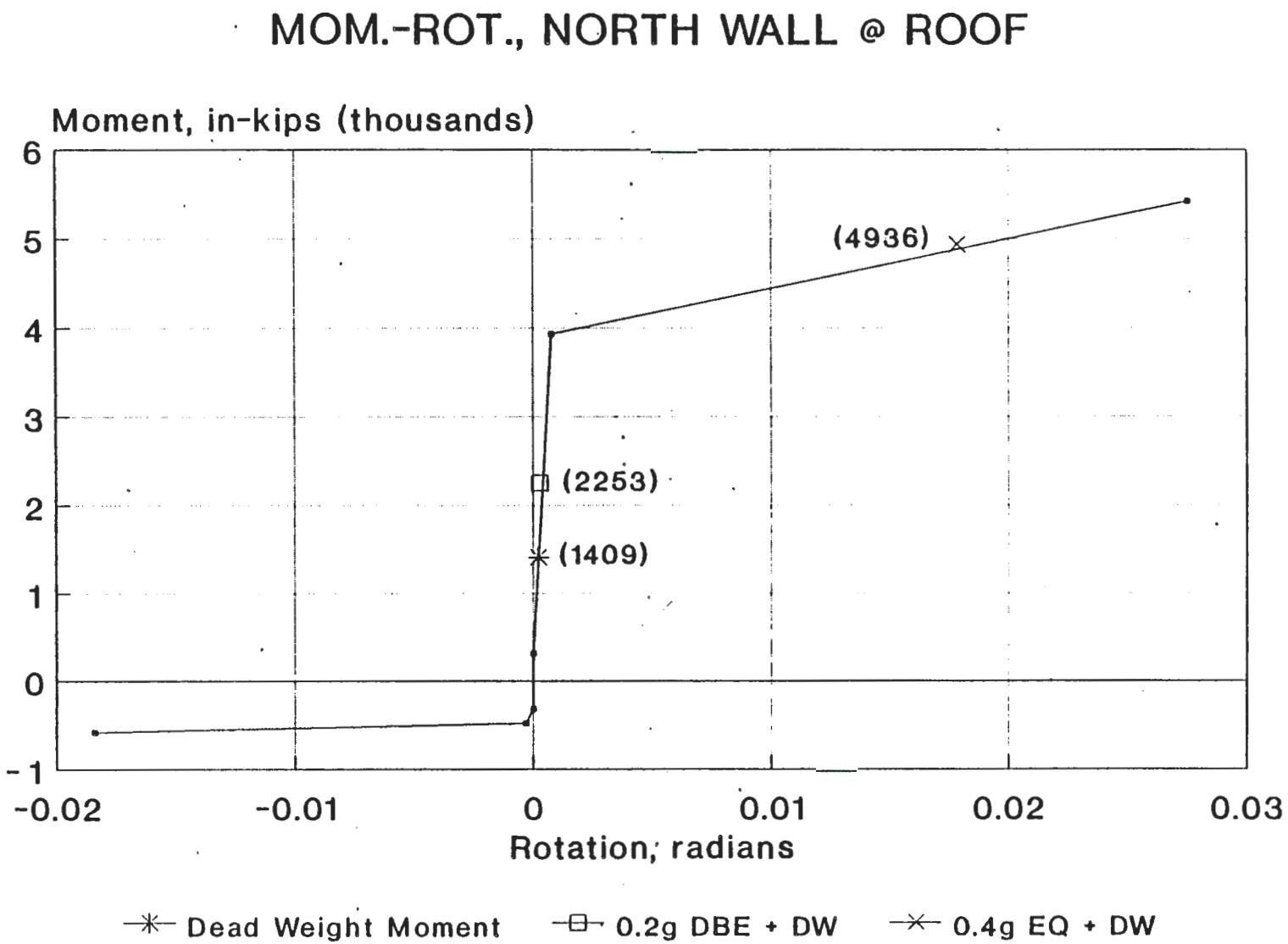

Figure 7-4. N. Wall @ Roof, Mom/Rot Properties

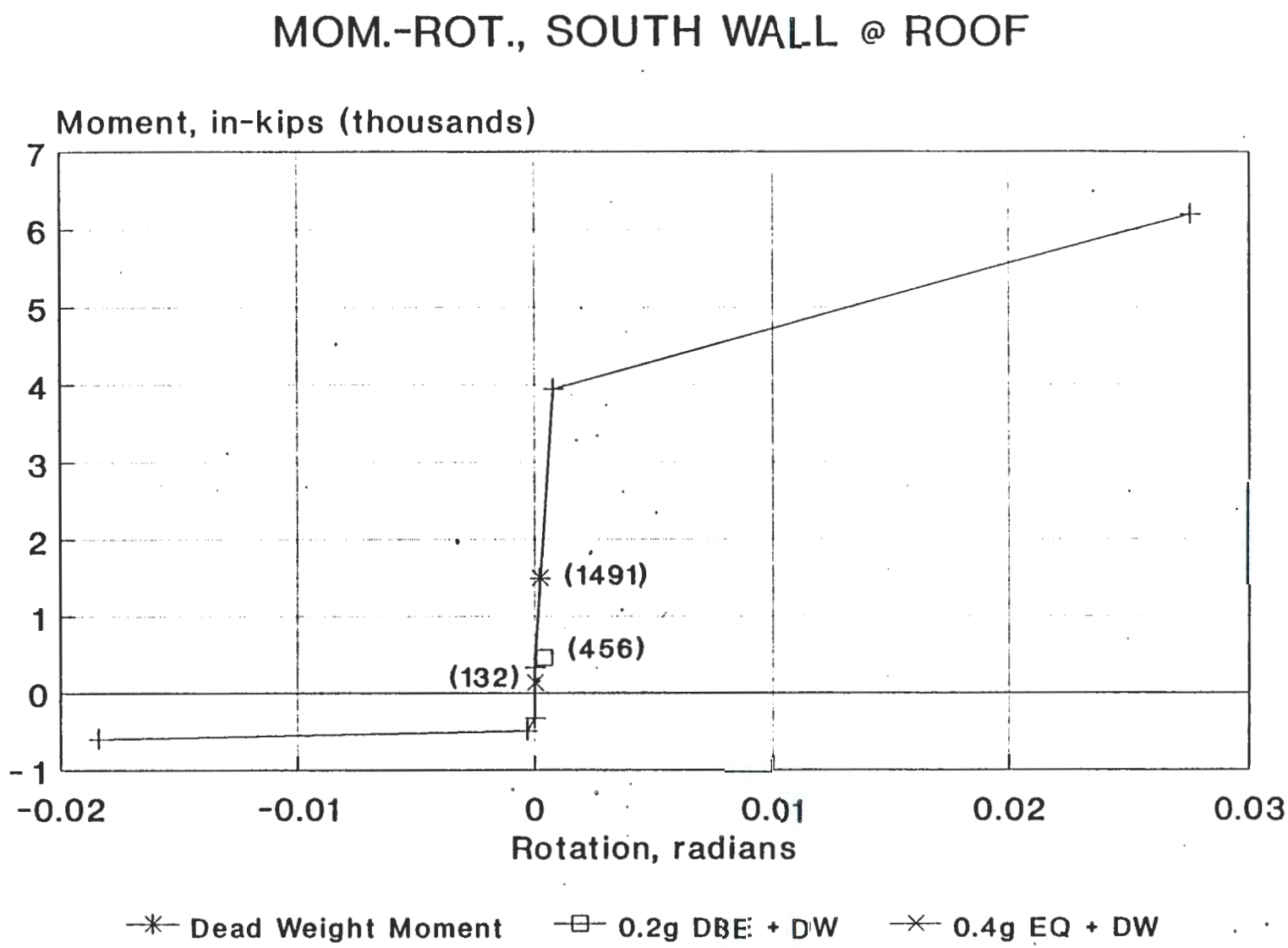

Figure 7-5. S. Wall @ Roof, Mom/Rot Properties

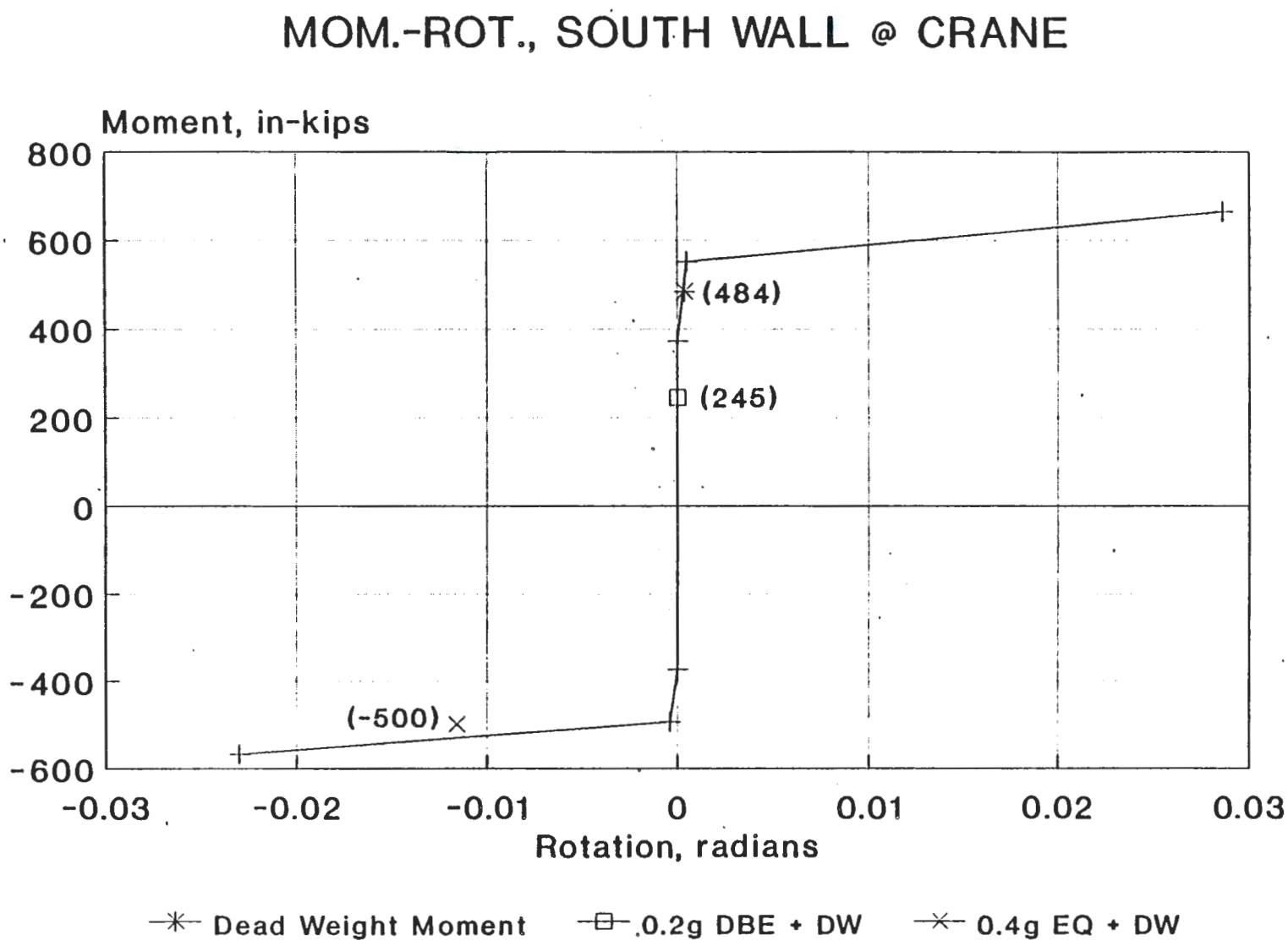

Figure 7-6. S. Wall @ Crane, Mom/Rot Properties.

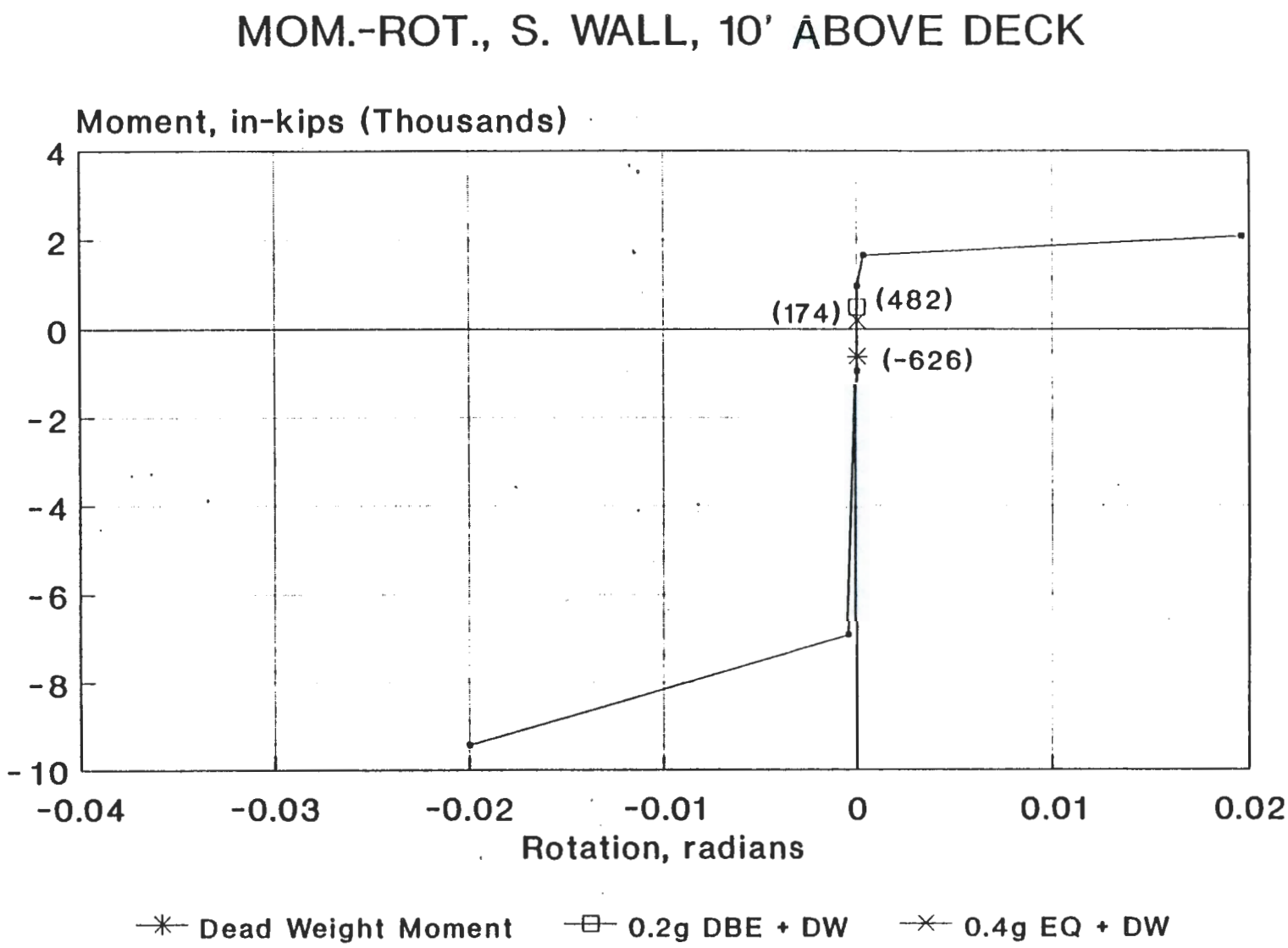

Figure 7-7. S. Wall, 10' Above Deck, Mom/Rot Properties

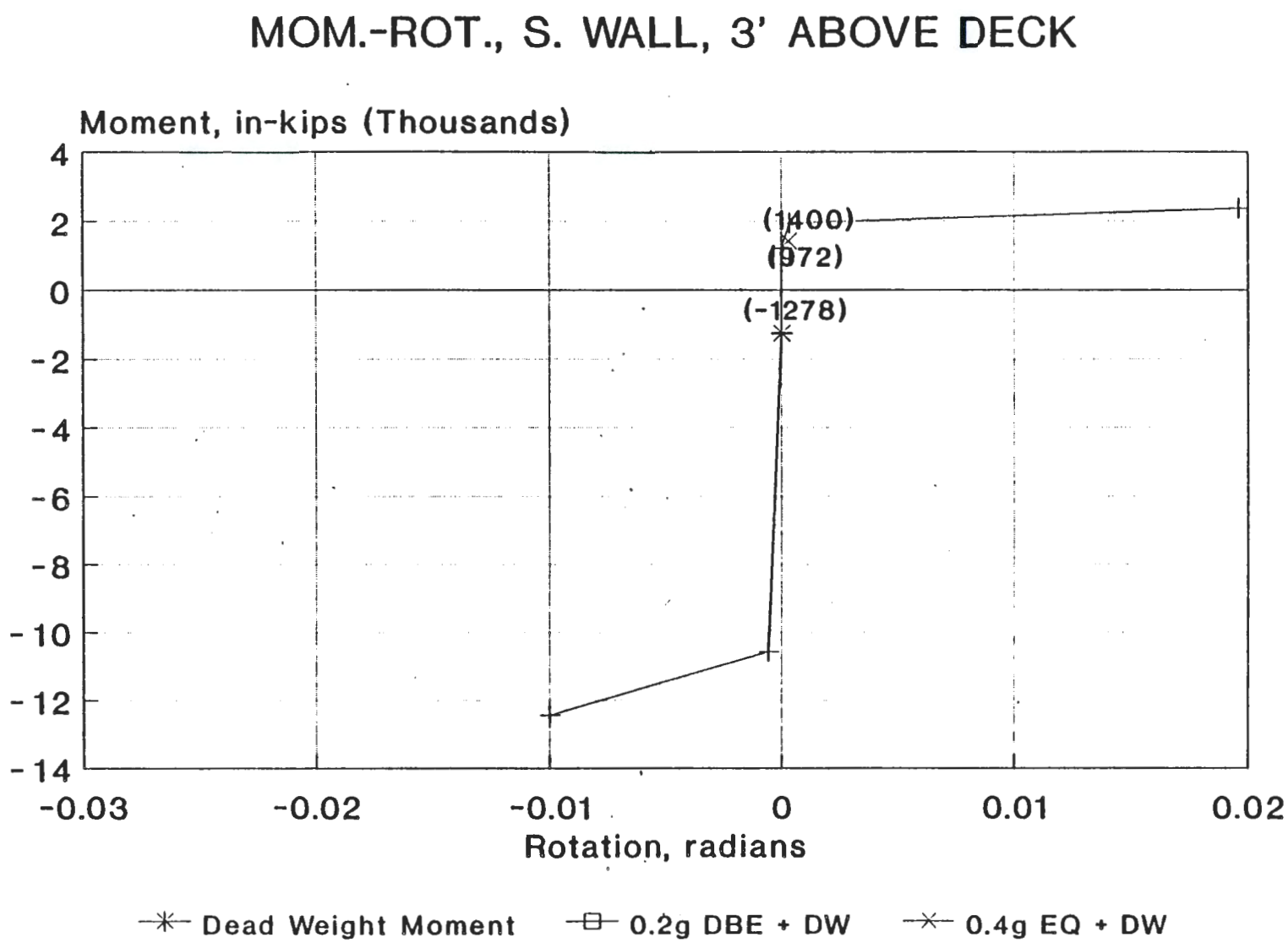

Figure 7-8. S. Wall, 3' Above Deck, Mom/Rot Properties

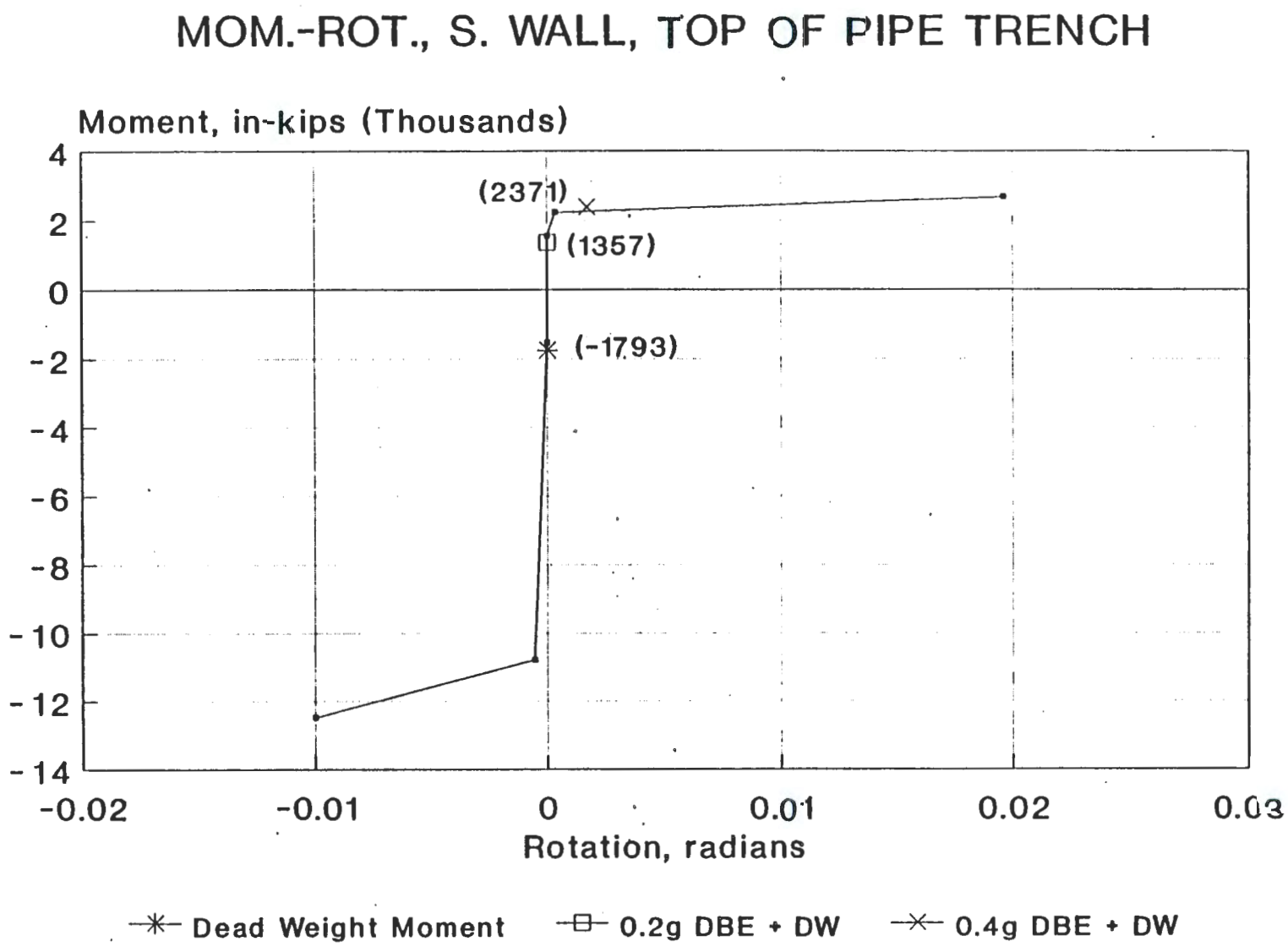

Figure 7-9. S. Wall, Top of Pipe Tr., Mom/Rot Properties.

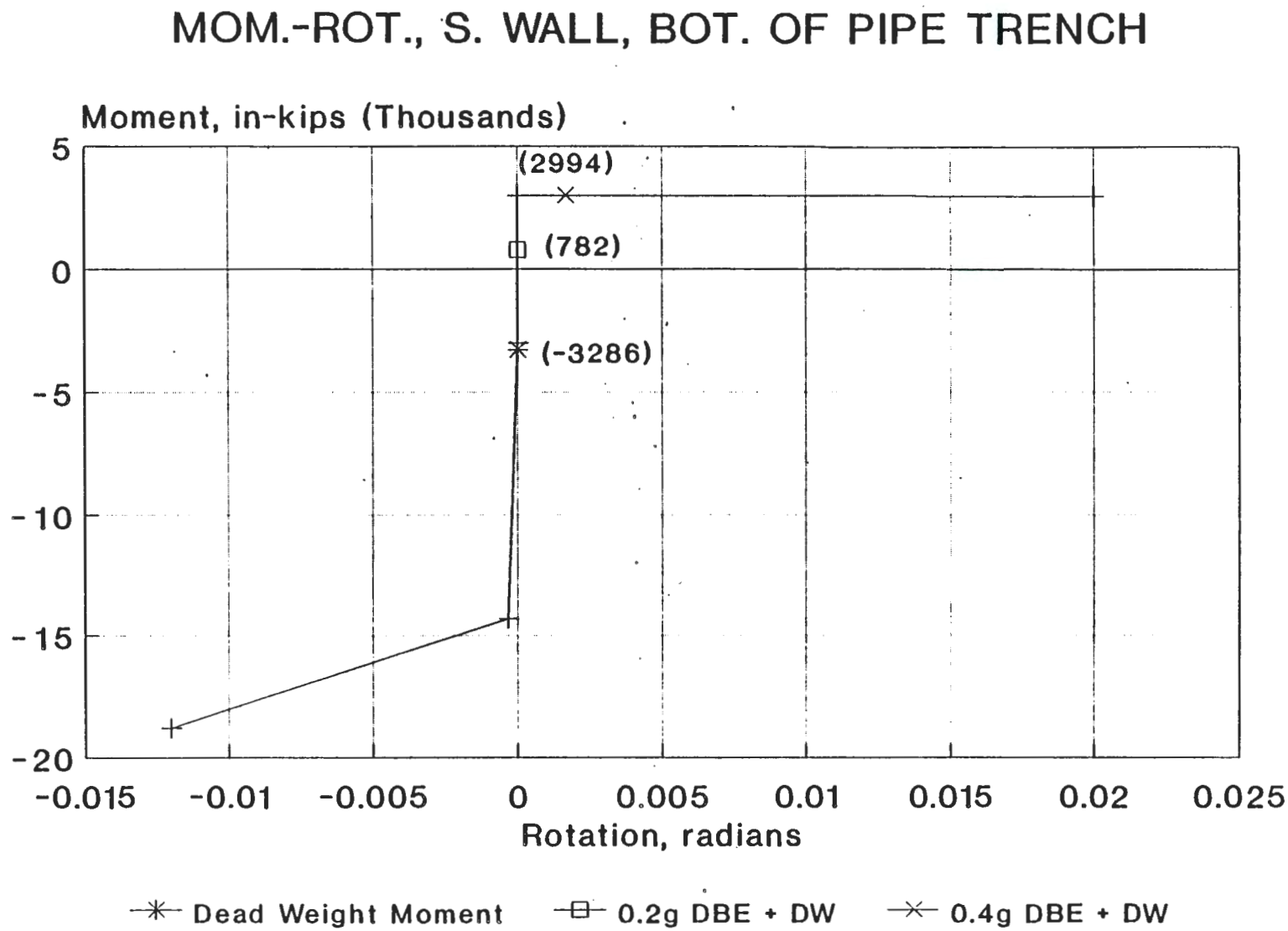

Figure 7-10. S. Wall, Bottom of Pipe Tr., Mom/Rot Properties

8.0 NONLINEAR ANALYSIS

8.1 NONLINEAR MODEL DEVELOPMENT

The significant nonlinearities in a reinforced concrete structure subjected to bending loads include (1) tensile cracking in the concrete (2) tensile yielding of the rebar (3) rebar bond slippage in cracked sections and (4) compressive crushing of the concrete. Normally, tensile cracking occurs at relatively low load levels and is often accounted for by performing linear analyses with a moment of inertia magnitude somewhere between the gross and cracked section. The B Plant canyon structure is somewhat unique in that in most sections the gross section crack initiation strength is greater than the cracked section yield strength. This design feature tends to limit the nonlinearities to local regions of high stress.

As indicated in Section 4.0, the canyon structure has a number of "precracked sections" in the form of construction joints. A comparison of the elastic overstress and construction joint locations is provided in Figure 8-1. Note that all of the high stress regions correspond to construction joint locations. This observation led to the decision to develop an initial model with the nonlinearities limited to the construction joints. This approach is analogous to performing a limit analysis in plastic design by modeling predetermined potential plastic hinge locations. The adequacy of the initial hinge location estimates is then verified by a post analysis evaluation of the sections between hinges (i.e. between construction joint locations).

One of the computer modeling options originally considered was to create a monolithic model using concrete solid and rebar elements. The primary reason this option was not pursued was because the capability of treating the bond slip and associated rebar yielding at the construction joints, did not appear to be adequate in the concrete models of existing computer codes.

8.1.1 Construction Joint Computer Model

Precise modeling of the local response in a construction joint is difficult. The phenomena to be modeled includes concrete gapping, rebar straining and bond slippage, and a complex compressive deformation pattern and potential spalling in the concrete. For dynamic modeling purposes, there are three major concerns: (1) conservative strength modeling (2) reasonable stiffness modeling and (3) reasonable plastic strain estimates in the rebar. Various computer models were considered, but the relatively simple joint model shown in Figure 8-2 was found to be adequate.

The essential features of the computer model include: (1) gap elements to restrict the tensile loading to the rebar (2) elastic/plastic truss elements to carry the tensile rebar loading and limit the tensile loading to the rebar yield strength and (3) gap/rebar element spacing equal to the center-to-center spacing of the tension/compression rebar. This spacing assumes that the compression zone is centered at the compression steel. This produces a moment

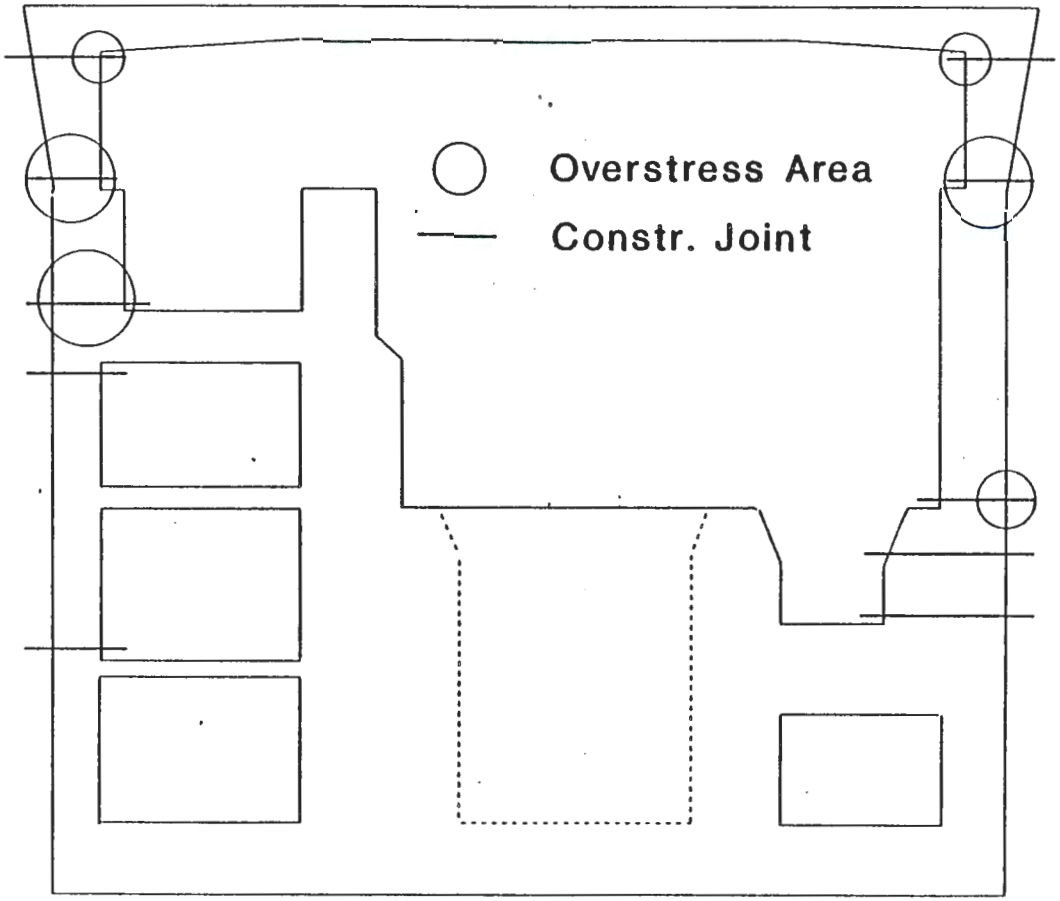

Figure 8-1. Elastic Overstress and Constr. Joint Locations

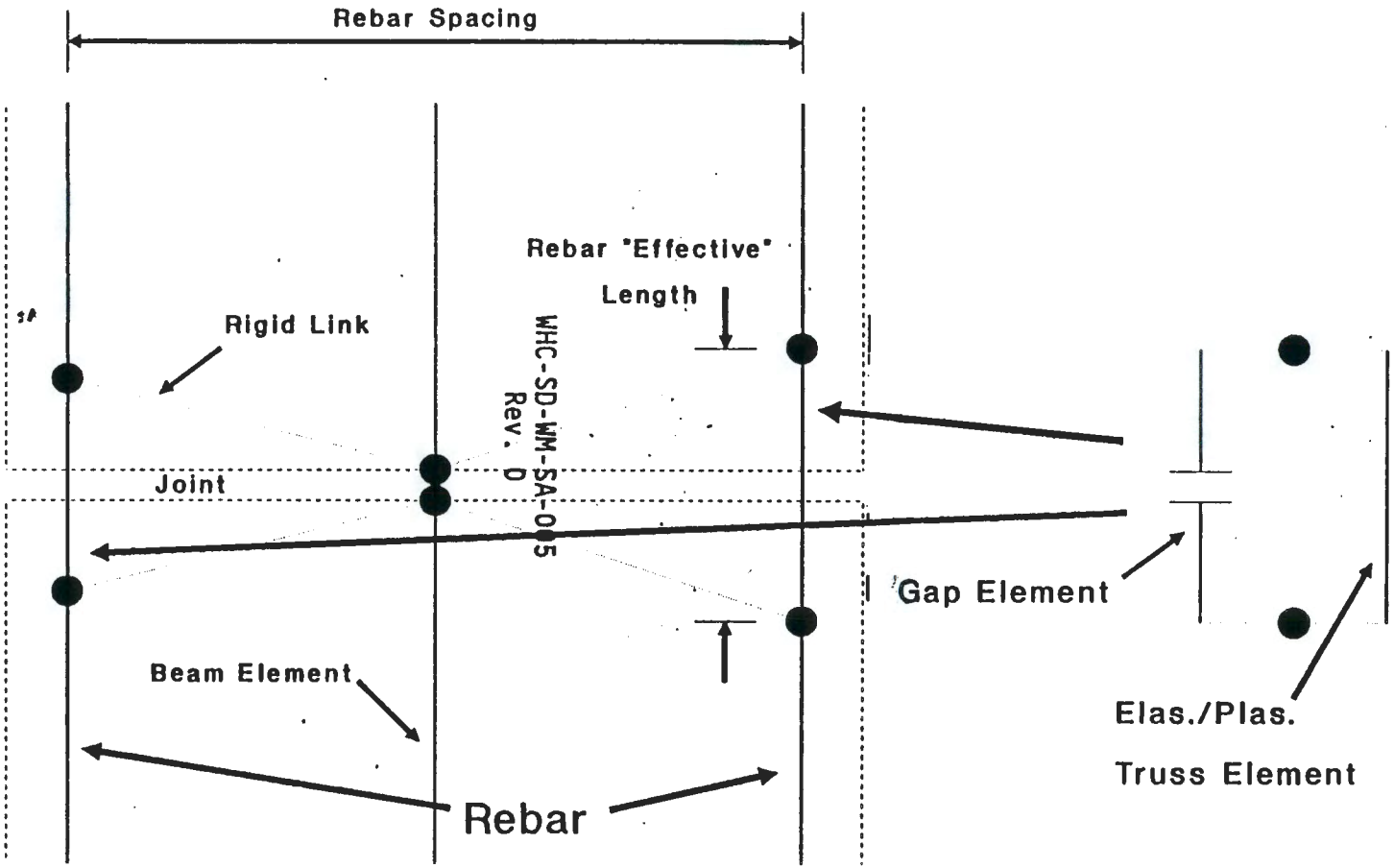

Figure 8-2. Construction Joint Computer Model Description.

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Rev. 0

CONSTRUCTION JOINT NONLINEAR PROPERTIES

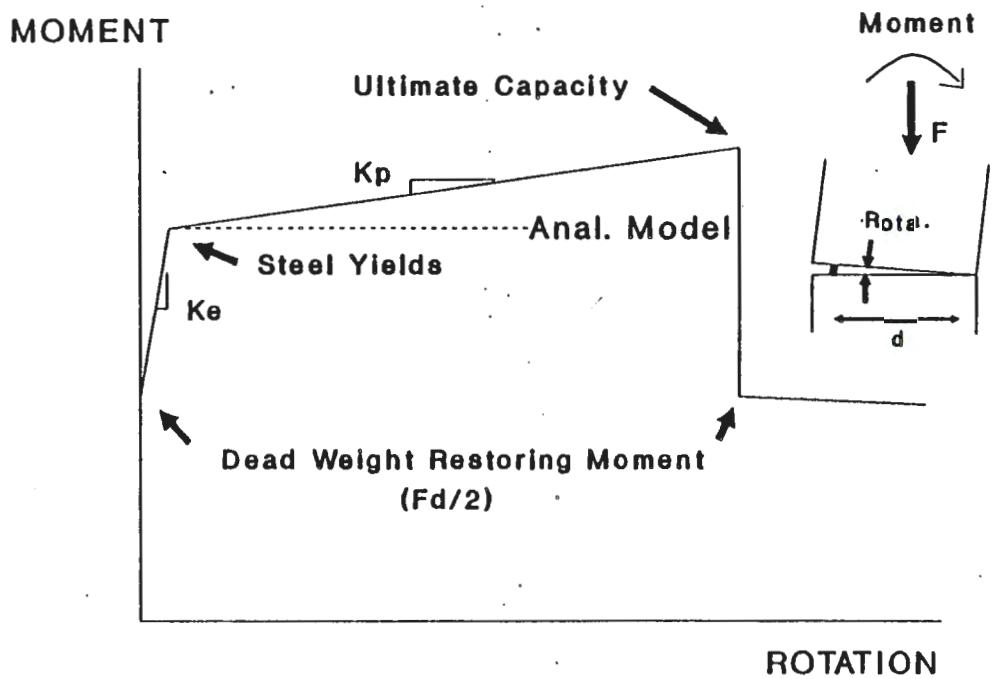


Figure 8-3. Construction Joint Moment-Rotation Properties

resisting couple distance which is constant. The conservatism of this assumption is discussed in the next paragraph. The gap element modeling also provides automatic handling of the "dead weight restoring moment" which provides a significant contribution to the moment capacity of the joint, as shown in Figure 8-3. This restoring moment changes during the seismic event as the axial load changes.

Another feature of the construction joint computer model is horizontal coupling to prevent relative horizontal movement at the construction joint. Initially, potential relative movement was permitted through the use of friction gap capability. However, numerical instabilities occurred which were found to be associated with these elements. It was then decided to provide horizontal coupling with a post analysis joint shear evaluation to assure that the shear/friction capacity of the joint was not exceeded.

The most important of the modeling concerns is assuring that the joint bending strength is conservative. Reasonably accurate estimates of the construction joint bending capacities were obtained using the BIAX2 computer code (Wallace 1989). The BIAX2 capacity analysis and results are summarized in Appendix D1. The conservatism of the computer model bending strength predictions are demonstrated in Figures 8-4 and 8-5. These figures compare the computer model and BIAX2 predictions for two rebar percentage extremes. Note that a perfectly plastic rebar response is used for the computer model based upon the minimum yield strength of 40 ksi (Grade 40 steel).

The "effective length" of the rebar is an attempt to simulate the joint stiffness. The rebar effective length is a function of the amount of rebar bond slip which varies with load magnitude. An attempt to model the local response at a cracked joint is addressed by Lai (Lai et al. 1984). A figure from the Lai reference is shown in Figure 8-6 which gives the approximate stress and strain distribution in the rebar adjacent to a joint.

From University of Illinois tests cited by Lai (Lai et al. 1984), the ultimate bond strength is equal to $14(fc')^{0.5}$. By assuming a constant bond stress (Figure 8-6) equal to the ultimate bond strength, a bond stress development length can be expressed as

$$l_d = A_s f_s / c_s u \qquad (8\text{-}1)$$

where,

A_s = rebar area
f_s = max. steel bar stress (between concrete sects.)
c_s = steel bar circumference
u = concrete/rebar bond strength = $14(fc')^{0.5}$.

The development length, l_d, increases as the stress, f_s, is increased. This results in a nonlinear rebar response as shown by the "Theoretical" curve shown in Figure 8-7. An approximate linear response can be obtained by assuming an effective length equal to one half of the yield stress development length, which gives the linear approximation in Figure 8-7 designated as "Model

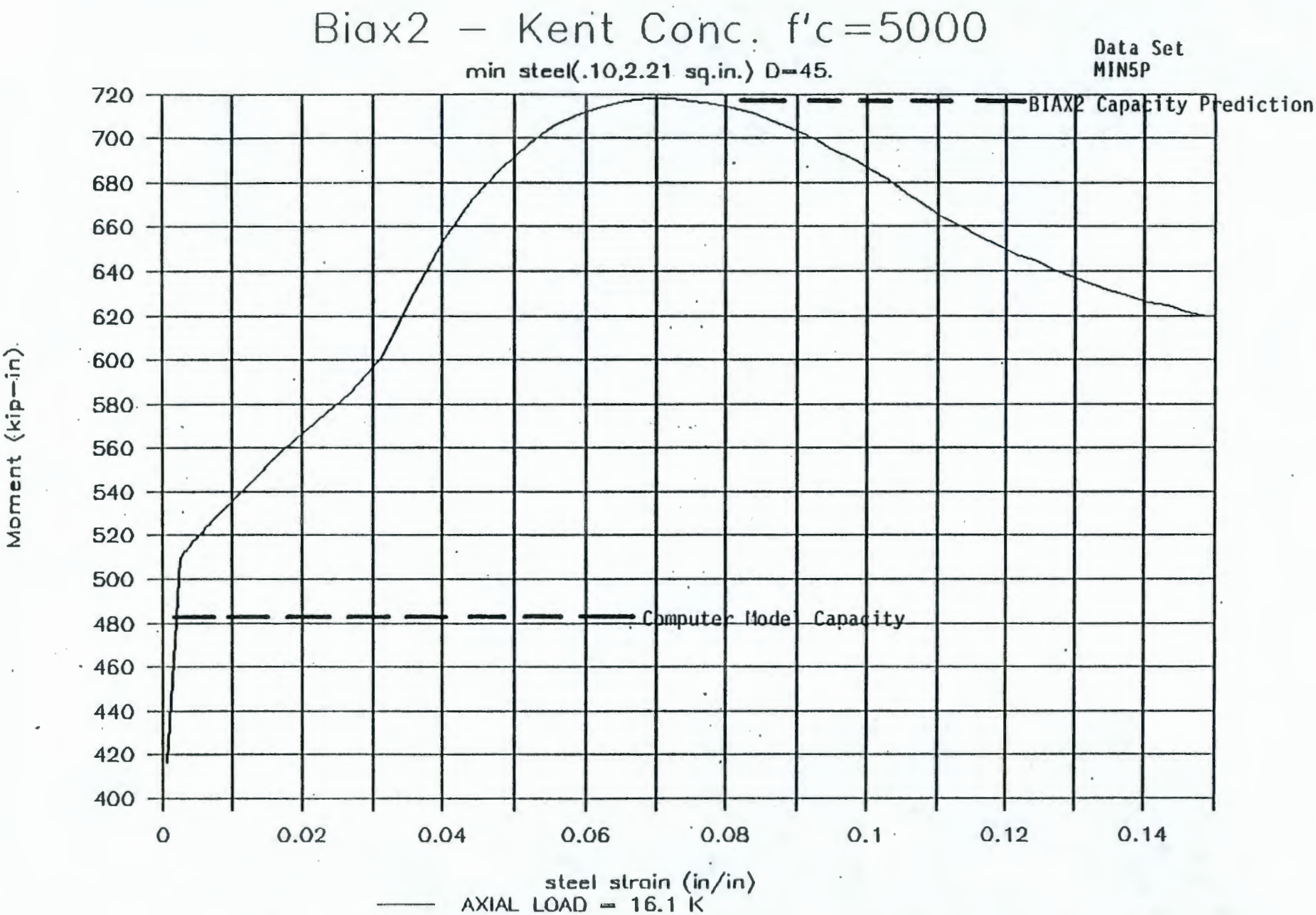


Figure 8-4. Comparison of BIAX2 and Computer Model Construction Joint Capacity (Min. Steel).

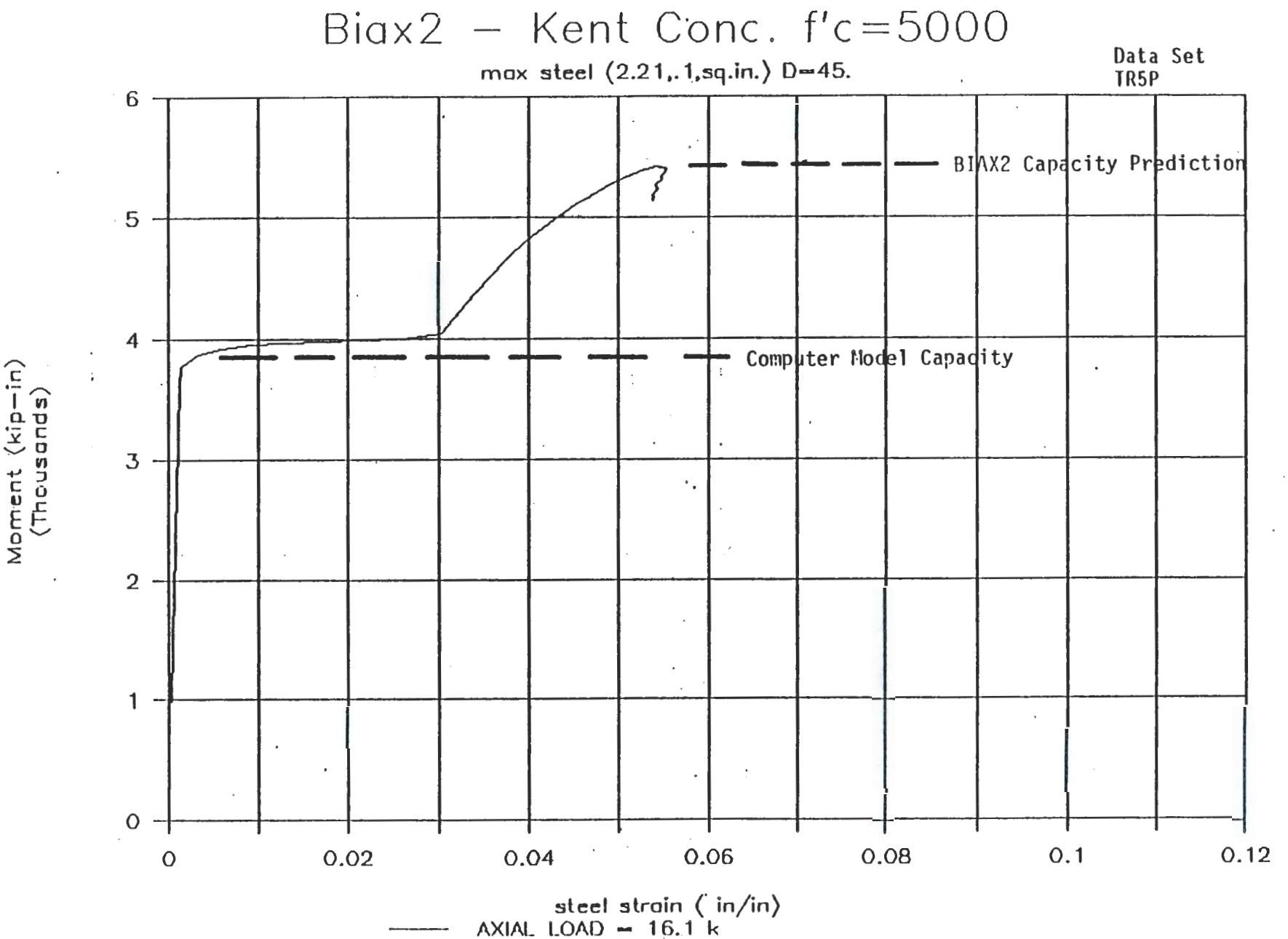


Figure 8-5. Comparison of BIAX2 and Computer Model Construction Joint Capacity (Max. Steel).

Assumption". Half of the development length is used to account for the linear strain distribution over the full development length (Figure 8-6). In the computer model, the effective length is equal to the full development length to account for rebar both above and below the joint. By assuming a perfectly plastic material, the "Model Assumption" response in Figure 8-7 is obtained.

A tabular listing of the rebar effective lengths used in the computer models is shown in Table 8-1. Note that the computer model truss elements, simulating the rebar response, vary in length from 5.25 to 12.89 inches. These effective lengths, based upon rebar slip at yield stress levels, were selected to simulate the "average" joint stiffness. Prior to rebar yielding, the response is on the soft side, whereas the post yielding response may be on the stiff side.

The adequacy of the model was also evaluated with respect to the phenomena of "cyclic softening". Cyclic tests of reinforced concrete cantelever beams were conducted at the University of Illinois (Takeda et al. 1970). A computer model of the cantelever beams was developed using the Figure 8-2 approach for the local response. The beam deflection contribution was simulated using the cracked section moment of inertia. A comparison of the measured and computer model predicted cyclic response is shown in Figure 8-8. Note that the computer model is in general more flexible (lower force for a given applied displacement) than the experimental response. The one exception to this is the elastic response following a series of plastic cycles where the model is overly stiff. It was concluded from this test comparison, that the "effective rebar length" model was conservative with respect to bending strength and provided a reasonable estimate of the local cyclic stiffness.

Using a rebar effective length for simulating stiffness results in an unconservative estimate of the peak rebar strain. The truss element simulation of rebar response produces a uniform strain distribution over the effective length. Typical strain distributions measured in the laboratory are shown in Figure 8-9 (Popov 1984). Using the effective length approach to Case 7G in Figure 8-9, a uniform strain prediction of 2.1% was obtained (0.276" deflection, 12.93" effective length). The measured peak strain for Case 7G was 3.7% which is 1.76 times higher than the model prediction. To account for this strain peaking, a "strain concentration factor" of 2.0 was applied to the computer strain predictions.

8.1.2 Nonlinear Structural Model

The nonlinear structural model was developed from the ANSYS elastic model discussed in Section 6.1. The elastic model was modified by introducing the nonlinear construction joint models (Figure 8-2) at each construction joint. A second modification involved combining the relatively stiff lower section of the structure into a single substructure element (ANSYS STIF50) as indicated in Figure 8-10. Model details, including node and element plots, are provided in Appendix D3. Between construction joints, gross-section moments of inertia were specified for the initial nonlinear runs. Later runs were made with reduced moment of inertia values in the roof as discussed in Section 8.3.

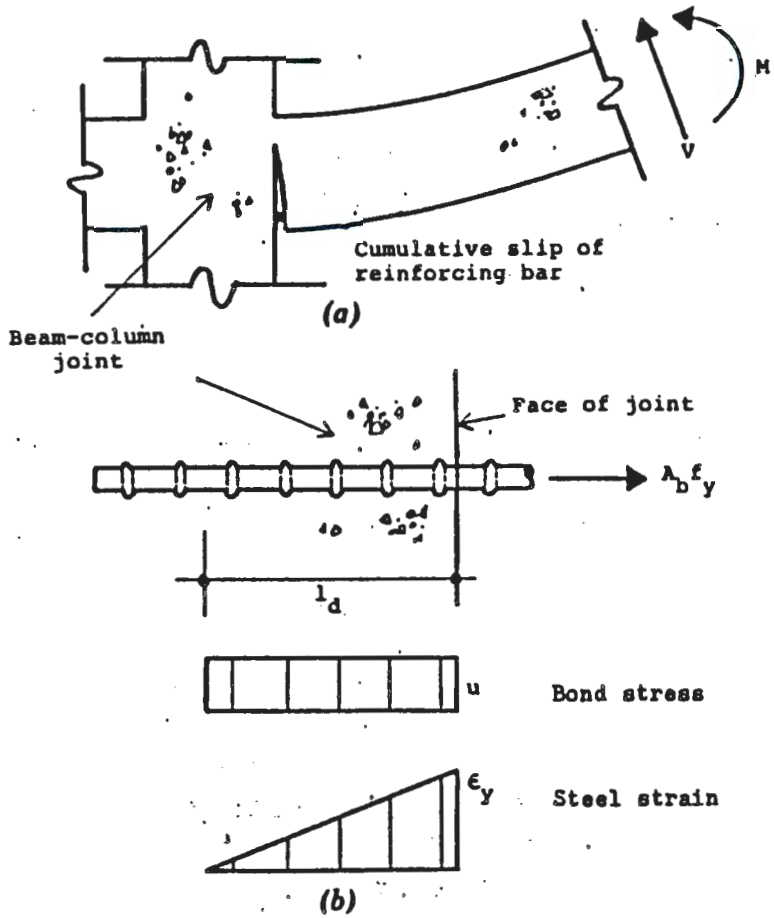


Figure 8-6. Rebar Bond Stress, Strain at Joint (Lai 1984).

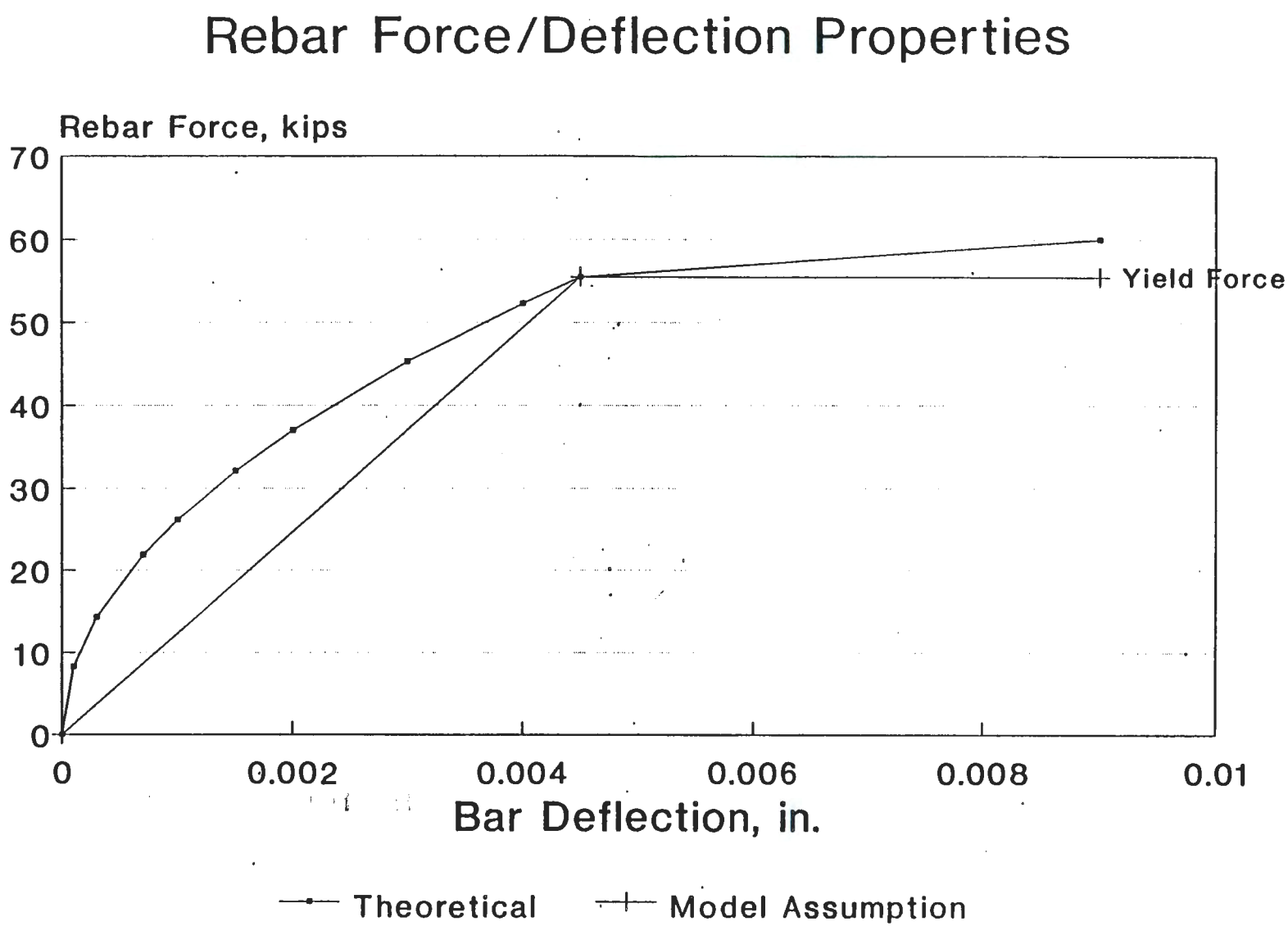


Figure 8-7. Theoretical & Model Rebar Response Comparison

Table 8-1. Construction Joint Computer Models Rebar Effective Lengths

Location	Dist. Between Rebar, in.	A_s per Foot, in^2	Circumference c_s, in.	Effective Length, in.
North Wall @ Roof				
- Outside	40.0	2.206	7.059	12.89
- Inside	40.0	0.10	0.785	5.25
South Wall @ Roof				
- Outside	40.0	2.206	7.059	12.89
- Inside	40.0	0.10	0.785	5.25
North Wall @ Crane				
- Outside	31.0	0.219	1.386	6.52
- Inside	31.0	0.10	0.785	5.25
South Wall @ Crane				
- Outside	31.0	0.219	1.386	6.52
- Inside	31.0	0.10	0.785	5.25
N. Wall, Above Crane Gallery Floor				
- Outside	55.0	0.527	2.094	10.38
- Inside	55.0	1.500	6.000	10.31
S. W., 10′ Above Deck				
- Outside	55.0	0.311	1.663	7.71
- Inside	55.0	2.667	10.67	10.31
S. W., 3′ Above Deck				
- Outside	55.0	0.311	1.663	7.71
- Inside	55.0	4.167	13.33	12.89
S. Wall, Top of Pipe Tr.				
- Outside	55.0	0.311	1.663	7.71
- Inside	55.0	4.167	13.33	12.89
S. Wall, Bot. of Pipe Tr.				
- Outside	97.0	0.000	0.000	No Rebar
- Inside	97.0	2.885	9.231	12.89

Adequacy of Joint Model for Cyclic Loading

Comparison with U. of Illinois Cyclic Beam Tests

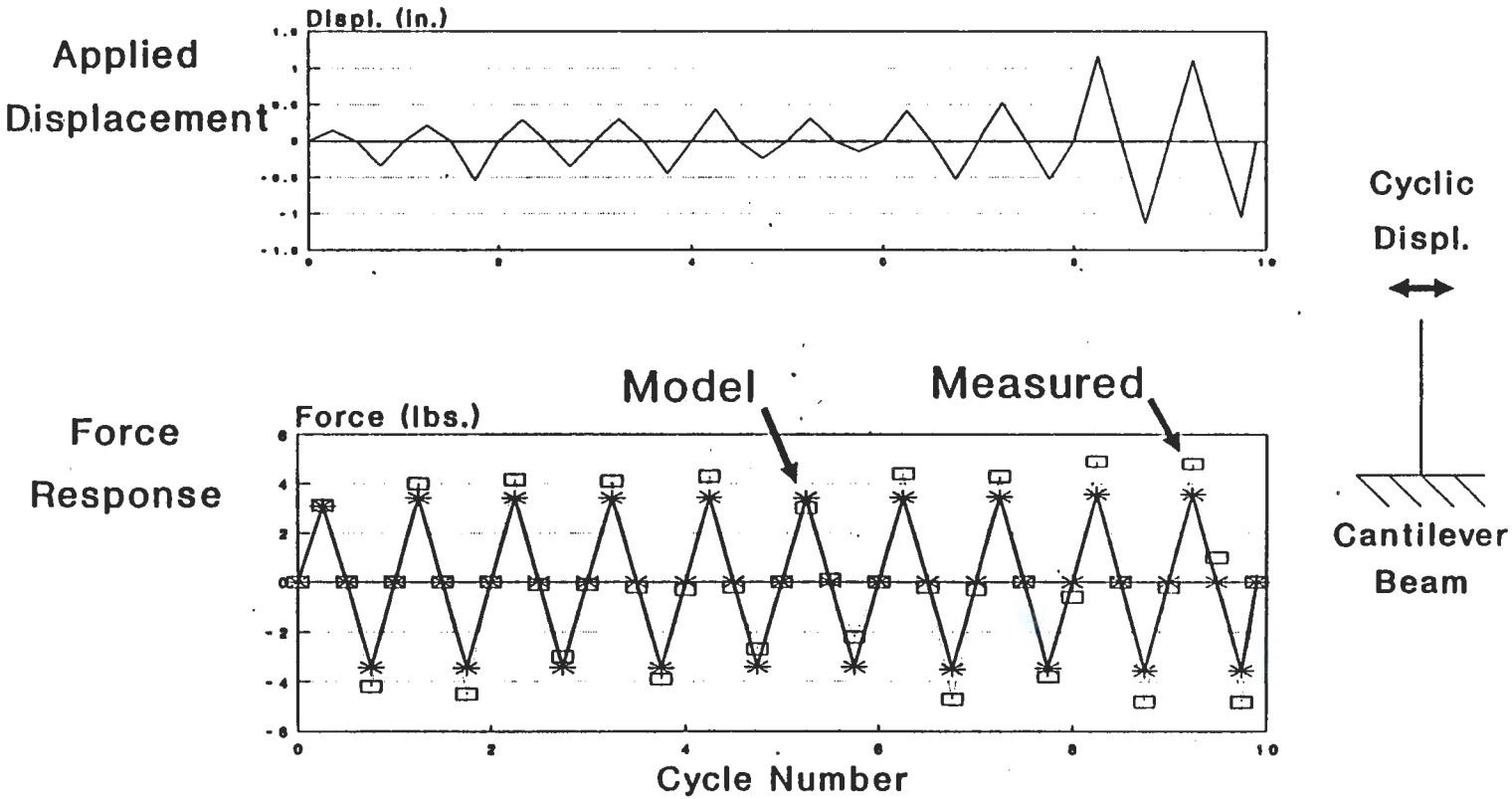


Figure 8-8. Computer Model Cyclic Load Predictions.

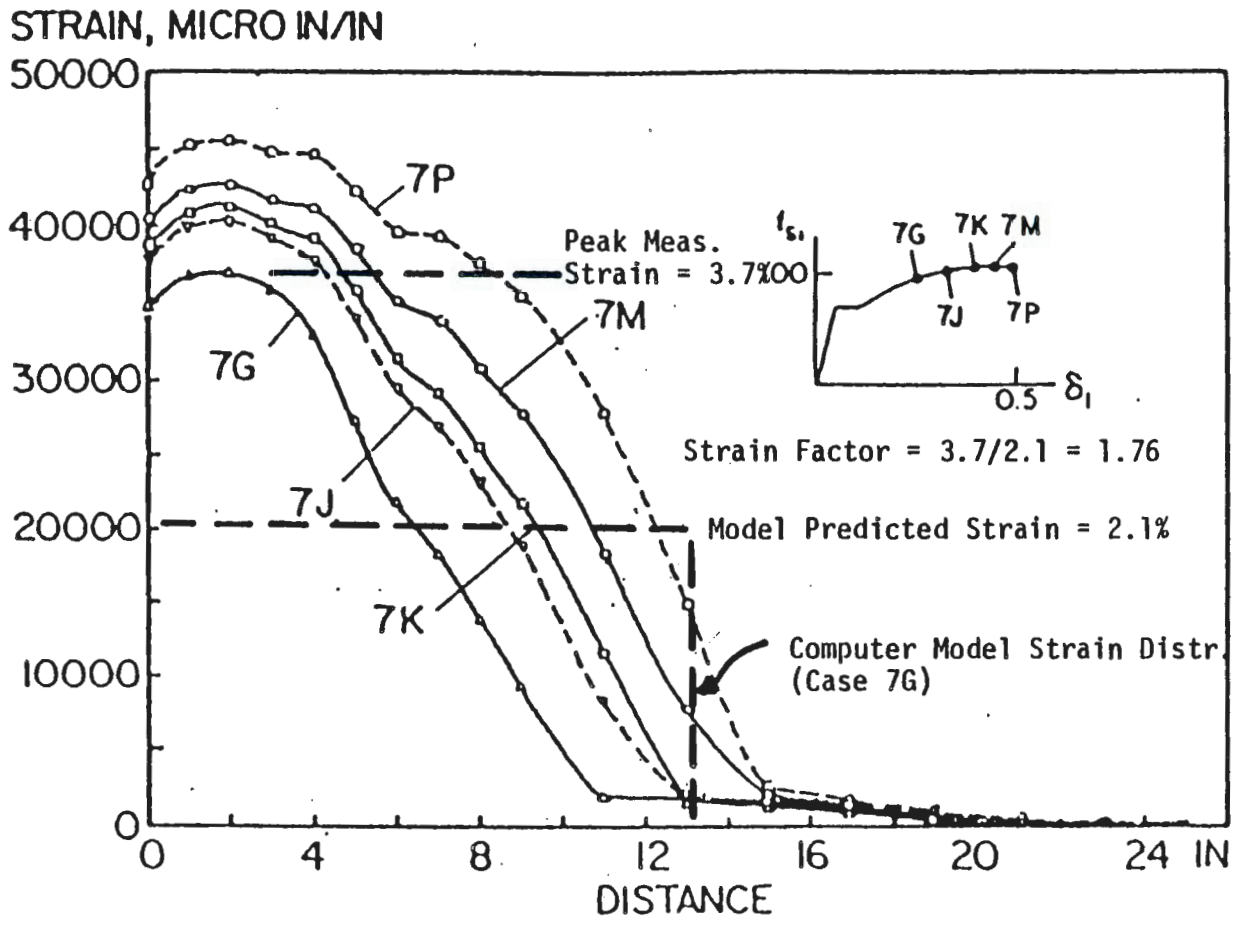


Figure 8-9. Computer Model vs. Measured Rebar Strain.

Nonlinear Computer Model

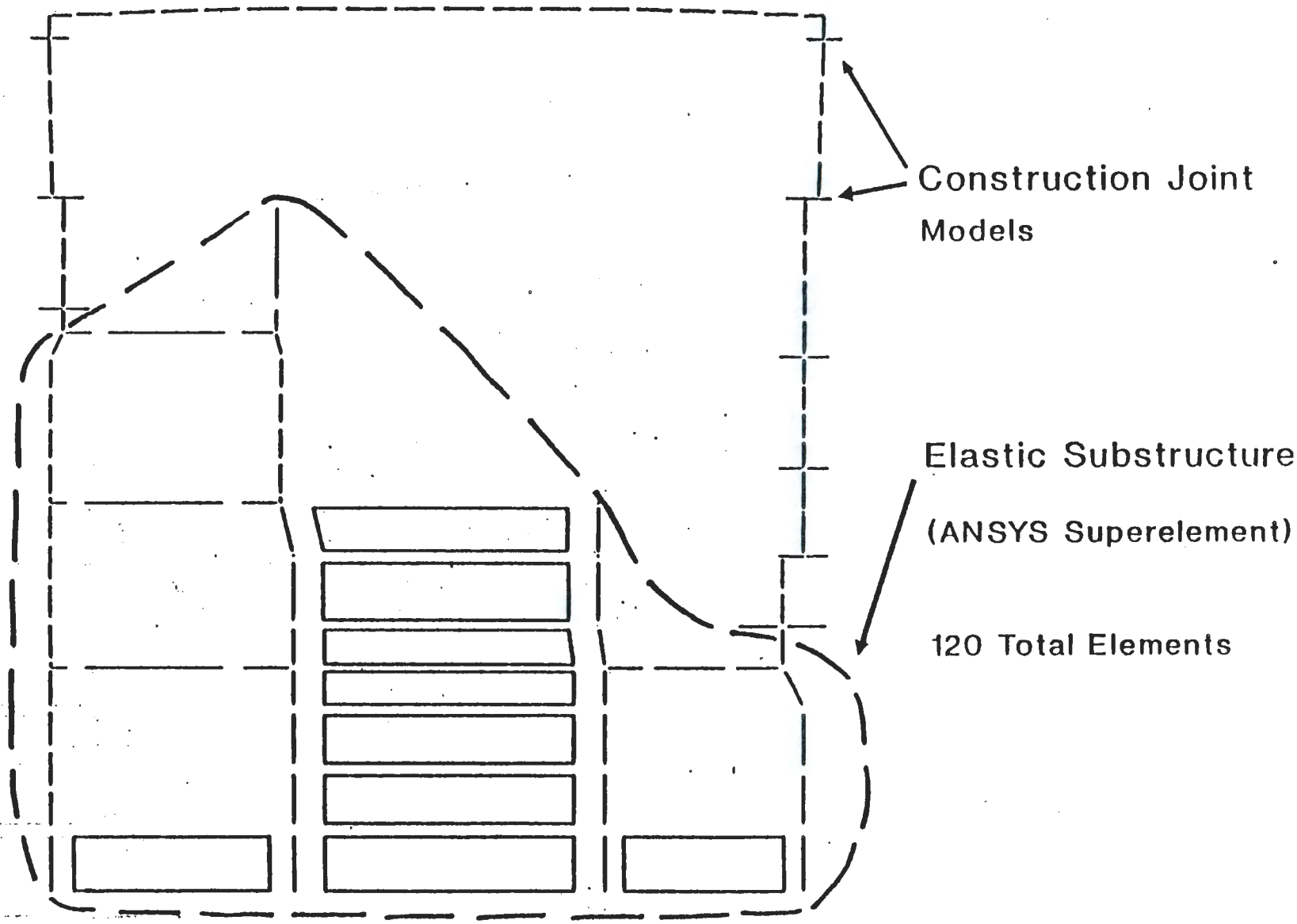


Figure 8-10. Nonlinear Computer Model Description.

8.2 STATIC CAPACITY ANALYSIS

As an initial estimate of the seismic capacity of the canyon structure, static capacity runs were made by incrementing on the horizontal acceleration. Since a vertical uplift reduces the bending capacity of the wall joints, an attempt was made to account for this potential reduction in the static capacity. The axial force varies with construction joint location and time. UCRL-15910 (Kennedy 1989) specifies that 40% of the peak vertical should be combined with 100% of the peak horizontal. To approximate the vertical uplift effect, a uniform vertical uplift of 0.15g was assumed, which at the time was the best estimate of 40% of the peak vertical. Combining this estimated seismic uplift with dead weight, resulted in a net downward g level of 0.85g.

A summary of the static capacity results are summarized in Figures 8-11 and 8-12. Figure 8-11 provides the horizontal roof deflection vs horizontal g level. Since the canyon structure is unsymmetrical, horizontal accelerations were applied in both transverse directions (left = north, right = south). For a uniformly applied horizontal acceleration, collapse was predicted to occur at about 0.5g. Based upon a review of the elastic analysis predictions, it became obvious that the horizontal accelerations are not uniform. The peak roof accelerations were estimated to be about three times the peak foundation accelerations. Assuming a linear distribution, with the roof acceleration 3 times the ground acceleration, the 0.7g (roof acceleration) capacity estimate was obtained.

An estimate of the collapse margin can be obtained by comparing the 0.7g acceleration with the foundation horizontal spectrum given in Figure 6-4. The peak spectral value is 0.68 g's which is close to the static capacity, indicating a need to perform a rigorous dynamic analysis.

Another item of interest from the static capacity evaluation is the horizontal roof deflection predictions. From Figure 8-11, the canyon structure capacity is essentially achieved at a horizontal roof deflection value of about 0.75 inches. In the south direction, static capacity is reached at a horizontal deflection level of about 1.25 inches. Although structural collapse would require much larger deflections, these values are indicative of an impending instability and are discussed further in Section 8.3.3.

8.3 NONLINEAR TIME HISTORY ANALYSIS

8.3.1 Time History Loading

In Section 6.0, a soil-structural interaction time history analysis is described. From this analysis, acceleration time histories were generated at various locations in the FLUSH model. The acceleration time histories generated at the canyon structure foundation level are shown in Figures 8-13 and 8-14. Note that the largest horizontal accelerations occur in the one to two second time range, whereas the peak vertical acceleration occurs at about 8 seconds. Although the horizontal loading was expected to dominate the structural response,

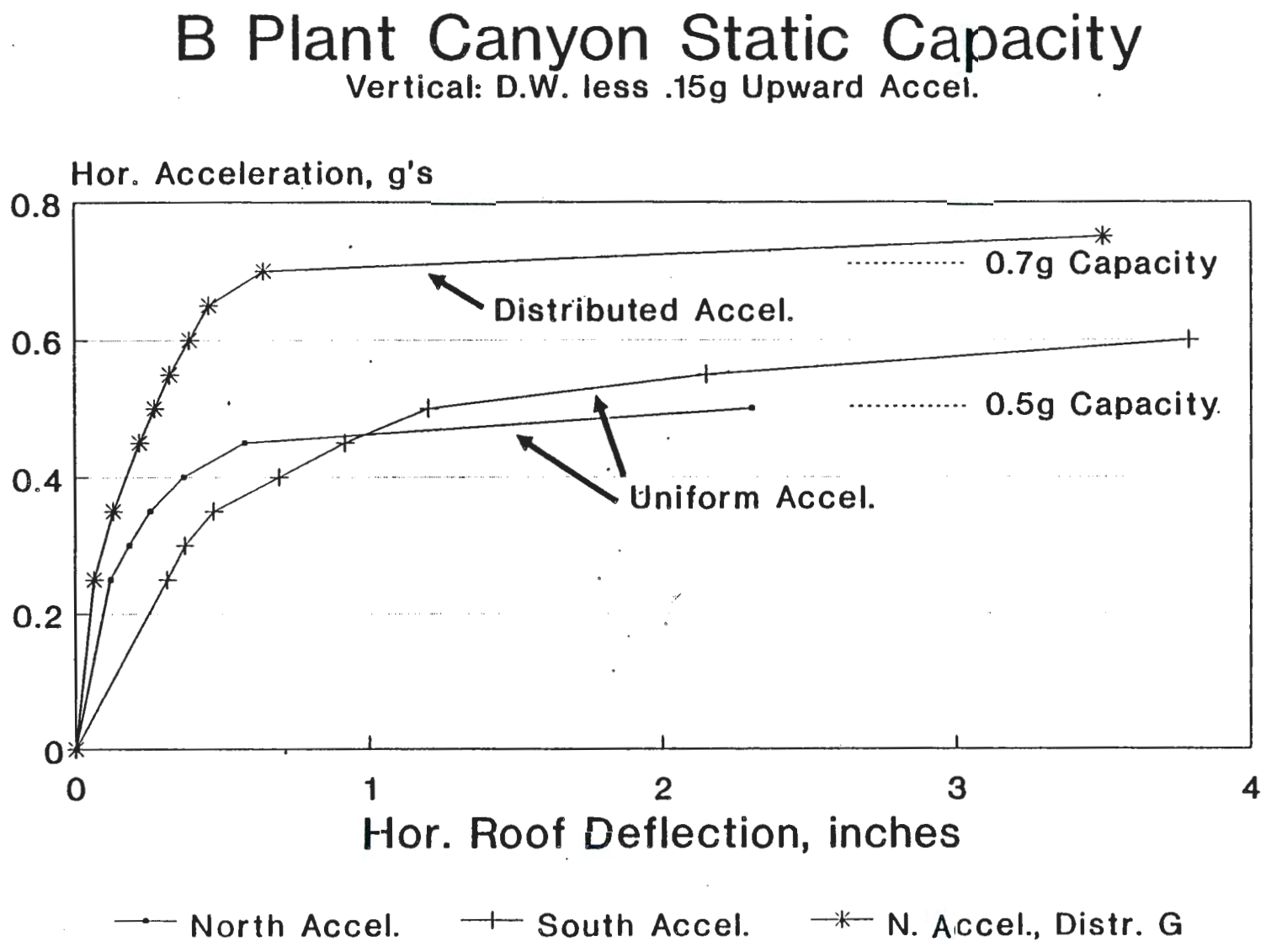


Figure 8-11. Force-Deflection Predictions from Static Anal.

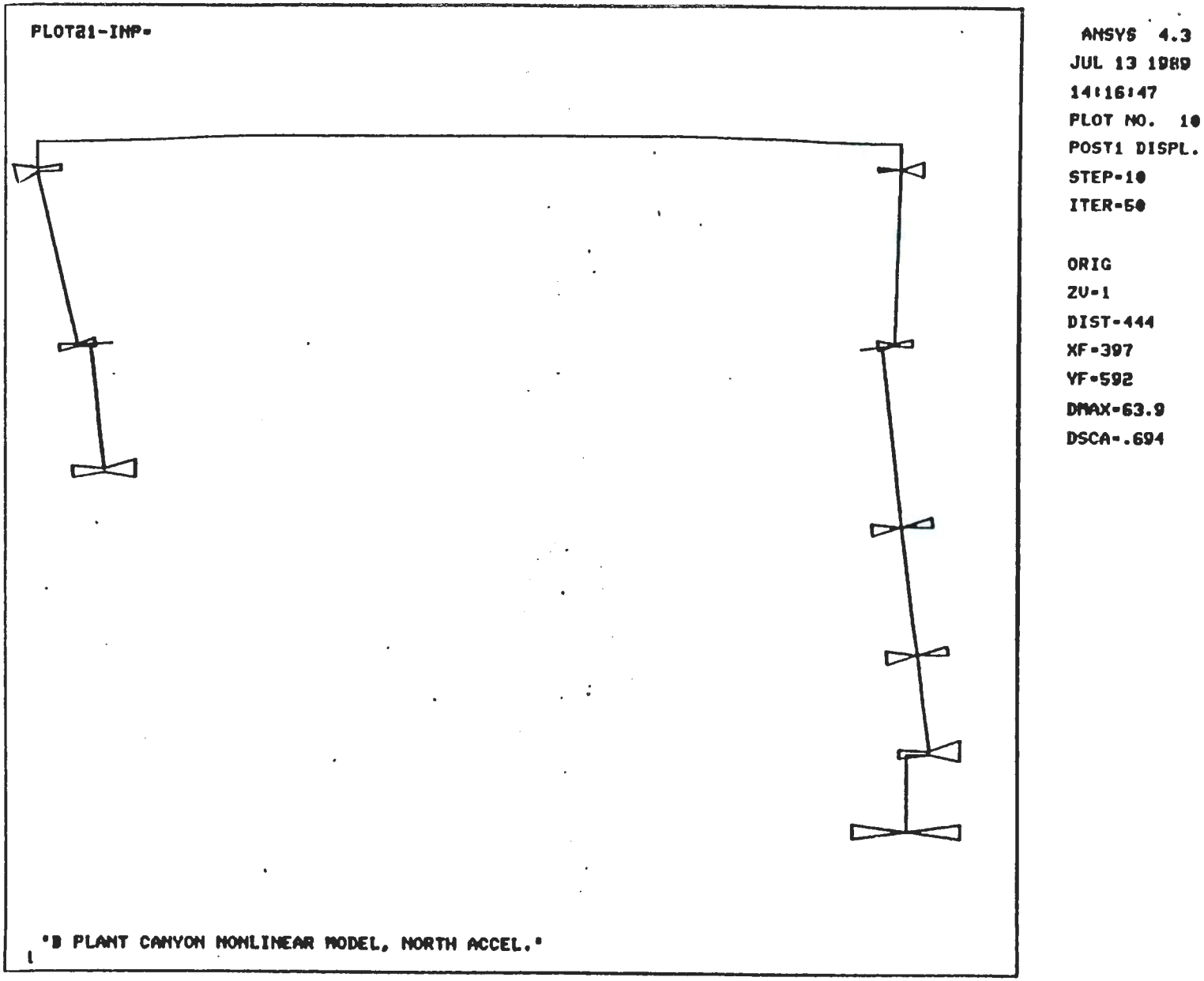


Figure 8-12. North Accel. Deformed Grid at Failure.

the full 10 second event was analyzed due to the large vertical acceleration at 8 seconds.

Ground accelerations cannot be applied directly to an ANSYS model in a time history analysis. The one exception to this is a single degree of freedom problem where there are no spacial variations in acceleration. There are two approaches for applying an acceleration time history in ANSYS. The first involves an applied displacement history obtained by double integrating the accelerations. The second approach is to attach a large mass (three orders of magnitude greater than the structure mass) to the base of the structure and apply a force history obtained from multiplying the acceleration history by the mass magnitude.

Both approaches were experimented with using a simple single degree of freedom model. For the single degree of freedom problem, both approaches gave the same response. However, some difficulty was experienced with the applied displacement approach in that a cummulative ground shift occurred. This problem has been encountered by WHC structural analysts in the past, and the large mass, force history approach has been the preferred approach. This approach was also recommended by the ANSYS program consultants.

The starting procedure for the applying the time history loading went as follows: (1) A dead weight analysis was performed with the foundation constrained at the base. This provided the dead weight reaction forces at the base. (2) The time history solution process was then begun by applying the dead weight at time zero. At the next time step (slightly beyond zero), the constraints were removed and replaced with dead weight reaction forces. (3) The force time history was then superposed on the dead weight reactions for subsequent time steps.

8.3.2 Time History Analysis Discussion

The acceleration time histories plotted in Figures 8-13 and 8-14, were defined in 5 millisecond time steps. The ANSYS user's manual (DeSalvo 1987) recommends an integration time step equal to 1/30th of the smallest natural period of interest. From the elastic analyses, the fundamental frequency was found to dominate the response spectrum solutions. From the "secant stiffness" approach discussed in Section 6.2, the fundamental frequency is in the 2 to 4 hz range. Using a natural period of 0.5 seconds, a time step of 17 milliseconds is required. However, a 17 millisecond time step is not sufficiently small to adequately describe the input motion. Also, the presence of gap elements generally requires a smaller time step.

Another factor affecting time step is solution stability. A 2.5 millisecond time step was found to be necessary to meet the default stability criterion (third derivative of displacement). Some runs were also made with a 1.25 millisecond time step to evaluate solution convergence. The 1.25 millisecond results were almost identical to the 2.5 millisecond predictions. Therefore, the final runs consistently used a 2.5 millisecond time step.

As discussed in Section 4.0, a 5% structural damping was assumed. For a time history analysis, damping is specified using alpha/beta parameters which results in a frequency dependent damping.

In the intial time history runs, gross section moments of inertia were used for the section properties between construction joints. Early in the analysis, it became apparent that the estimated crack initiation moments would be exceeded in the roof region. A precise accounting for concrete cracking in a dynamic analysis is difficult. A common approach in the industry is to use a percentage of the gross section properties. One ASCE recommendation is to use the average of the gross and cracked section properties in dynamic analyses (ASCE 1986, p. 327).

To investigate the sensitivity of the canyon structure response to the roof section moment of inertia values, a 1.5 second run was made with the gross section reduced by a factor of two. The resulting peak rebar strain increased by only a few percent, which led to the conclusion that the peak response was not very sensitive to the roof section properties. However, since the reduced moment of inertia gave a higher response, all subsequent runs were made with the reduced roof section properties.

In the NDE report (Appendix A), a few surface shrinkage cracks were reported in the north and south walls. The existence of these cracks and their potential extension during a DBE, would have some effect on the stiffness of the affected sections. However, based upon the relatively small effect of the roof stiffness change discussed in the previous paragraph, the shrinkage crack effects were considered to be secondary and did not influence the structural model.

As indicated in the next section, the 0.2g DBE predicted response was well below collapse. Therefore, the time history input was factored upward to attempt to estimate the collpase capacity. Shorter time steps were required to meet the stability criterion, which made the runs more expensive than for the 0.2g DBE. Therefore, the runs were limited to a 2 second time duration, which, based upon the 0.2g event should provide the peak response. Runs were made for both a 0.3g and 0.4g time history.

8.3.3 Time History Results & Structural Adequacy Evaluation

Using a time step integration value of 2.5 milliseconds for a 10 second event, results in a total of 4000 time steps. To obtain a meaningful evaluation of the resulting output, considerable post processing was required. Postprocessing results in graphical and tabular form is provided in Appendix D4. A brief summary is provided in this section.

8.3.3.1 Construction Joints Adequacy. The initial postprocessing concentrated on areas where the yield moment was exceeded. For the 0.2g DBE analysis, all of the rebar yielding occurred at the crane level (elements 18, 19 and 71). Of these three locations, the outer rebar at the north wall crane level (element 18) experienced the largest strains. Stress and strain history plots for this element are provided in Figures 8-15 and 8-16. Note that the 40 ksi minimum yield strength is reached several times during the 10 second duration. As

anticipated, the largest strain occurred in the 1.5 to 2.0 time range. Applying a "strain concentration factor" of 2.0 (Section 8.1.1), a peak plastic strain of 1.6% was predicted. From Appendix D1, the bending capacity of the crane level construction joints is limited by the minimum rebar ultimate strain of 12%, indicating a large margin against exceeding joint bending capacity.

This relatively low peak plastic strain is related to the fact that plasticity occurred at only the crane levels. In order for a collapse to occur, the structure has to become unstable. At least three "plastic hinges" must form in order to achieve a "mechanism" associated with an instability. With plastic hinge action limited to the crane level joints, the structure is stable and relatively low plastic strains are expected. Based upon the static capacity analysis results, a failure mechanism cannot be achieved until the yield moment is reached at a roof level construction joint (i.e. the outer rebar yields). The highest roof level rebar stresses occurred at the north wall (element 59). As indicated in Figure 8-17, a peak stress value of about 27 ksi occurred in this rebar at a time of 1.66 seconds. Since this stress level is well below the 40 ksi yield strength, a significant margin against collapse is indicated.

Another indication of margin against collapse is horizontal roof displacement. From Section 8.2, the structure is stable if north deflections stay below about 0.75 in. and south deflections are below about 1.25 in. The predicted roof displacement time history is provided in Figure 8-18. Note that peak north and south displacements of 0.22 in. and 0.48 in. were predicted, which are well below the pending instability displacements.

As mentioned in Section 8.1, the joint shear histories need to be evaluated to assure that the shear/friction capacities are not exceeded. The associated potential collapse mode is a horizontal shifting at a construction joint. Section 11.7 of ACI 349-85 (ACI 1987) addresses shear-friction for evaluating "shear transfer across a given plane, such as:... , or an interface between two concretes cast at different times". Section 11.7.4.3 specifies a friction coefficient of 0.6 for "concrete placed against hardened concrete not intentionally roughened". For concrete surfaces intentionally roughened, a coefficient of 1.0 is given.

Shear-to-normal force ratios were calculated for each construction joint vs. time (Appendix D4). This ratio stayed below 0.6 for all times in all of the joints except the north crane level and roof level joints. The crane level joints, are unique in that they have built-in shear keys. The normal and shear time history response at the north crane level joint is shown in Figure 8-19. A peak shear force of 17,150 lbs. was predicted. For the 18 inch wide shear key, the corresponding shear stress is 17,150/(18x12) = 79 psi. From Section 11.3 of ACI 349, the allowable shear stress is 139 psi for 4800 psi concrete, if no credit is taken for the compressive normal force. Therefore, the crane level shear keys are adequate for the 0.2g DBE.

At the roof level, the largest shear/normal force ratio is 0.89 (time = 1.845 sec.). As mentioned above, a friction coefficient of 0.6 is readily justified. For the B Plant canyon structure, which has many design features for minimizing leakage, it is likely that some sort of joint preparation occurred before the roof was poured, which supports the use of a higher friction

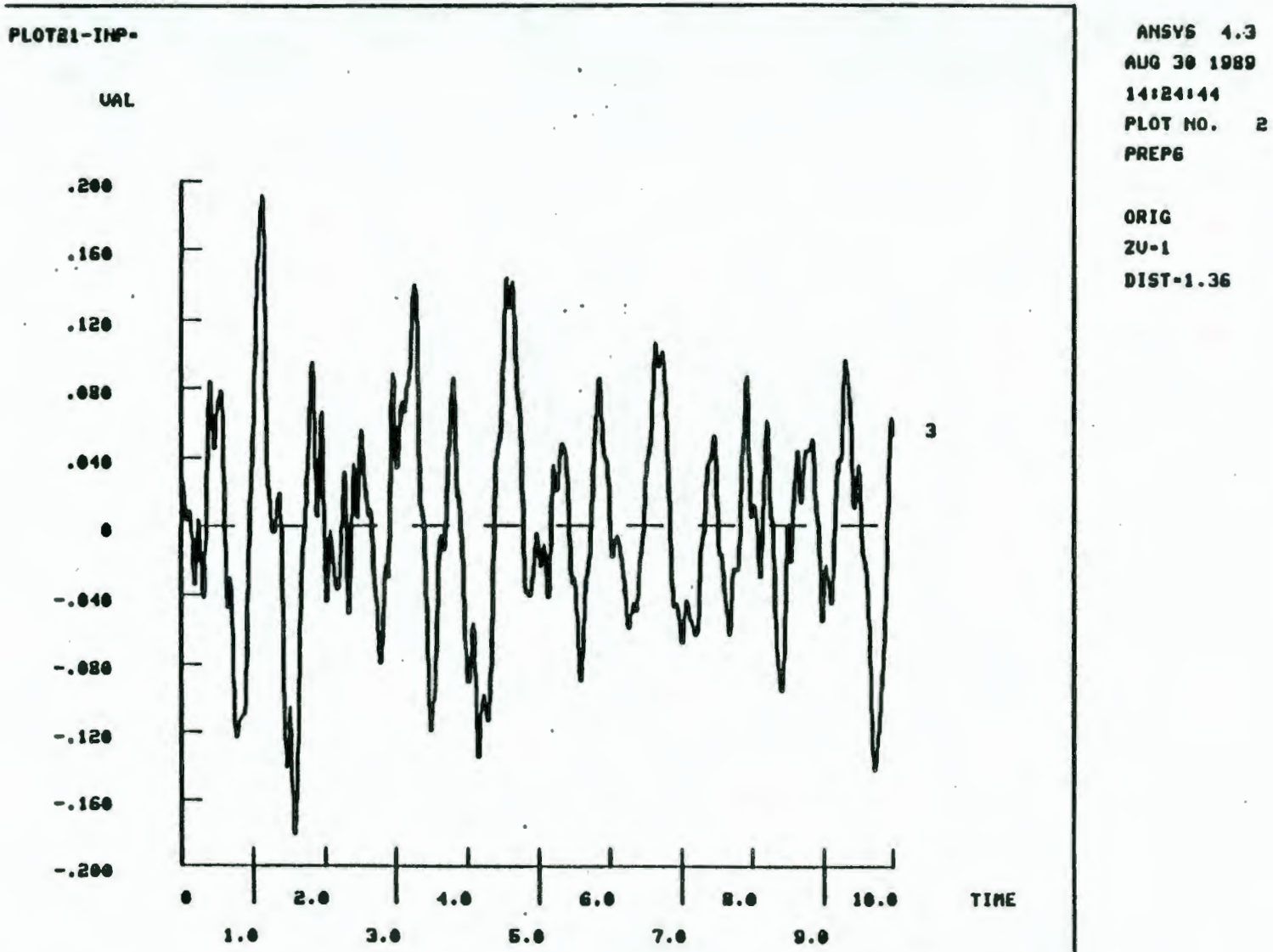


Figure 8-13. FOUNDATION HORIZONTAL ACCEL. HISTORY

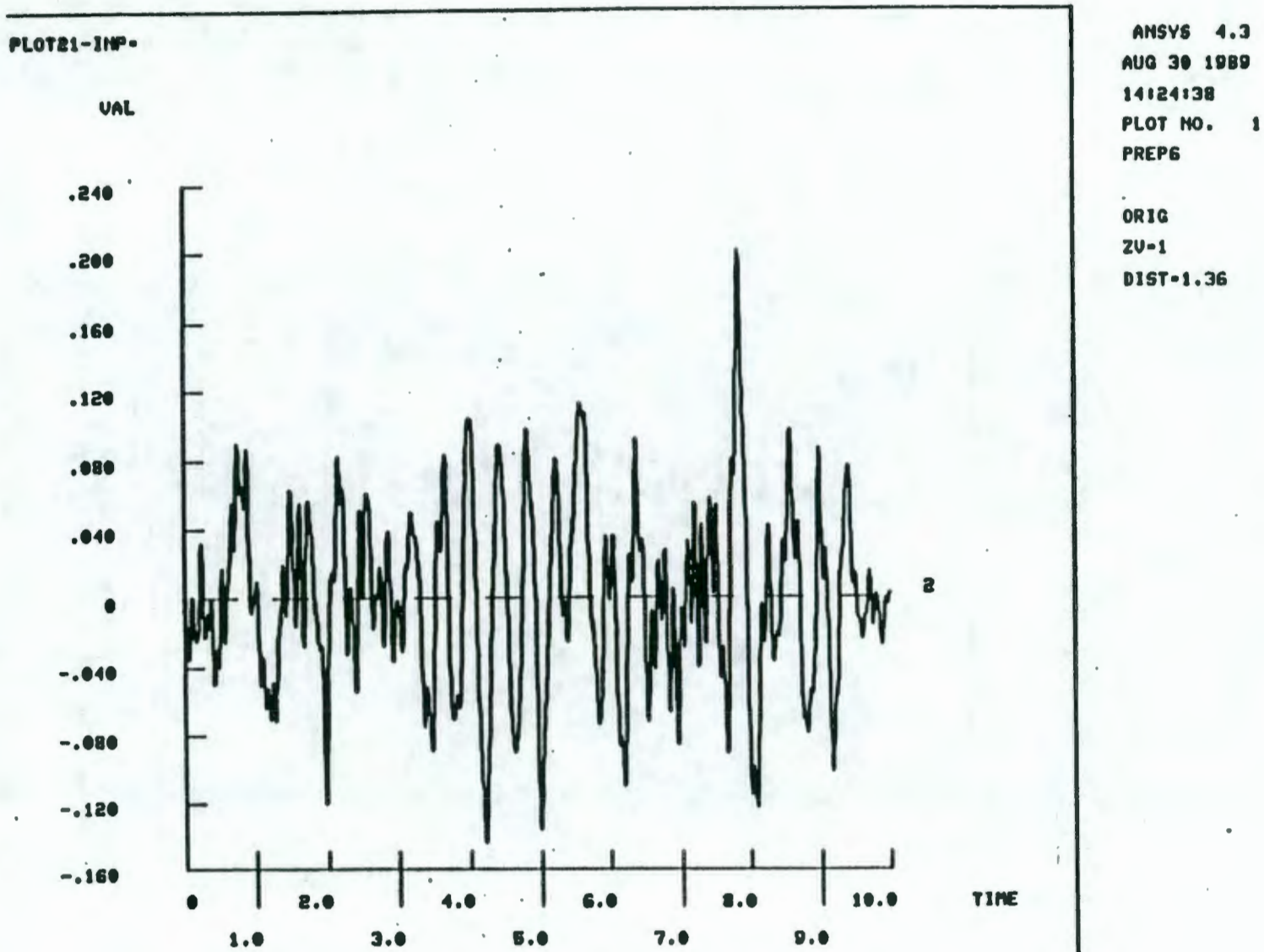


Figure 8-14. FOUNDATION VERTICAL ACCEL. HISTORY

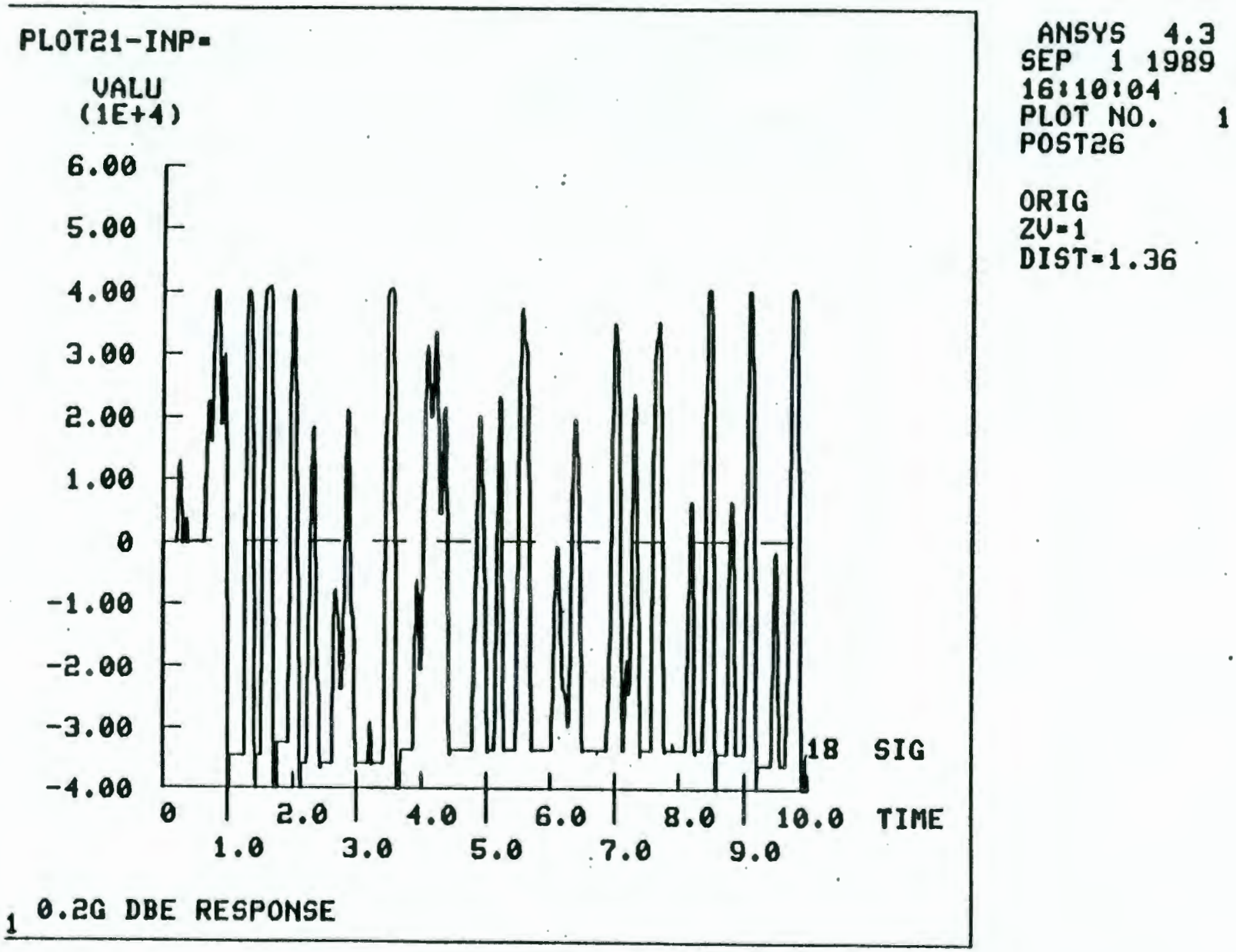


Figure 8-15. Crane Level Rebar Stress History (Ele. 18).

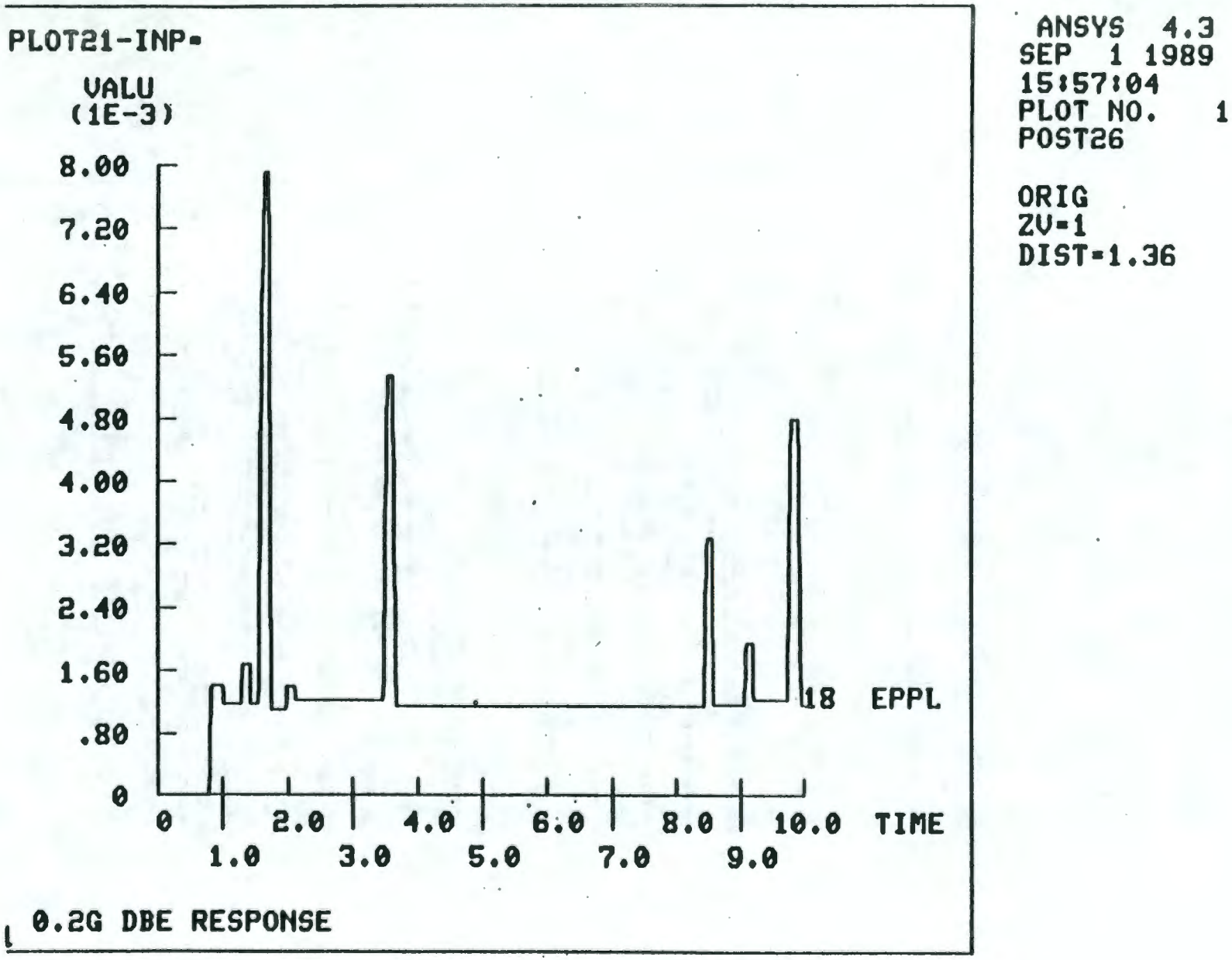
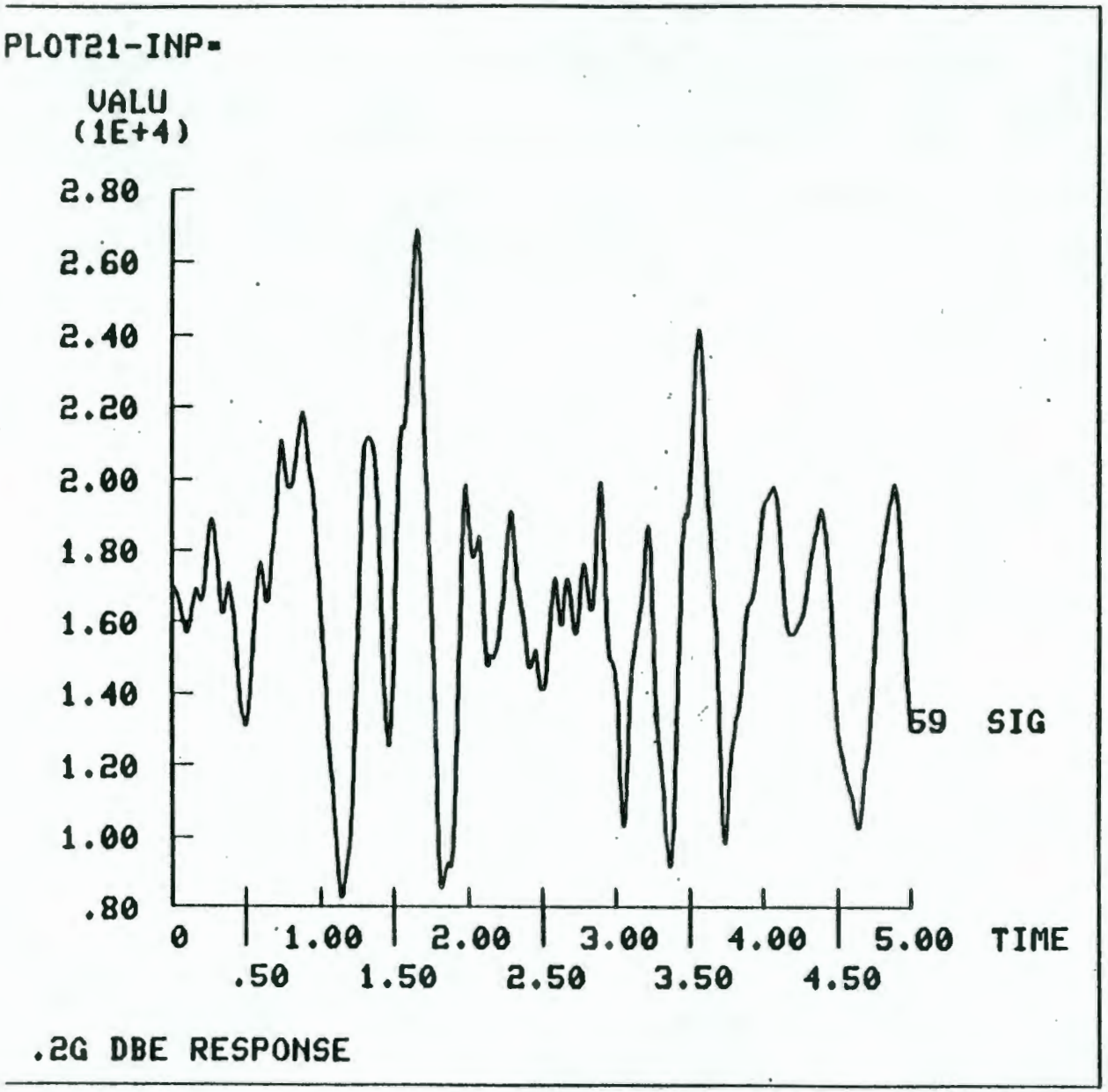


Figure 8-16. Crane Level Rebar Plastic Strain History.



ANSYS 4.3
AUG 28 1989
15:21:34
PLOT NO. 4
POST26

ORIG
ZV=1
DIST=1.36

Figure 8-17. Max. Roof Level Rebar Stress History (Ele. 59).

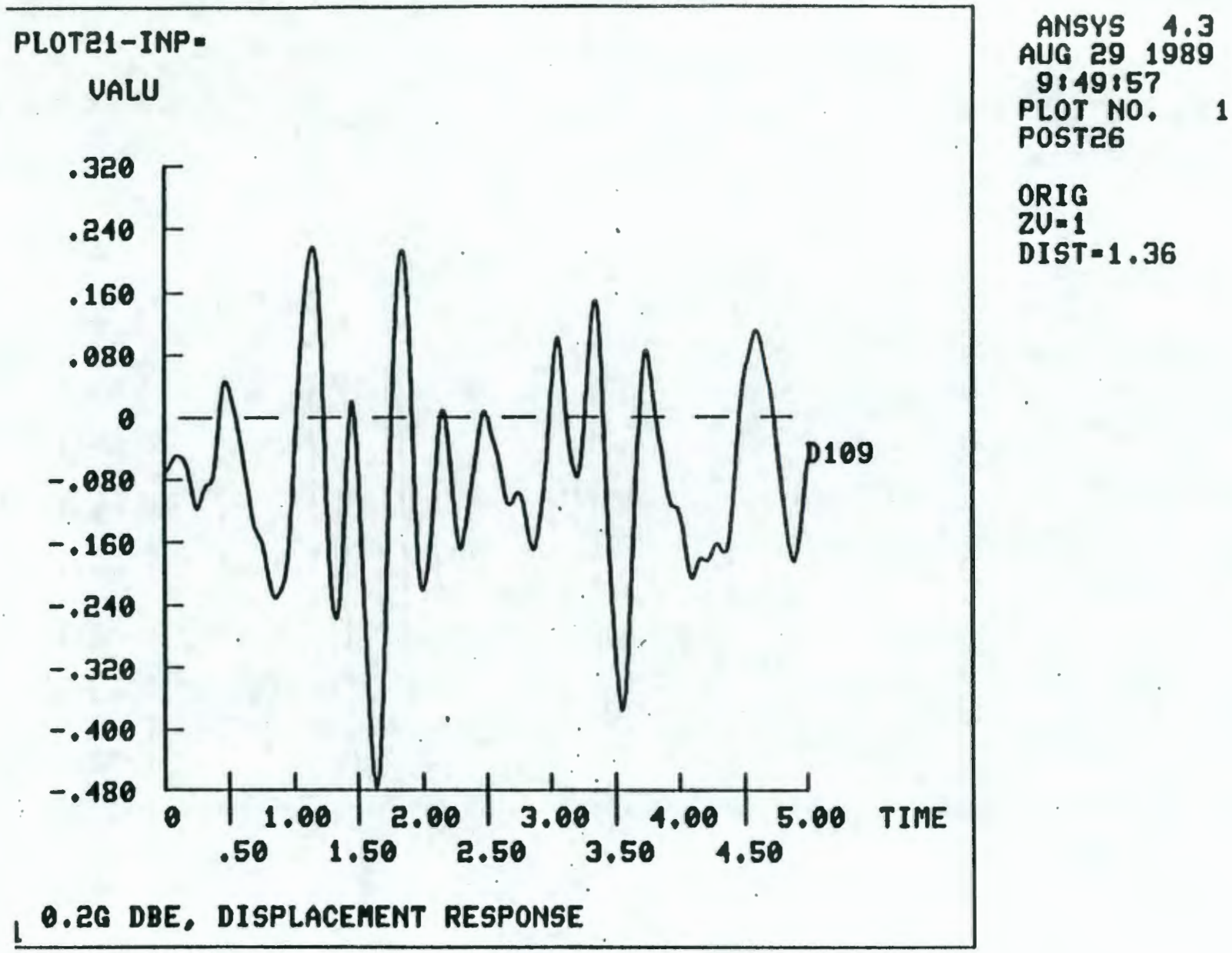


Figure 8-18. Roof Horizontal Displacement Time History.

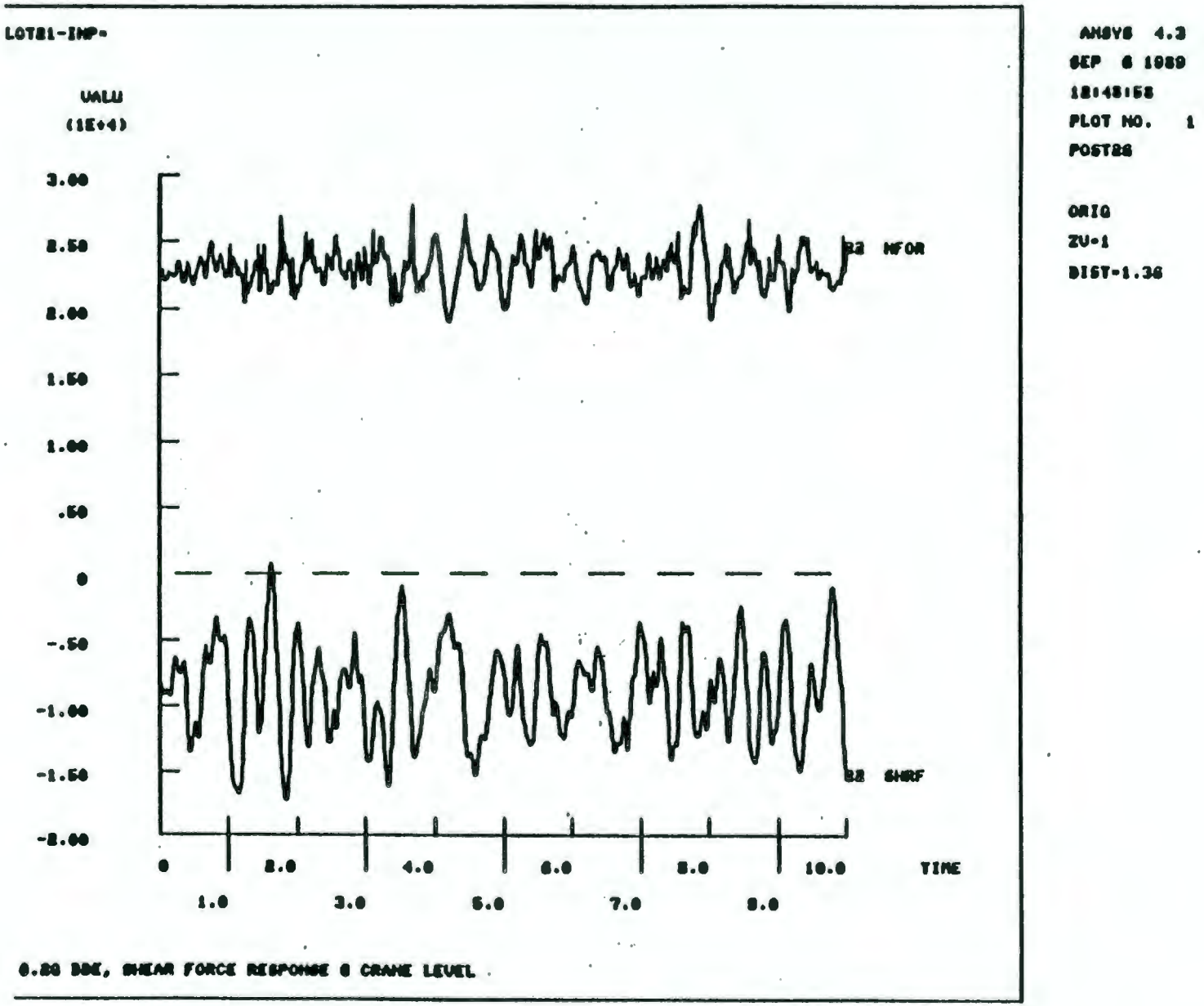


Figure 8-19. N. Crane Level Normal/Shear Force History.

coefficient. Also, credit can be taken for the excess reinforcing steel not needed for bending strength at the time of maximum shear. At the time of maximum shear, the reinforcing stress is 21 ksi (Figure 8-17). Since the steel stress is about half of the yield strength, half of the steel area can be considered as shear reinforcement. Per Eq. (11-27) of ACI 349, the resulting shear strength of the joint is 30 kips, which is well above the maximum shear force of 15,670 lbs.

The maximum edge shear on the roof slab was also examined. A peak shear stress of 36 psi occurred in the roof slab at the south wall junction at 1.645 sec. As mentioned above, the ACI allowable shear stress is 139 psi, indicating a positive margin.

8.3.3.2 Roof/Wall Adequacy. Demand/Capacity curves were generated for the walls and roof between construction joints (Figures 8-20 through 8-22). These curves were generated, in part, to evaluate the initial assumption that the nonlinearities in the canyon structure response are limited to the construction joints. The demand curves were taken from the peak negative and positive predicted moments from Appendix D4, using load factors of 1.0 for the combined dead weight and seismic loads per Section 9.2.1 of ACI-349. The capacity curves were based upon design strengths as defined by Section 9.3 of ACI-349 (ACI 1987), using strength reduction factors of 0.9. This approach is conservative relative to Section 4.2.3 of UCRL-15910 which allows strength reduction factors of 1.0. The capacity curves for the walls include the added strength contributed by the dead weight restoring moment. The "crack initiation moments" are also shown based upon Eq. (9-8) of ACI-349 using a modulus of rupture of $0.15f_c$.

In Section 8.3.2, the use of reduced values for the roof moment of inertia is mentioned, due to predicted cracking. The roof demand curves shown in Figure 8-20 were generated with these reduced values. Even with the roof stiffness reduced, predicted roof moments exceed the crack initiation moments in the bottom center and top edge regions of the canyon roof. Note that the demand moments are within the capacities for the full span of the roof.

Figures 8-21 and 8-22 address the north and south wall demand vs capacity. Note that the introduction of "plastic hinges" at the construction joints results in maximum moments which remain within the wall capacities. This confirms the assumption that the wall nonlinearities are limited to construction joints. Also note that no cracking is predicted except for a small region in the south wall (inside bottom). This demonstrates the adequacy of the gross section assumption for the wall stiffness.

8.3.4 Collapse Margin Estimate

In the previous section, seismic adequacy is demonstrated by showing that the section strength is not exceeded at any location. Although this approach is adequate relative to the UCRL-15910 requirements, it does not provide a margin against collapse. In Section 7.3, an attempt was made to obtain an indication of the collapse margin, by considering an earthquake of twice the DBE severity (0.4g). This approximate quasi linear approach indicated that the 0.4g earthquake was close to collapse capacity. The Section 7.3 approach used

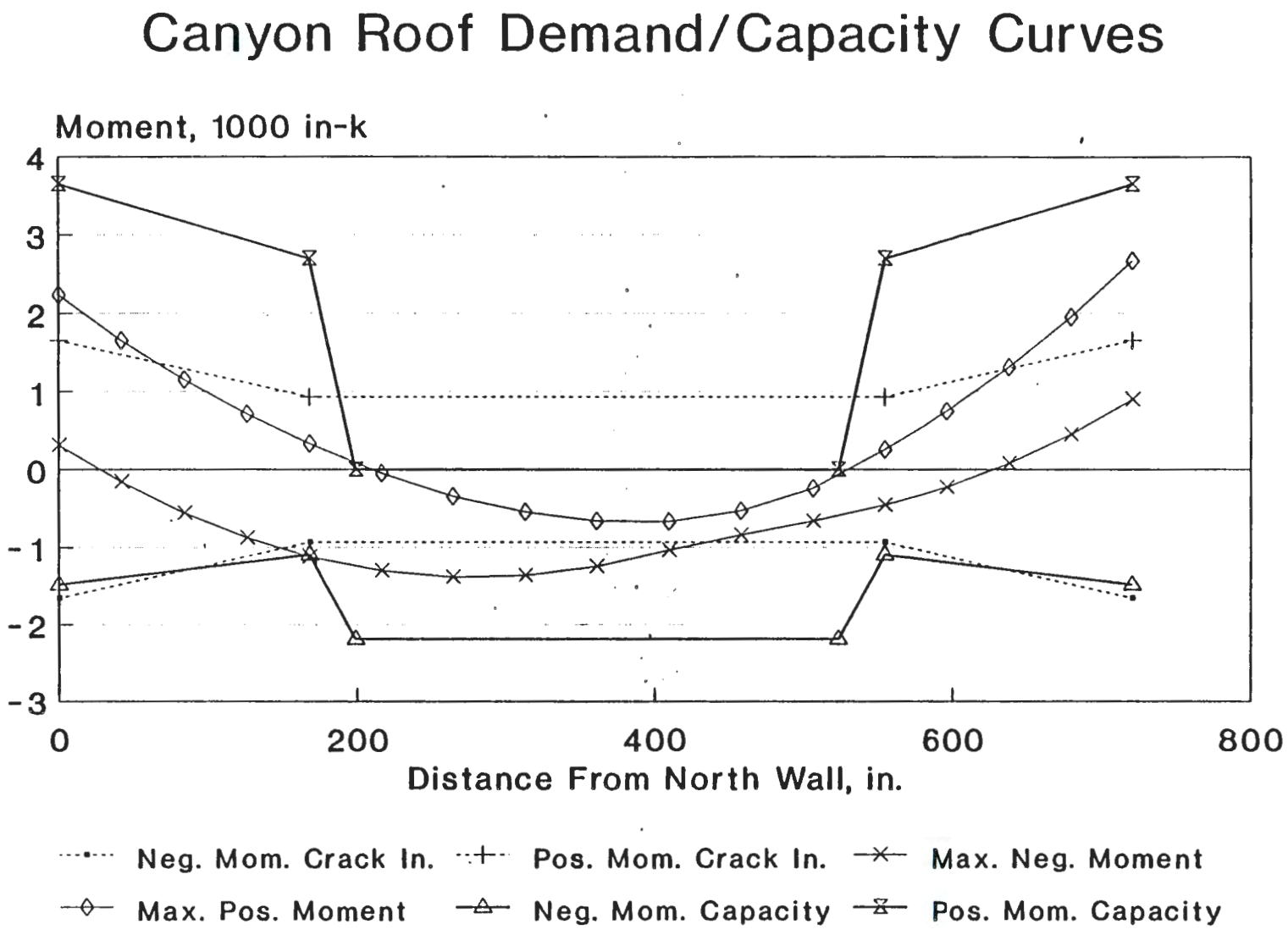


Figure 8-20. Roof Demand/Capacity Curves

North Wall Demand/Capacity Curves

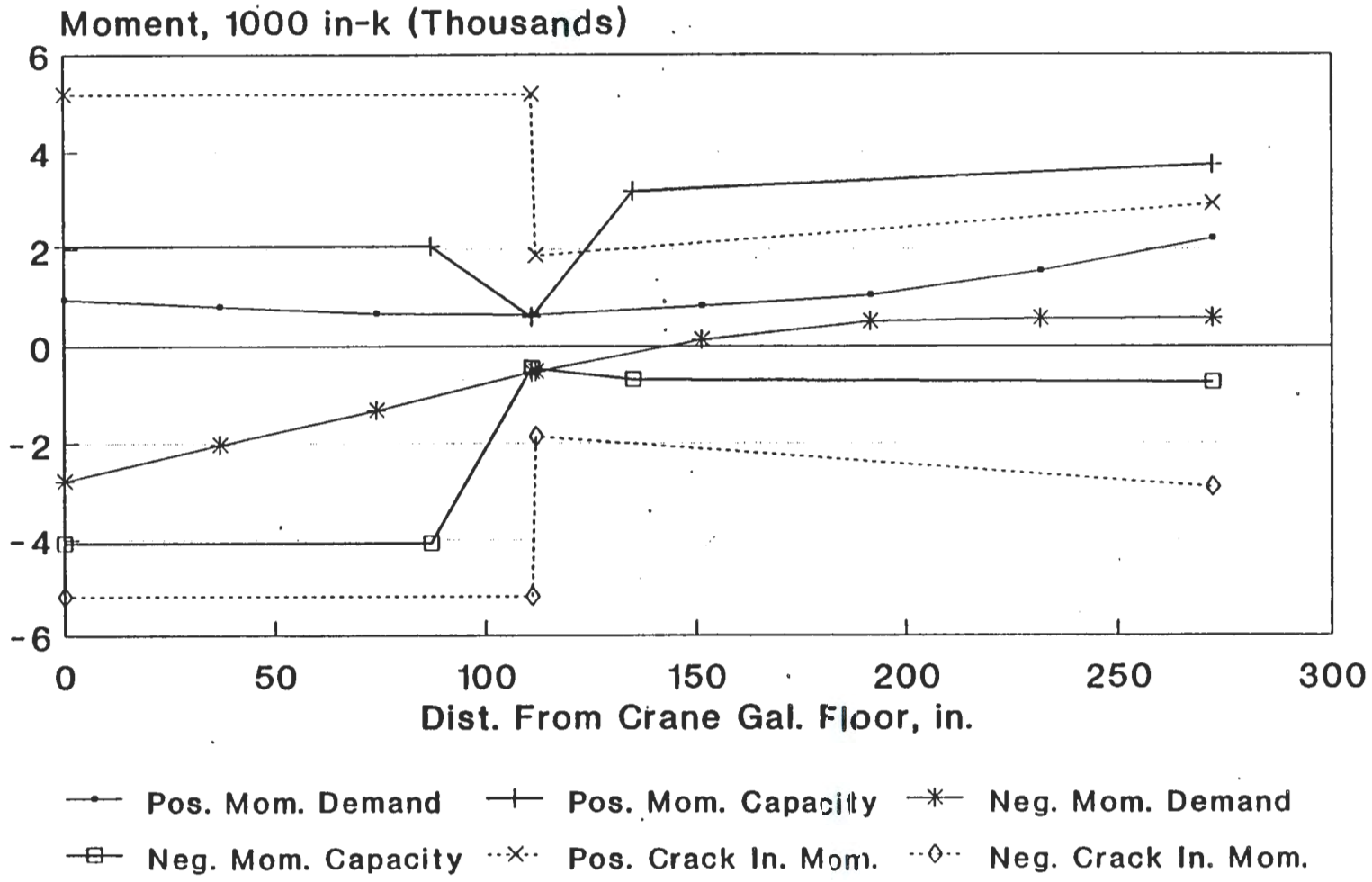


Figure 8-21. N. Wall Demand Vs. Capacity

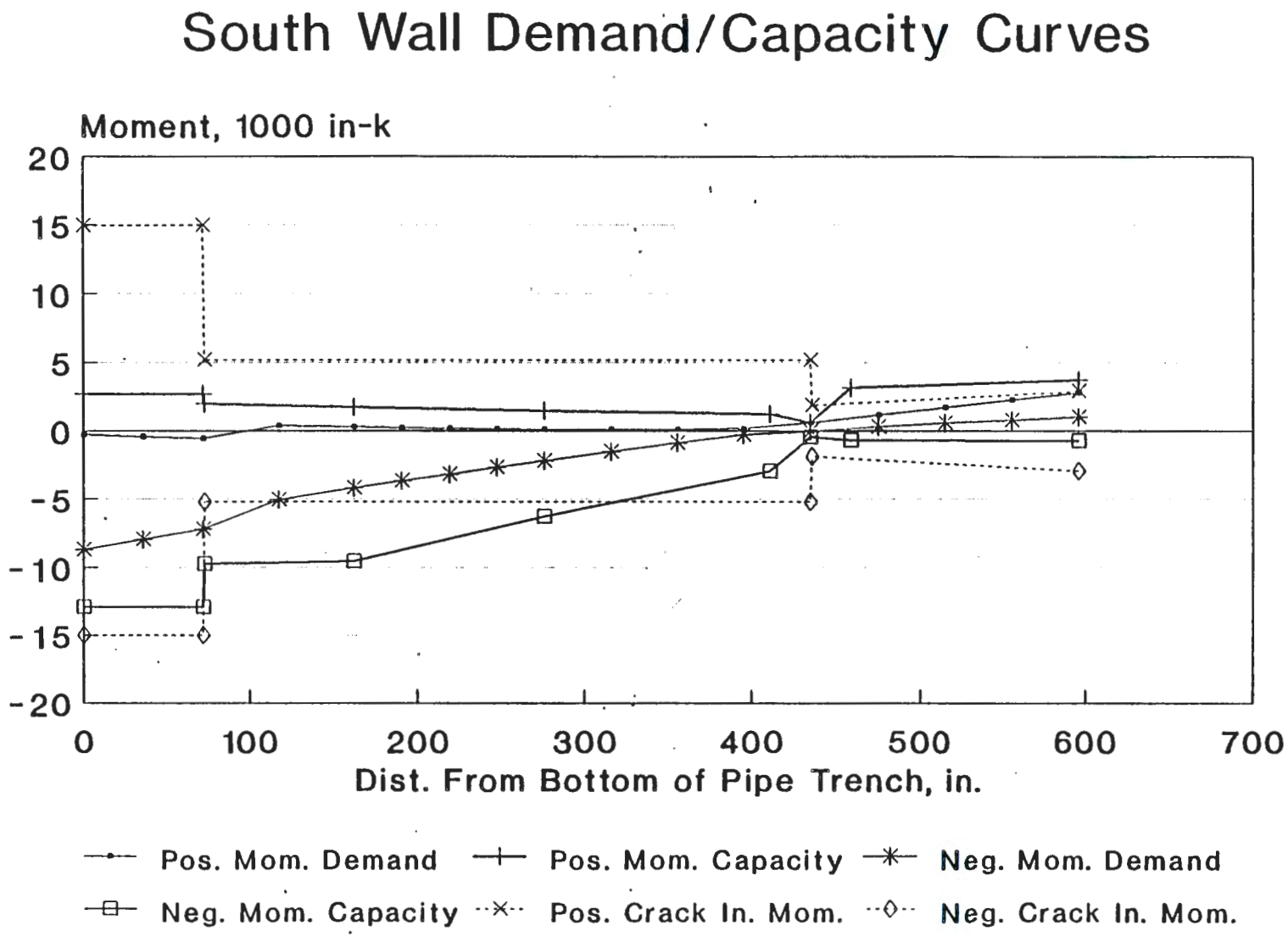


Figure 8-22. S. Wall Demand Vs Capacity.

sectional capacities with strain hardening (BIAX2 computed ultimate section capacities).

A second attempt to obtain the collapse capacity was made using the nonlinear time history model, by applying a time history ratioed up to a 0.4g peak acceleration. The 0.4g earthquake demand/capacity curves for the roof are shown in Figure 8-23. Note that both the positive and negative bending capacity is exceeded near the rebar bend points on the north end (approximate 200 inches from the north wall. While this does not necessarily mean collapse, it does indicate local capacity exceedence which the model does not account for. To account for this local "hinging" in the roof, construction joint type hinges (Figure 8-2) were introduced at the midpoint of the rebar bend points at both the north and south locations.

The 0.4g time history run was then repeated for the modified model with the resulting roof demand/capacity curves shown in Figure 8-24. As indicated, the resulting demand moments are within the roof capacity. Introducing hinges in the roof increased the peak rebar strain at the crane level (element 19) from 3% to over 6% for the 0.4g event. The crane level construction joints are highly under-reinforced, indicating that the moment capacity is limited by the rebar rather than the concrete compressive strength. The BIAX2 joint capacity evaluations (Appendix D) of the crane level joints predicted that the rebar in these joints would reach ultimate strain levels at joint capacity (12% assumed in the BIAX2 calculations) for monotonic loading.

Under a cyclic seismic loading, rebar strains at failure could be significantly less than the material ultimate strain. Thus crane level rebar failure is likely for the 0.4g event. Further modelling efforts to account for crane level rebar failures was considered, but it was judged that the analysis effort had reached a point of diminishing returns and that the 0.4g event was close to the dynamic capacity. This judgement, coupled with the quasi-linear results discussed in Section 7.3, led to the conclusion that the 0.4g event is a reasonable estimate of the seismic capacity of the canyon structure. Based upon this estimate, the collapse margin for the specified 0.2g DBE is in the neighborhood of 100%.

0.4g DBE Roof Demand/Capacity Curves

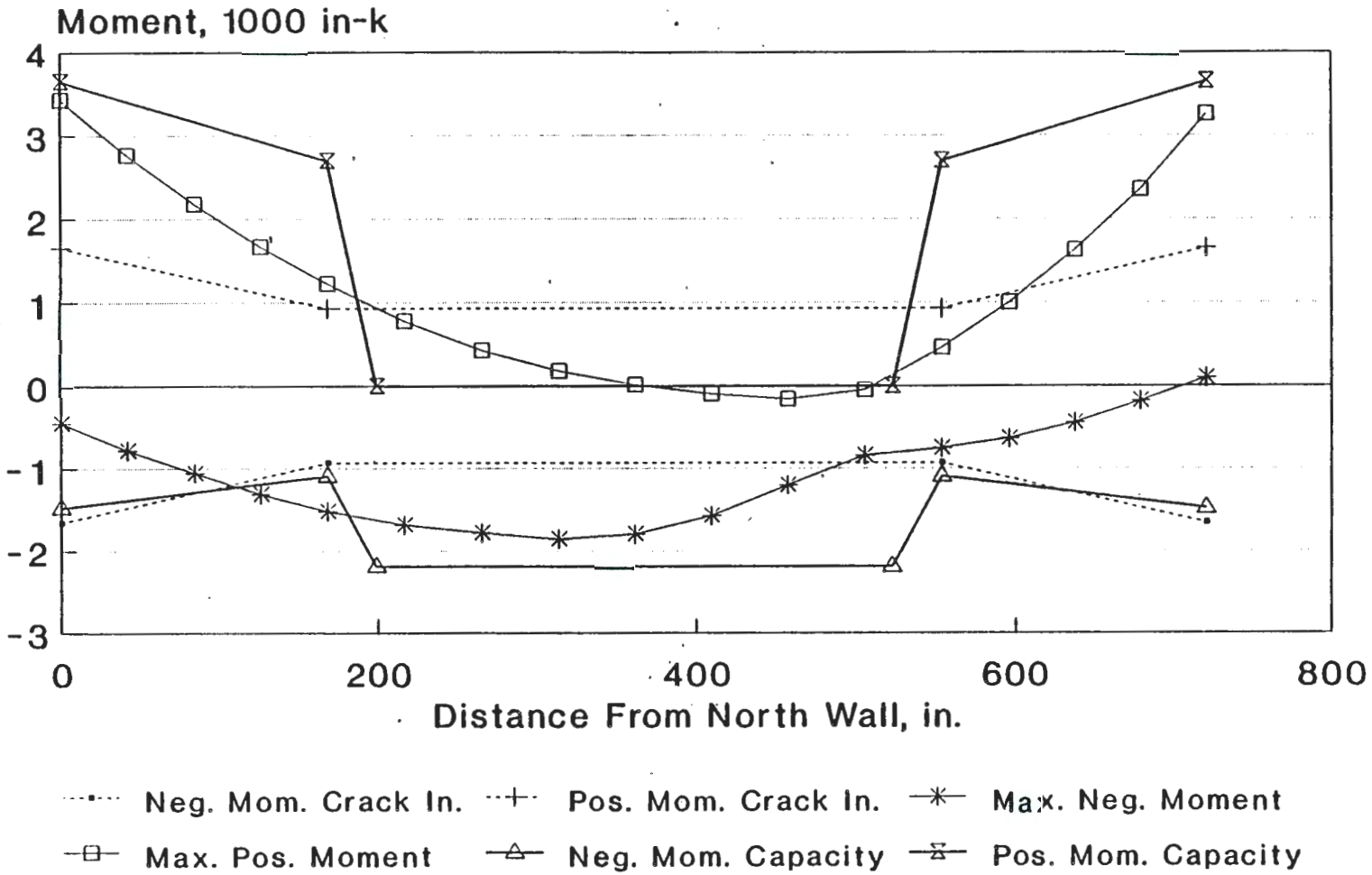


Figure 8-23. 0.4g Roof Demand/Capacity

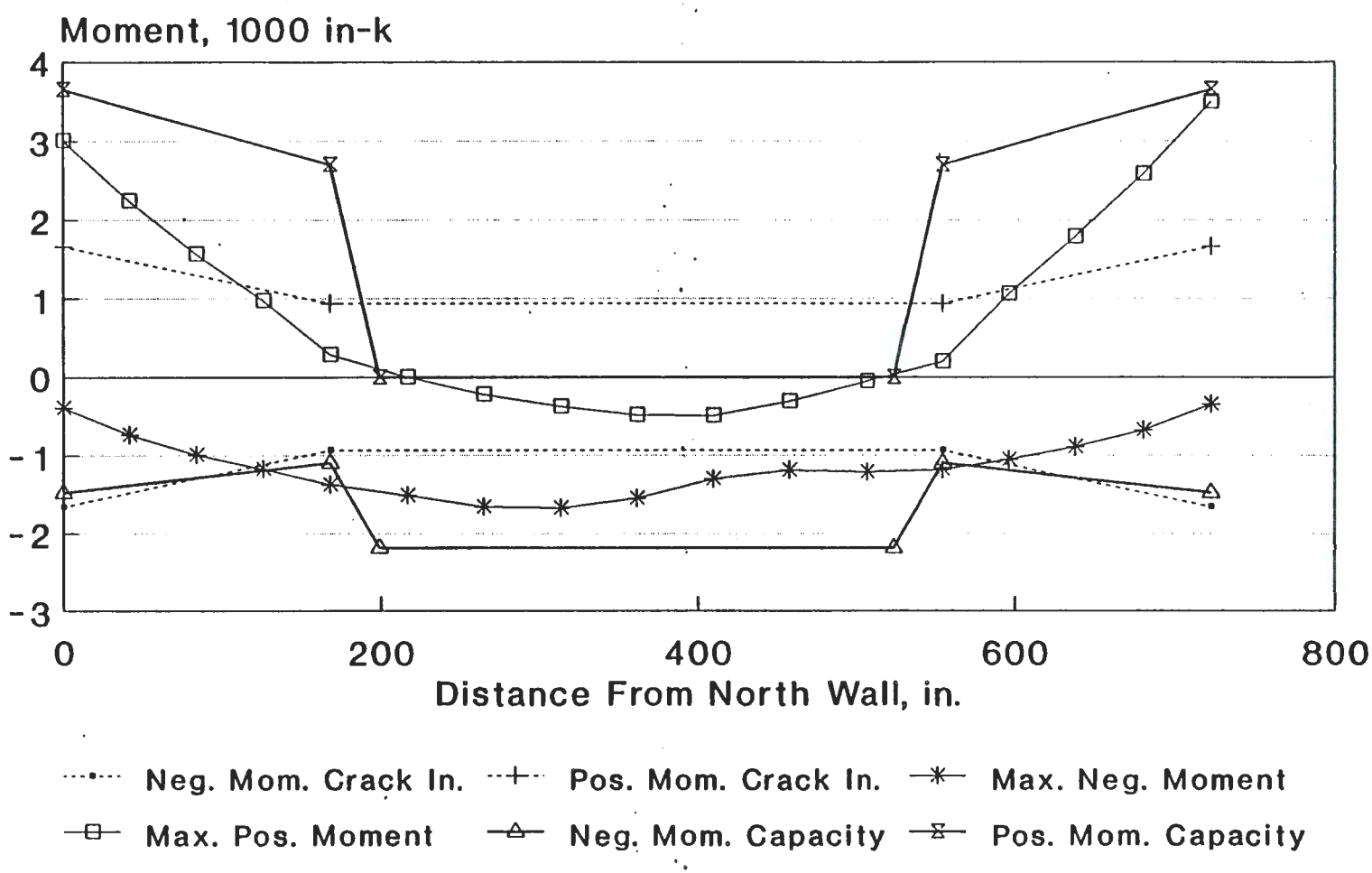


Figure 8-24. 0.4g Roof Demand/Capacity with Roof Hinges

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APPENDIX A

NONDESTRUCTIVE EVALUATION OF CANYON STRUCTURE

CONTENTS:

A. Muenow NDE Report.....Page A2

B. Roof Rebar Survey Report.....Page A69

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NONDESTRUCTIVE EVALUATION OF JOINTS, CRACKS AND OTHER DISCONTINUITIES IN THE WALLS, ROOF AND SHIELD WALLS OF BUILDING 221B HANFORD SITE

BY
RICHARD A. MUENOW, P.E.
and
F. R. VOLLERT, P.E.

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INTRODUCTION

From August 22 through August 26, 1988, reinforced concrete nondestructive testing (NDT) was conducted for the 221-B Canyon Building structure at the Hanford site near Richland, Washington. The NDT was authorized by Westinghouse Hanford Company (WHC) (reference 1). The necessary structural engineering technical direction and assistance from WHC was provided by F. R. Vollert, Principal Engineer. The required NDT equipment, instrumentation, technology, and procedures were provided by Richard A. Muenow, and James Ramsey, Muenow and Associates, Inc.

The reinforced concrete 221-B Canyon Building is 810.5 feet long, 68 feet wide and 77 feet high. The structure was constructed in 1943. The reinforced concrete structural features are relatively massive. They include the north and south canyon walls, roof slab, galleries, gallery shielding wall, process cells, and a hot pipe trench. The building has complete cross section expansion joints spaced at 40 feet. The concrete walls in the structure have cross section or thickness changes over their height, and were placed in lifts with horizontal and vertical construction joints (reference 2).

OBJECTIVES

Updated seismic analyses are planned by WHC for the 221-B Canyon

Building which might be able to account for the added bending strength in the walls due to the tensile strength of the concrete where the walls are monolithic or uncracked in the bending plane. Previously, a limited number of the construction joints were investigated with NDT. Some were found to be unbonded (reference 3). Therefore, this thorough NDT investigation of the 221-B Building was completed to: define the locations in the reinforced concrete walls and roof where concrete tensile capacity exists or where structural repairs might be implemented to ensure concrete tensile strength; determine the in-situ concrete compressive strength and modulus of elasticity; locate and evaluate the construction joints, potential for cracking and concrete degradation; confirm the reinforcing steel locations and details at joints and juncture; and assess the extent of reinforcing corrosion, if any.

PULSE ECHO TEST THEORY

Pulse echo NDT testing is based upon the propagation of stress waves (mechanical energy) through a solid and the reflection of such energy at changes of density within the material of propagation. All basic theory for this test method is founded upon the laws of reflection and refraction as stated by Snell. In practice, pulse echo tests are conducted by introducing energy, containing a side frequency spectrum, by impact with a variety of hammers; with the main consideration being as sharp a wave front as possible. As this energy propagates through the material, both dispersion and divergence occur, Dispersion controls the total length energy will travel, which is currently in excess of 350 feet in one direction. Divergence controls the cone of influence or the beam of energy within the material, which is currently a 1:2 ratio for frequency used. As the energy propagates through the material, if no internal material density changes are encounted, the energy will impinge on the opposite side or surface of the member, an air/solid interface with a 15 to 1 accoustic density change, and up to 95% of that energy will be reflected back towards the energy source. If internal density changes are encountered, such as cracks, honeycomb, low density material, voids and/or disruptions of cement matrix around reinforcement steel bars, then the identical reflection process takes place as with an air/solid interface. However, with internal reflections, a signature, based

upon frequency, attenuation, risetime and ringing, is developed which characterize the nature of any reflecting surface. Immediately adjacent to the point of impact, a piezoelectric transducer is located to receive the reflected energy. This transducer simply transforms the reflected mechanical energy into electrical energy which constitutes the envelope of data. This data is then processed, computer enchanced and presented on a storage CRT. In addition to the data which characterizes internal discontinuities, longitudinal and shear wave velocities are also calculated by measuring transit time in microseconds and knowing the path length of travel. From these longitudinal and shear velocity values, estimated and correlated in situ concrete compressive strengths are recorded as well as values for Possions ratio and Modulus of Elasticity.

Mapping the extent, depth and characteristics of an internal discontinuity is accomplished by conducting pulse echo tests on a regular grid system and then developing a computer generated model.

GROUND PENETRATING RADAR

Pulsed radar is a geophysical tool that has many applications in engineering and construction. This tool is an impulse radar system which radiates repetitive short time duration electromagnetic pulses into materials from a broad bandwidth antenna placed in close proximity with and electromagnetically coupled to the surface. The equipment functions as an echo sounding system using radar pulses of only a few nanoseconds in duration and is able to detect and measure the depth of reflecting discontinuities in materials to within a few centimeters or millimeters depending upon the electromagnetic parameters of the various media.

Pulsed radar has been used for an exploration tool for the shallow subsurface in geophysical and material applications. The technique is also known as electromagnetic subsurface profiling or subsurface interface radar, and it can be considered the electromagnetic equivalent of the acoustic methods used for marine sub-bottom profiling. In practice, continuous profiles are generated by towing a transducer over the area of interest while running the system's graphic recorder. These profile records are immediately available for observation and interpretation in real time, and survey tactics can be adjusted or modified as conditions dictate. The data can also be recorded on magnetic tape for later processing and playback.

System Description

The radar system is composed of a control unit, which contains a built-in microprocessor programmed for real-time or off-line signal enhancement, several transducers for various range and resolution capabilities, and a high speed scanning graphic recorder for data presentation. The transducer is connected to the radar control unit by a standard 30 meter long control cable, although cable lengths up to 200 meters can be used.

The system power supply furnishes a regulated dc voltage to the transmitter which, when triggered, generates a base band voltage pulse of approximately 3 nanoseconds in duration. This pulse is shaped to quasi-gaussian form and radiated into the material by means of the broadband antenna. The radiated signal is a brief electromagnetic transient having a bandwidth of approximately 120 MHz in the low VHF range (30MHz). The transmitter pulse repetition rate is 50 KHz, and the average radiated power is about half a milliwatt (0.42mw).

The reflected signals are received by the same antenna used for transmission and the receiver electronics amplify the incoming pulses and translate the high frequency waveforms to the audio frequency range by means of a time-domain sampling technique. Progressive amplitude samples are taken from each successive received waveform and used to reconstruct a waveform

of similar shape having a much longer time base. In the present time-domain sampling system, 3125 successive transmitter pulses are used to construct the useful portion of the composite long-time-base received waveform, resulting in a transiated waveform repetition rate of 50000/3125 or 16 pulses per second. The resulting frequency content of this sampled receiver output waveform is in the audio frequency range where it can be readily recorded, processed and displayed. In reference to the sample rate, if the transducer is scanned at the rate of a moderate walk (about 100 cm/sec) then the antenna moves 100/16 or about 6cm during the time interval between each composite sampled waveform. Therefore high resolution horizontal profiles are obtainable while moving at moderate speeds, allowing the detection of fairly small subsurface targets such as small diameter pipelines, cables and voids.

The profile data is displayed on a graphic recorder similar to those used in marine bottom and sub-bottom profiling. The input waveform to the recorder consists of the transmitted pulse, the reflection from the surface, and reflections from various interfaces and targets in the subsurface. While the transmitted pulse input to the antenna during the transmit cycle is a short monopulse, the filtering effect of the finite-bandwidth antenna and the subsurface media results in the sinusoidal appearance of the reflected signal.

The recorder is an intensity modulated device, with the

sweep of the stylus across the chart paper synchronized with the transmit pulse trigger. Signal amplitudes above a preset threshold level are printed as varying levels of grey and black but weaker or lower amplitude signals remain white. The paper moves as the stylus is scanning, producing a profile or vertical section showing surface and subsurface reflections or interfaces. Dark bands occur at signal peaks, and the narrow white lines are the "zero crossings" of the signal between peaks. The chart paper is calibrated in nanoseconds, but can be also calibrated in terms of depth once the relationship between depth and pulse travel time is known.

The VHF frequency range dielectric constant and conductivity of the material being probed determine the electromagnetic propagation velocity (depth calibration) and the propagation loss (depth of penetration) of the subsurface radar system.

Depth Calibration

In order to calibrate the radar system for accurate depth determination, it is usually necessary to obtain the measured echo travel time of a pulse from a conspicuous subsurface interface or other target and then drilling down to the level of the reflection to measure the actual depth. From this information, the effective propagation velocity, Vm, through the overlying material can be derived from the following equation:

$$Vm = 2D/t$$

where D is the measured depth to the reflecting surface, and t is the elapsed time between the transmitted and received pulse.

The effective relative dielectric constant, Er, of the penetrated earth material can also be derived from the relationship:

$$Er = (c/Vm)^2$$

where c is the propagation velocity in air (about the velocity of light, $3X10^8$ m/sec), or about 1 ft/nanosecond.

Knowledge of the effective relative dielectric constant of the material is useful in broadly estimating the type of discontinuity being probed and/or the moisture content of the materials. Table 1 lists the relative dielectric constants and conductivities for several types of materials as determined by various investigators. It must be noted that these electromagnetic parameters are dependent to varying degrees upon temperature, pressure, frequency and the presence of impurities; and upon the particular measurement techniques used by the investigator.

As Table 1 shows, the presence of water and the physical state of the water has the greatest effect on the dielectric constant and conductivity. Since the dielectric constants in the table vary from 1 to 81, the velocity of propagation varies from 1 to 9 and thus a different depth scale is used on the radar data for ice, water and saturated sand.

TABLE 1

Approximate VHF Electromagnetic Parameters

of Typical Earth Materials

Material	Conductivity (mhos/m)	Dielectric constant (Er)
Air	0	1
Fresh Water	10-4 to 3X10-2	81
Sea water	4	81
Sand (dry)	10-7 to 10-3	4 to 6
Sand (saturated)	10-4 to 10-2	30
Silt (saturated)	10-3 to 10-2	10
Clay (saturated)	10-1 to 1	8 to 12
Dry sandy coastal soil	2X10-3	10
Marshy forested land	8X10-3	12
Rich agricultural land	10-2	15
Medium hills, forested	5X10-3	13
Fresh water ice	10-4 to 10-2	4
Permafrost	10-5 to 10-2	4 to 8
Granite (dry)	10-8	5
Limestone (dry)	10-9	7 to 9
Asphalt		3 to 5
Concrete		6 to 7
Peat (dry)		5 to 8
Peat (wet)		50 to 60
Coal		4 to 5
Dolomite		6 to 8
Ferrous oxide		15
Quartz		4
Toluene		2 to 3
Snow		1.2 to 2.3

Another method can be used to determine the velocity of propagation directly without the need for subsurface drilling. This technique is known as the Common Depth Point (CDP) method, one that is used extensively in seismic exploration. Briefly, this method entails the placement of two separate antennas (one for transmitting and the other for receiving) at a close spacing

over a detected horizontal subsurface interface. Then by moving the antennas along a straight line away from their original positions at uniform increments such that the same subsurface reflections are maintained, the radar pulses will travel through several different path lengths through the subsurface media. With knowledge of the vertical echo travel time and the travel times observed for several antenna positions at known separation distances the effective propagation velocity, Vm, in the medium is given by:

$$V_M = \frac{X}{[t(x)^2 - t(d)^2]^{.5}}$$

where: X = the horizontal distance between the transmitting and receiving antennas.

t(x) = arrival time of a reflection from an interface at X antenna separation.

t(d) = two-way vertical travel time to the reflecting interface.

This method has been used successfully to determine soil moisture content with depth and to locate the water table under favorable conditions in sandy soils.

Penetration Depth

The penetration depth of subsurface radar is dependent upon the effective conductivity of the earth material being probed, which in turn is dependent primarily on the water content and the amount of salts in solution. Conductivity is also influenced by

temperature and density as well as the frequency of the electromagnetic waves being used. Conductivity is related to loss tangent (dissipation factor) by the following equation:

$$\tan(1) = \frac{c}{2 \text{ pi } f \text{ Eo Er}}$$

where: c = conductivity in mhos/meter

f = frequency in Hz

Eo = dielectric constant of free space = 8.85X10 -2 farads/meter

Er = relative dielectric constant

tan(1) = loss tangent

pi = 3.14159

Using the above information, the approximate attenuation, A, for various materials, as listed in Table II, can be calculated from the following relationship:

$$A=12.863 \times 10^{-8} \cdot f(Er)\ 0.5[(\tan 2\ c+1)\ 0.5^{-1}]\ 0.5 \text{ db/m}$$

TABLE II

Attenuation in Decibels/meter (db/m)

Frequency in MHz

Material	1	10	100	500
Pure water	0.025	0.039	0.408	16.191
Sand Soil (moist)	0.471	0.513	0.773	4.047
Clay soil (dry)	0.013	0.075	0.425	1.649
Clay soil (moist)	0.780	3.803	17.93	53.75
Sea water	34.50	108.54	326.54	592.03
Granite (dry)	----------.0732X10^{-5}, ----------			

Since the "in situ" electrical properties of soil, rock, concrete and water vary greatly, it is difficult to estimate the radar's performance before a specific survey. However, as a guide to the prospective penetration depths in various materials, results using subsurface radar indicate that penetration depths greater than 30 meters have been achieved.

TEST LOGISTICS

Nondestructive testing (NDT) was conducted at the 221-B Canyon Building on the accessible major reinforced concrete structural elements. These elements are the north and south canyon walls, the roof, the gallery shielding wall, and gallery floors. The crane gallery shielding wall, and the interior east-west wall separating the cells from the hot pipe trench and wind tunnel are unaccessible for NDT.

Pulse echo NDT with 90° straight beam and 45° angle beam transducers was conducted to: determine the compressive strength and modulus of elasticity for the concrete; and locate and evaluate construction joints, potential cracking and degradation, including degradation due to reinforcement corrosion, and voids.

The straight beam transducer data is used to determine the concrete compressive strength and modulus of elasticity, and to locate in-plane cracking, laminations, degradation, and voids. The compressive strength values are obtained from velocity vs. strength curves for concrete similar to that in the 221-B Building. These curves do not include concrete core sample test data from the 221-B Building, but concrete test data from the Hanford site are included. The modulus of elasticity values are calculated using the relationship:

$$E = V^2 d \frac{(1-u)(1-2u)}{(1-u)}$$

E = Modulus
V = Velocity
d = Thickness of Concrete
u = Poisson's Ratio (0.12)

The 45° beam transducer data is used to locate and evaluate construction joints, through thickness cracking, and deterioration of crack and joint surfaces.

The pulse echo NDT locations, data, and results for the 221-B Building are given in Tables 1a, 1b, 1c, 2a, 2b, and 2c.

Ground penetrating radar NDT was used to confirm the locations and spacing of reinforcing steel in the 221-B Building walls, roof, and gallery floors. It was particularly applied at locations with possible construction joints, as identified from the design drawings and visual inspection of the structure. The use of radar was only used to locate the structurally vital vertical reinforcement in the walls, and the north-south reinforcement in the roof and floors. The radar NDT indicated the absence of serious reinforcement steel corrosion in the 221-B structural members examined. The ground penetrating radar NDT locations and results are given in the Tables 3a, 3b, 3c, and 3d.

TEST RESULTS

NORTH AND SOUTH CANYON WALLS

The results of the pulse echo NDT using the 45° transducer for the canyon walls are compiled in Tables 1a and 1b. The results using the 90° transducer, including the obtained values for concrete compressive strength and modulus of elasticity, are compiled in Table 2a. The ground penetrating radar NDT locations, results, and observations for these walls are in Tables 3a and 3b. The conclusions about the condition, concrete strength properties, and construction details for the north and south walls from the NDT data are:

The construction joint at the crane rail level (elevation 737.25) is unbonded in both walls.

Generally intermittent, weak bonded construction joints are located in the north wall at the pipe gallery floor, the top and under sides of the crane gallery floor slab, and the wall to roof slab juncture.

Generally intermittent, weak bonded construction joints are located in the south wall at the floor and top of the hot pipe trench, 3 to 4 ft. above the canyon deck level, and the wall to roof slab juncture.

The construction joints at the base of these walls with the foundation slab are generally well bonded, based on pulse echo 45° transducer NDT in the electrical gallery on the north wall.

There are vertical reinforcement layers on both the interior and exterior surfaces of the north wall over the full height.

The vertical reinforcement bars in the north wall are continuous (unspliced) through the construction joint at the pipe gallery floor level. The vertical reinforcement is spliced at the other north wall construction joints (exception, in section 16 vertical reinforcement splices were not detected in the crane gallery floor slab area).

The radar NDT shows layers of vertical reinforcement on the exterior and interior surfaces of the south wall. The exterior layer was confirmed to extend down to a least the Hot Pipe Trench floor level. The interior layer could not be detected below the canyon deck level.

The vertical reinforcement bars in the south wall are spliced at the construction joins at the crane rail level and wall to

roof slab juncture (exception, in section 18 splices were also detected 3 to 4 ft. above the canyon deck level). Overlapping vertical dowels are detected near the Hot Pipe Trench floor level.

The concrete in the north and south walls is in good to excellent condition. The nominal concrete compressive strength and modulus of elasticity for these walls are 5980 psi and 4.86 X 10^6 psi, respectively. These walls show minimal concrete degradation and cracking. The relatively few visible cracks (horizontal and diagonal) on the exteriors have maximum depths of 6 to 9 inches. These appear to be shrinkage cracks which developed during the initial concrete cure. They have progressed little, if any since.

Pulse echo NDT with the 90° transducer vertically down the walls from the roof confirms that unbonded construction joints exist at several levels in the north and south walls.

No evidence of reinforcement steel corrosion was found in the north and south walls.

ROOF

The results of the pulse echo NDT (90° transducer only) for

the roof, including the concrete compressive strength and modulus of elasticity, are compiled in Table 2c. The ground penetrating radar NDT locations, results, and observations are in Table 3c. The conclusions about the condition, concrete strength properties and reinforcement bar placements for the roof from the NDT data are:

> The roof slab has top and bottom layers of north-south reinforcement bars, but the top layer could only be detected to extend about 10 feet in from the edges (not 18 feet as the the drawings depict).*
>
> At the top face extending 10 feet in from the edges, a layer of wire fabric was detected. The wire fabric is not shown on the design drawings.
>
> Top and bottom layers of east-west reinforcement were detected which show agreement with the design drawings.
>
> The concrete in the roof slab is in good to excellent condition. The nominal concrete compressive strength and modulus of elasticity are 5340 psi and 4.71 X 10^6 psi, respectively. Cracking and degradation were <u>not</u> detected

* This apparent drawing contradiction was later found to be in error. See p. A69 and Section 4.1.2 of the body of the text.

in the reinforced concrete roof slab.

No evidence of reinforcing steel corrosion was found in the roof slab.

GALLERIES

The results of the pulse echo NDT for the gallery walls and floors using the 45° and 90° transducers are compiled in Table 1c and 2b, respectively. The concrete compressive strength and modulus of elasticity values obtained are included. The ground penetrating radar NDT locations, results, and observations for the galleries are in Table 3d. In the pipe gallery on the shielding wall, there is not sufficient accessible surface area for conducting radar NDT. The crane gallery is not accessible for NDT without special radiation work procedures. The conclusions about the condition, concrete strength properties, and construction details for the gallery walls and floor slabs from the NDT data are:

Generally intermittent, bonded construction joints were detected in the shielding wall at the base in the electrical gallery, the pipe gallery floor level, and the operating gallery floor level. Design drawings also show a shielding wall construction joint at the crane gallery floor level, but this area is not readily accessible for a NDT confirmation.

The operating gallery and pipe gallery floor slab construction joints at the north and shielding walls are unbonded.

The radar NDT was only able to detect reinforcing steel on the front face (gallery side) of the 7 ft. to 9 ft. thick shielding wall. Vertical reinforcement bars 24 in. on center were detected in the operating gallery shielding wall. These bars are unspliced at the operating gallery floor level. Therefore, is is likely that they are continuous down to the pipe gallery floor level. In the electrical gallery, vertical dowels 24 in. on centers anchoring the base of the shielding wall to the base slab were detected.

Radar NDT for the Operating and Electrical gallery floor slabs detected north-south reinforcement steel layers which closely agree with the design drawings. The top layers of wire fabric detected in these slabs are not shown on the drawing (Note: Concrete core drilling in the electrical gallery floor slab, subsequent to the NDT, for installing compressor anchors did encounter 1/4 inch diameter wire fabric, Reference 4).

The concrete in the gallery shielding wall is in good to excellent condition. The nominal concrete compressive

strength and modulus of elasticity is 6000 psi and 4.87×10^6 psi, respectively. Cracking and degradation were not detected in the concrete gallery shielding wall.

No evidence of reinforcing steel corrosion was found in the gallery shielding wall, and the floor slabs.

ASSESSMENT OF STRUCTURAL CONDITION

Both nondestructive test data and visual observations at the 221-B Building confirm a good to excellent in-situ condition for the concrete and reinforcement steel. The visible cracks, in a majority of cases, on the north and south walls have a total depth of less than 6 inches. The east end wall of the 221-B Building is in much different condition. In the east wall total depth cracks, concrete deterioration at joints and spalling at structural member intersections were identified in an earlier study.

The single major apparent structural deficiency in the 221-B Building is the almost total lack of concrete bond at most horizontal construction joints in the north, south, and gallery shielding walls. Either continuous or spliced vertical reinforcement is located at these construction joints, however, the reinforcement is for the most part, in excellent condition with no reduction in section due to corrosion.

There are two generally accepted industry methods or concepts for repairing reinforced concrete nonbonding, and restoring structural load paths if required. The two methods frequently used in conjunction, are epoxy adhesive injection and external post tensioning. Epoxy injection repairs are very effective in reestablishing both bond and continuity to planes of weakness. The physical properties or strength of epoxy far exceed those of concrete. The

epoxy restored volume of material in the repair areas become stronger than the nominal concrete capabilities.

External post tensioning is an old repair technique for reinforced concrete structures. Modern applications are gaining due to advancements in the materials, hardware and post tensioning techniques required. The application of external post tensioning to restore structural stability has been recently used for buildings, bridges and pressure tanks such as concrete water storage and concrete silos used for mass storage, such as at central terminals.

In summary, two methods used in conjunction could facilitate an effective restoration and establish bond at all the open horizontal joints in the 221-B Building walls, if required. Epoxy injection and external post tensioning to effectively bond horizontal joints in walls could greatly increase the current 221-B Building earth resistance and seismic capacity if need be. These methods appear feasible because, the building concrete and reinforcement steel are in excellent condition, allowing the use of high stress or load in these materials during post tensioning.

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2. Drawings W69334, W69565, W69566, W70064.

3. "Nondestructive Evaluation of Concrete in Buildings 221-B and 271-B, Hanford Site, Washington", Muenow and Associates, Inc., Charlotte, N. C. 1986.

4. Personal Communication, F. R. Vollert, Westinghouse Hanford Company, September 19, 1988.

TABLE 1a
PULSE ECHO, 45° BEAM TRANSDUCER
221-B NORTH CANYON WALL

DATE	TEST LOCATION/DESCRIPTION	RESULTS/REMARKS
8/22/88	Sections 8 & 9, Pipe Gallery Floor Level (Elevation 698) 4 Test Points, Wave Propagation Down	Horizontal Joint Located in 3' Thick Wall Section, Unbonded at 2 Test Points, Interior 18" Weakly Bonded at Other 2 Test Points
8/22/88	Section 8, Operating Gallery Floor Level (Elevation 712) 2 Test Points, Wave Propagation Down	Possible Horizontal Joint in 3' Thick Wall Section, Solid Bond at 1 Test Point, Weak Bond at Other Test Point
8/22/88	Section 8, Underside of Crane Gallery Floor Slab (Elevation 724) 3 Test Points, Wave Propagation Up	Possible Horizontal Joint in 3' Thick Wall Section, solid bond at one test point, 70% unbonded at one test point, and 40% weak bond at one test point.
8/22/88	Section 8, Crane Gallery Floor Level (Elevation 728) 2 Test Points, Wave Propagation Down	Horizontal Joint Located in 5' Thick Wall Section, Both Test Points Unbonded
8/22/88	Section 8, Crane Rail Level (Elevation 737.25) 2 Test Points, Wave Propagation Up	Horizontal Construction Joint Confirmed at 5' to 3' Thickness Change, Unbonded, Random Fractures on Joint Surfaces, Both Test Points
8/22/88	Section 8, Roof to Wall Juncture (Elevation 750.67) 2 Test Points, Wave Propagation Up	Horizontal Joint Located in 4' Thick Wall Section, Mostly Unbonded, Some Intermittent Bond, Both Test Points
8/23/88	Section 2 at RR Tunnel, Underside of Crane Gallery Floor Slab (Elevation 724), Wave Propagation Up, 2 Test Points	Possible Horizontal Joint, Inside 2' of 3' Thick Wall Section Has Good Bond, inside 1' has good bond at one test point
8/23/88	Section 2 at RR Tunnel, Crane Gallery Floor Level (Elevation 728), Wave Propagation Up, Unable to Examine Full Depth	Horizontal Joint Located in 5' Thick Wall Section, Weak Bond Over Depth Examined

TABLE 1a
PULSE ECHO, 45° BEAM TRANSDUCER
221-B NORTH CANYON WALL

DATE	TEST LOCATION/DESCRIPTION	RESULTS/REMARKS
8/25/88	Section 2 at RR Tunnel, Crane Gallery Floor Level (Elevation 728), 2 Test Points, Wave Propagation Down	Horizontal Joint Located in 5' Thick Wall Section. Interior 20-30% Weakly Bonded, Exterior Depth Has Intermittent Weak Bond
8/23/88	Section 2 at RR Tunnel, Crane Rail Level (Elevation 737.25), Wave Propagation Down	Horizontal Construction Joint Confirmed at 5' to 3' Thickness Change, Unbonded
8/23/88	Section 2 at RR Tunnel, Roof to Wall Juncture (Elevation 750.67), Wave Propagation Up, 2 Test Points	Horizontal Joint Located in 4' Thick Wall Section, Unbonded at 1 Test Point, 60% Weak Intermittent Bond at Second Test Point
8/23/88	Section 2 at RR Tunnel, Visible Horizontal Cracks Near Roof to Wall Joint, 2 Places, Wave Propagation Up	Crack Depths are 3" to 6"
8/26/88	Section 16, Visible Pour Line 30" Above Grade (Elevation 696), Wave Propagation Down	Unbonded Construction Joint, Located in 3' Thick Wall Section
8/26/88	Section 16, Pipe Gallery Floor Level (Elevation 698), Wave Propagation Up	Possible Horizontal Joint, Solid Bond, 3' Thick Wall Section
8/26/88	Section 16, Operating Gallery Floor Level (Elevation 712), Wave Propagation Down	Possible Horizontal Joint, Solid Bond, 3' Thick Wall Section
8/26/88	Section 16, Underside of Crane Gallery Floor Slab (Elevation 724), Wave Propagation Down	Interior 30% of 3' Thick Wall Weakly Bonded
8/26/88	Section 16, Crane Gallery Floor Level (Elevation 728), Wave Propagation Down	Possible Horizontal Joint, Well Bonded, 5' Thick Wall
8/26/88	Section 16, Crane Rail Level (Elevation 737.25), Wave Propagation Down	Horizontal Construction Joint Confirmed at 5' to 3' Wall Thickness Change, Unbonded

TABLE 1a
PULSE ECHO, 45° BEAM TRANSDUCER
221-B NORTH CANYON WALL

DATE	TEST LOCATION/DESCRIPTION	RESULTS/REMARKS
8/26/88	Section 16, Roof to Wall Juncture (Elevation 750.67), Wave Propagation Up	Horizontal Joint Located in 4' Thick Wall Section
8/24/88	Section 12, Roof to Wall Juncture (Elevation 750.67), Wave Propagation Up, Crossing Visible Horizontal and Diagonal Cracks, 2 Test Points	Horizontal Joint Located in 4' Thick Wall Section, 70% to 80% Unbonded, Cracking is Shallow or Superficial

TABLE 1b
PULSE ECHO, 45° BEAM TRANSDUCER
221-B SOUTH CANYON WALL

DATE	TEST LOCATION/DESCRIPTION	RESULTS/REMARKS
8/23/88	Section 8, Hot Pipe Trench Floor Level (Elevation 701), 3 Test Points, Wave Propagation Up and Down	Horizontal Joint Located in 8'-6" Thick Wall Section, Only the Mid 1/3 of the Thickness Bonded Strongly at 2 Test Points, the Interior 2/3 of the Thickness Bonded Strongly at the Third Test Point
8/23/88	Section 8, Top of Hot Pipe Trench, (Elevation 707), 2 Test Points, Wave Propagation Up	Horizontal Joint Located in 8'-6" Thick Wall Section, Interior 2/3 Bonded Strongly at 1 Test Point, Only the Mid 1/3 Bonded Strongly at Other Test Point
8/23/88	Section 8, 15' Below Crane Rail Level (Elevation 720), Wave Propagation Up	Pour Line Located in 5' Thick Wall Section, The Back (or Interior) 2/3 is Bonded, This Pour Line Only Found in Section 8
8/25/88	Section 8, Same Level as Above, (Elevation 720), 2 Test Points, Wave Propagation Down	70% to 90% of the 5' Thick Wall Section Has Strong Bond at This Pour Line
8/25/88	Section 8, 3'-4' Above the Canyon Deck Level, (Elevation 715), 2 Test Points, Wave Propagation Down	Horizontal Joint Located in 5' Thick Wall Section, The Back (or Interior) 1/3 is Weakly Bonded, The Outer 2/3 Has Intermittent Areas of Weak Bond
8/23/88	Section 8, Crane Rail Level (Elevation 737.25), Wave Propagation Down	Horizontal Construction Joint Confirmed at 5' to 3' Thickness Change, Unbonded, Numerous Discontinuities Noted

TABLE 1b
PULSE ECHO, 45° BEAM TRANSDUCER
221-B SOUTH CANYON WALL

DATE	TEST LOCATION/DESCRIPTION	RESULTS/REMARKS
8/23/88	Section 8, At Miscellaneous, Visible Horizontal and Diagonal Cracks Above the Crane Rail Level, 2 Test Points, Wave Propagation Up	Crack Depths from the Exterior Surface are 5" to 9"
8/23/88	Section 8, Roof to Wall Junctures, (Elevation 750.67), Wave Propagation Up and Down	Horizontal Joint Located in 1' Thick Wall Section, Mostly Unbonded, Intermittent Weakly Bonded Areas
8/25/88	Section 18, Hot Pipe Trench Floor Level, (Elevation 701), Wave Propagation Down	Horizontal Joint Located in 8'-6" Thick Wall Section, Only the Back (or Interior) 1' is Bonded Weakly, Remainder Unbonded
8/25/88	Section 18, Top of Hot Pipe Trench, (Elevation 707), Wave Propagation Down	Horizontal Joint Located in 8'-6" Thick Wall Section, Some Weak Bond Near Interior Surface, Remainder is Unbonded
8/25/88	Section 18, 3'-1' Above the Canyon Deck Level (Elevation 715), Wave Propagation Down	Horizontal Joint Located in 5' Thick Wall Section, the Back (or Interior) 50% is Bonded
8/25/88	Section 18, Crane Rail Level, (Elevation 737.25), Wave Propagation Down	Horizontal Construction Joint Confirmed at 5' to 3' Thickness Change, Unbonded
8/25/88	Section 18, Roof to Wall Juncture, (Elevation 750.67), Wave Propagation Up	Horizontal Joint Located in 4' Thick Wall Section, 60% to 70% Bonded from the Back (or Interior) Surface
8/25/88	Section 16, Hot Pipe Trench Floor Level, (Elevation 701), Wave Propagation Down	Horizontal Joint Located in 8'-6" Thick Wall Section, the Back (or Interior) 2/3 is Weakly Bonded, Outer 1/3 is Unbonded
8/25/88	Section 16, Top of Hot Pipe Trench, (Elevation 707), Wave Propagation Down	Horizontal Joint Located in 8'-6" Thick Wall Section, the Back (or Interior) 70% is Strongly Bonded, There are Intermittently Bonded Areas in the Outer 1/3

TABLE 1b
PULSE ECHO, 45° BEAM TRANSDUCER
221-B SOUTH CANYON WALL

DATE	TEST LOCATION/DESCRIPTION	RESULTS/REMARKS
8/25/88	Section 16, 3'-4' Above the Canyon Deck Level, (Elevation 715), Wave Propagation Down	Horizontal Joint Located in 5' Thick Wall Section, Unbonded
8/25/88	Section 16, Crane Rail Level, (Elevation 737.25), Wave Propagation Down	Horizontal Construction Joint Confirmed at 5' to 3' Thickness Change, Unbonded
8/25/88	Section 16, Roof to Wall Juncture, (Elevation 750.67), Wave Propagation Up	Horizontal Joint Located in 4' Thick Wall Section, the Back (or Interior) 50% is Strongly Bonded, the Outer 50% is Unbonded
8/25/88	Section 7, Hot Pipe Trench Floor Level, (Elevation 701), Wave Propagation Down	Horizontal Joint Located in 8'-6" Thick Wall Section, Bonded Strongly Except for the Front (or Exterior) 18" of Thickness
8/25/88	Section 7, Top of Hot Pipe Trench, (Elevation 707), Wave Propagation Down	Horizontal Joint Located in 8'-6" Thick Wall Section, the Back (or Interior) 60% is Strongly Bonded, the Remainder is Unbonded
8/25/88	Section 7, 3'-4' Above Canyon Deck Level, (Elevation 715), Wave Propagation Down	Horizontal Joint Located in 5' Thick Wall Section, the Back (or Interior) 50% is Strongly Bonded, the Outer 50% Thickness is Unbonded
8/25/88	Section 7, Crane Rail Level, (Elevation 737.25), Wave Propagation Down	Horizontal Construction Joint Confirmed at 5' to 3' Thickness Change, Unbonded
8/25/88	Section 7, Roof to Wall Juncture, (Elevation 750.67), Wave Propagation Up	Horizontal Joint Located in 4' Thick Wall Section, Unbonded

TABLE 1c
PULSE ECHO, 45° BEAM TRANSDUCER
221-B GALLERIES

DATE	TEST LOCATION/DESCRIPTION	RESULTS/REMARKS
8/24/88	Operating Gallery at Cell 5, North Wall and Floor Slab Juncture, Wave Propagation Down Wall and In Floor Towards Wall	No Horizontal Joint in 3' Thick North Wall at Elevation 712, Operating Gallery Floor Slab Keys Into North Wall Slab Joint at Wall Unbonded
8/24/88	Operating Gallery at Cell 5, Shielding Wall and Floor Slab Juncture, Wave Propagation Down Wall and In Floor Towards Wall	Horizontal Joint Located in 7' Thick Shielding Wall at Elevation 712, Joint is 50% Bonded Intermittently, Unbonded Construction Joint Between Floor Slab and the Shielding Wall, No Slab/Shield Wall Key Detected
8/24/88	Operating Gallery at Cell 9, North Wall and Floor Slab Juncture, Wave Propagation Down Wall and In Floor Towards Wall	Same as Cell 5 Test at this Juncture, but No Slab Key Detected
8/24/88	Operating Gallery at Cell 9, Shielding Wall and Floor Slab Juncture, Wave Propagation Down Wall and In Floor Slab Towards Wall	Same as Cell 5 Test at this Juncture, Except Horizontal Joint in Shielding Wall is 14" Above Operating Gallery Floor
8/24/88	Operating Gallery at Cell 11, North Wall and Floor Slab Juncture, Wave Propagation Down Wall and In Floor Towards Wall	Same as Cell 9 Test at this Juncture
8/24/88	Operating Gallery at Cell 11, Shielding Wall and Floor Slab Juncture, Wave Propagation Down Wall and In the Floor Towards Wall	Horizontal Joint Located in 7' Thick Shielding Wall About 14" Above Floor, the Back (or Interior) 2' is Strongly Bonded, the Outer 5' is Unbonded, Unbonded Construction Joint Between Floor Slab and Shielding Wall, No Slab/Shield Wall Key Detected
8/24/88	Operating Gallery at Cell 16, North Wall and Floor Slab Juncture, Wave Propagation Down Wall and In Floor Towards Wall	Same as Cell 9 Test at this Juncture

TABLE Ic
PULSE ECHO, 45° BEAM TRANSDUCER
221-B GALLERIES

DATE	TEST LOCATION/DESCRIPTION	RESULTS/REMARKS
8/24/88	Operating Gallery at Cell 15, Shielding Wall and Floor Slab Juncture, Wave Propagation Down Wall and In Floor Towards Wall	Same as Cell 9 Test at this Juncture
8/23/88	Pipe Gallery at Cell 22, North Wall and Floor Slab Juncture, Wave Propagation Down Wall and In Floor Towards Wall	No Horizontal Joint in 3' Thick North Wall at Elevation 698, Pipe Gallery Floor Slab Keys Into North Wall, Slab Joint at Wall Unbonded
8/23/88	Pipe Gallery at Cell 22, Shielding Wall and Floor Slab Juncture, Wave Propagation Down Wall and In Floor Towards Wall	Horizontal Joint Located in 9' Thick Shielding Wall at Elevation 698, Intermittent Bonding, Pipe Gallery Floor Keys Into Shielding Wall, Slab Joint at Wall Unbonded
8/23/88	Pipe Gallery at Cell 15, North Wall and Floor Slab Juncture, Wave Propagation Down Wall and In Floor Towards Wall	Possible Horizontal Joint Located in 3' Thick N Wall at Elevation 698, Intermittent Bonding, Pipe Gallery Floor Keys Into North Wall, Slab Joint at Wall Unbonded
8/23/88	Pipe Gallery at Cell 15, Shielding Wall and Floor Slab Juncture, Wave Propagation Down Wall and In Floor Towards Wall	Same as Cell 22 Test at this Juncture
8/25/88	Electrical Gallery at Cell 22, North Wall and Base Slab Juncture, Wave Propagation Down Wall	Horizontal Joint Located at Base of 3' Thick North Wall (Elevation 683.5), Well Bonded
8/25/88	Electrical Gallery at Cell 22, Shielding Wall and Base Slab Juncture, Wave Propagation Down Wall	Horizontal Joint Located at Base of 9' Thick Shielding Wall (Elevation 683.5), the Back (or Interior) 1/3 is Well Bonded, Center 1/3 Unbonded, Outer 1/3 Intermittently Bonded
8/25/88	Electrical Gallery at Cell 23, North Wall and Base Slab Juncture, Wave Propagation Down Wall	Horizontal Joint Located at Base of 3' Thick North Wall (Elevation 683.5), Unbonded

TABLE 1c
PULSE ECHO, 45° BEAM TRANSDUCER
221-B GALLERIES

DATE	TEST LOCATION/DESCRIPTION	RESULTS/REMARKS
8/25/88	Electrical Gallery at Cell 23, Shielding Wall and Base Slab Juncture, Wave Propagation Down Wall	Horizontal Joint Located at Base of 9' Thick Shielding Wall (Elevation 683.5), the Back (or Interior) 1/3 is Weakly Bonded, the Outer 2/3 is Unbonded
8/25/88	Electrical Gallery at Cell 25, North Wall and Base Slab Juncture, Wave Propagation Down Wall	Same as Cell 22 Test at this Juncture
8/25/88	Electrical Gallery at Cell 25, Shielding Wall and Base Slab Juncture, Wave Propagation Down Wall	Horizontal Joint Located at Base of 9' Thick Shielding Wall, the Back (or Interior) 20% is Strongly Bonded, the Outer 80% Has About 50% Effective Bond

TABLE 2a PULSE ECHO, 90° BEAM TRANSDUCER, 221-B BUILDING WALLS

NO.	DATE	LOCATION	THICKNESS (FEET)	VELOCITY (FT/SEC)	COMPRESSIVE STRENGTH (PSI)	ELASTIC MODULUS (10 PSI)	COMMENTS
1	8/22/88	Section 8 North Wall, Edge of Roof Slab	68	14,620	5,800	4.82	
2	8/22/88	Section 8, North Wall, Edge of Roof Slab	68	14,620	5,800	4.82	
3	8/22/88	Section 8, North Wall, Below Roof Slab	4	15,430	6,300	4.91	
4	8/22/88	Section 8, North Wall, Below Roof Slab	4	15,430	6,300	4.91	
5	8/22/88	Section 8, North Wall, 2' Below Roof Slab	3.5	15,150	6,300	4.91	
6	8/22/88	Section 8, North Wall, Above Crane Rail	3	14,370	5,200	4.70	
7	8/22/88	Section 8, North Wall, Above Crane Rail	3	15,150	6,300	4.91	
8	8/22/88	Section 8, North Wall, Below Crane Rail	5	15,430	6,300	4.91	
9	8/22/88	Section 8, North Wall, Below Crane Rail	5	15,190	6,300	4.91	
10	8/22/88	Section 8, North Wall, Edge of Crane Gallery Floor Slab	22	15,720	6,500	4.95	
11	8/22/88	Section 8, North Wall, Below Crane Gallery Floor Slab	3	14,370	5,200	4.70	

NO.	DATE	LOCATION	THICKNESS (FEET)	VELOCITY (FT/SEC)	COMPRESSIVE STRENGTH (PSI)	ELASTIC MODULUS (10 PSI)	COMMENTS
12	8/22/88	Section 8, North Wall, Below Operating Gallery Floor	3	15,150	6,300	4.91	
13	8/22/88	Section 8, North Wall, Below Operating Gallery Floor	3	15,150	6,300	4.91	
14	8/22/88	Section 8, North Wall, Above Pipe Gallery Floor	3	15,430	6,300	4.91	
15	8/22/88	Section 8, North Wall, Below Pipe Gallery Floor	3	15,430	6,300	4.91	
16	8/23/88	Section 8, South Wall, Edge of Roof Slab	68	14,340	5,200	4.70	
17	8/23/88	Section 8, South Wall, Above Crane Rail Level	3	15,030	6,300	4.91	
18	8/23/88	Section 8, South Wall, Below Crane Rail Level	5	15,430	6,300	4.91	
19	8/23/88	Section 8, South Wall, Below Crane Rail Level	5	14,670	5,800	4.82	
20	8/23/88	Section 8, South Wall, Top of Hot Pipe Trench	8.5	15,720	6,500	4.95	
21	8/23/88	Section 8, South Wall, Bottom of Hot Pipe Trench	8.5	15,430	6,300	4.91	
22	8/23/88	Section 8, South Wall, Bottom of Hot Pipe Trench	8.5	15,430	6,300	4.91	

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NO.	DATE	LOCATION	THICKNESS (FEET)	VELOCITY (FT/SEC)	COMPRESSIVE STRENGTH (PSI)	ELASTIC MODULUS (10 PSI)	COMMENTS
23	8/23/88	Section 8, South Wall, Under Hot Pipe Trench	22.5	15,430	6,300	4.91	
24	8/23/88	Section 2, North Wall, Edge of Roof Slab	68	13,660	4,800	4.59	
25	8/23/88	Section 2, North Wall, Edge of Roof Slab	68	13,660	4,800	4.59	
26	8/23/88	Section 2, North Wall, Below Roof Slab	4	14,670	5,800	4.82	
27	8/23/88	Section 2, North Wall, Below Roof Slab	4	14,340	5,200	4.70	
28	8/23/88	Section 2, North Wall, Above Crane Rail	3	14,340	5,200	4.70	
29	8/23/88	Section 2, North Wall, Above Crane Rail	3	14,030	5,200	4.70	
30	8/23/88	Section 2, North Wall, Above Crane Rail	3	14,340	5,200	4.70	
31	8/23/88	Section 2, North Wall, Above Crane Rail	3	14,670	5,800	4.82	
32	8/23/88	Section 2, North Wall, Above Crane Rail	3	15,430	5,200	4.70	
33	8/23/88	Section 2, North Wall, Above Crane Rail	3	14,620	5,800	4.82	

NO.	DATE	LOCATION	THICKNESS (FEET)	VELOCITY (FT/SEC)	COMPRESSIVE STRENGTH (PSI)	ELASTIC MODULUS (10^6 PSI)	COMMENTS
34	8/23/88	Section 2, North Wall, At Joint At Crane Rail Elevation	3	14,800	5,800	4.82	
35	8/23/88	Section 2, North Wall, Below Crane Rail	5	14,800	5,800	4.82	
36	8/23/88	Section 2, North Wall, Below Crane Rail	5	14,340	5,200	4.70	
37	8/23/88	Section 2, North Wall, Below Crane Rail	5	14,670	5,800	4.82	
38	8/23/88	Section 2, North Wall, Below Crane Rail	5	14,340	5,200	4.70	
39	8/23/88	Section 2, North Wall, Edge of Crane Gallery Slab	22	15,430	6,300	4.91	
40	8/23/88	Section 2, North Wall, Under Crane Gallery Floor Slab	3	14,340	5,200	4.70	
41	8/23/88	Section 2, North Wall, Above RR Tunnel	3	14,670	5,800	4.82	
42	8/25/88	Section 8, South Wall, 3'-4' Above Canyon Deck	5	14,340	5,200	4.70	Above Horizontal Joint

NO.	DATE	LOCATION	THICKNESS (FEET)	VELOCITY (FT/SEC)	COMPRESSIVE STRENGTH (PSI)	ELASTIC MODULUS (10 PSI)	COMMENTS
43	8/25/88	Section 8, South Wall, 3'-4' Above Canyon Deck	5	15,010	5,800	4.82	Below Horizontal Joint
44	8/25/88	Section 8, South Wall, 3'-4' Above Canyon Deck	5	14,030	5,200	4.70	Above Horizontal Joint
45	8/25/88	Section 8, South Wall, 3'-4' Above Canyon Deck	5	14,670	5,800	4.82	Below Horizontal Joint
46	8/25/88	Section 2, North Wall, Above Crane Gallery Floor	5	14,340	5,200	4.70	
47	8/25/88	Section 2, North Wall, Above Crane Gallery Floor	5	14,670	5,800	4.82	
48	8/25/88	Section 2, North Wall, Edge of Crane Gallery Floor Slab	22	14,340	5,200	4.70	
49	8/25/88	Section 2, North Wall, Edge of Crane Gallery Floor Slab	22	14,340	5,200	4.70	
50	8/26/88	Section 18, South Wall, Edge of Roof Slab	68	14,670	5,800	4.82	
51	8/26/88	Section 18, South Wall, Below Roof Slab	4	14,030	4,800	4.59	
52	8/26/88	Section 18, South Wall, Below Crane Rail Level	5	14,670	5,800	4.82	

NO.	DATE	LOCATION	THICKNESS (FEET)	VELOCITY (FT/SEC)	COMPRESSIVE STRENGTH (PSI)	ELASTIC MODULUS (10 PSI)	COMMENTS
53	8/26/88	Section 18, South Wall, 3'-4' Above Canyon Deck	5	14,670	5,800	4.82	
54	8/26/88	Section 18, South Wall, Above Hot Pipe Trench	8.5	14,670	5,800	4.82	
55	8/26/88	Section 18, South Wall, Hot Pipe Trench Wall	8.5	14,340	5,200	4.70	
56	8/26/88	Section 16, South Wall, Edge of Roof Slab	68	14,670	5,800	4.82	
57	8/26/88	Section 16, South Wall, Above Crane Rail Level	3	14,340	5,200	4.70	
58	8/26/88	Section 16, South Wall, Below Crane Rail Level	5	14,670	5,800	4.82	
59	8/26/88	Section 16, South Wall, Above Hot Pipe Trench	8.5	15,360	6,300	4.91	
60	8/26/88	Section 16, Hot Pipe Trench Wall	8.5	14,340	5,200	4.70	
61	8/26/88	Section 7, South Wall, Edge of Roof Slab	68	15,010	6,300	4.91	
62	8/26/88	Section 7, South Wall, Below Roof Slab	4	15,010	6,300	4.91	

NO.	DATE	LOCATION	THICKNESS (FEET)	VELOC (FT/SEC)	STRENGTH (PSI)	ELASTIC MODULUS (10 PSI)	COMMENTS
63	8/26/88	Section 7, South Wall, Above Crane Rail Level	3	15,010	6,300	4.91	
64	8/26/88	Section 7, South Wall, Below Crane Rail Level	9	15,010	6,300	4.91	
65	8/26/88	Section 7, South Wall, Above Hot Pipe Trench Wall	8.5	15,010	6,300	4.91	
66	8/26/88	Section 7, South Wall, Hot Pipe Trench Wall	8.5	14,340	5,200	4.70	
67	8/26/88	Section 7, South Wall, Slab Under Hot Pipe Trench	22.5	15,360	6,300	4.91	
68	8/26/88	Section 16, North Wall, Edge of Roof Slab	68	14,670	5,800	4.82	
69	8/26/88	Section 16, North Wall, Below Roof Slab	4	15,010	6,300	4.91	
70	8/26/88	Section 16, North Wall, Above Crane Rail Level	3	15,010	6,300	4.91	
71	8/26/88	Section 16, North Wall, Below Crane Rail Level	5	15,010	6,300	4.91	
72	8/26/88	Section 16, North Wall, Below Crane Rail Level	5	15,010	6,300	4.91	

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NO.	DATE	LOCATION	THICKNESS (FEET)	VELOCITY (FT/SEC)	COMPRESSIVE STRENGTH (PSI)	ELASTIC MODULUS (10 PSI)	COMMENTS
73	8/26/88	Section 16, North Wall, Edge Crane Gallery Floor Slab	22	15,010	6,300	4.91	
74	8/26/88	Section 16, North Wall, Edge Crane Gallery Floor Slab	22	15,010	6,300	4.91	
75	8/26/88	Section 16, North Wall, Below Crane Gallery Floor	3	14,800	5,800	4.82	
76	8/26/88	Section 16, North Wall, Below Crane Gallery Floor	3	15,940	6,500	4.95	
77	8/26/88	Section 16, North Wall, Below Crane Gallery Floor	3	14,150	5,200	4.70	
78	8/24/88	Section 11, North Wall, Edge of Roof Slab	68	15,430	6,300	4.91	
79	8/24/88	Section 11, North Wall, Below Roof Slab	4	14,030	5,200	4.70	
80	8/24/88	Section 12, North Wall, Below Roof Slab	4	14,030	5,200	4.70	
81	8/24/88	Section 12, North Wall, Below Roof Slab	4	14,340	5,200	4.70	
82	8/24/88	16" x 29" x 17' Concrete Beam on 271-B Roof	17	14,670	5,800	4.82	Reference Test

NO.	DATE	LOCATION	THICKNESS (FEET)	VELOCITY (FT/SEC)	COMPRESSIVE STRENGTH (PSI)	ELASTIC MODULUS (10 PSI)	COMMENTS
83	8/24/88	16" x 29" x 17' Concrete Beam on 271-B Roof	2.4	15,730	6,500	4.95	Reference Test
84	8/24/88	16" x 29" x 17' Concrete Beam on 271-B Roof	2.4	14,670	5,800	4.82	Reference Test
85	8/24/88	16" x 29" x 17' Concrete Beam on 271-B Roof	2.4	15,360	6,300	4.91	Reference Test
86	8/24/88	16" x 29" x 17' Concrete Beam on 271-B Roof	1.3	14,670	5,800	4.82	Reference Test
87	8/24/88	16" x 29" x 17' Concrete Beam on 271-B Roof	1.3	14,670	5,800	4.82	Reference Test
88	8/24/88	16" x 29" x 17' Concrete Beam on 271-B Roof	1.3	14,670	5,800	4.82	Reference Test
89	8/24/88	Section 13, North Wall, Below Roof Slab	4	14,340	5,800	4.82	

TABLE 2b - PULSE ECHO, 90° BEAM TRANSDUCER, 221-B BUILDING GALLERIES

NO.	DATE	LOCATION	THICKNESS (FEET)	VELOCITY (FT/SEC)	COMPRESSIVE STRENGTH (PSI)	ELASTIC MODULUS (10 PSI)	COMMENTS
1	8/23/88	Pipe Gallery Shielding Wall at Cell 22	9	15,430	6,300	4.91	
2	8/23/88	Pipe Gallery, North Wall at Cell 22	3	15,720	6,500	4.95	
3	8/23/88	Pipe Gallery, Shielding Wall at Cell 15	9	14,670	5,800	4.82	
4	8/23/88	Pipe Gallery, North Wall at Cell 15	3	14,340	5,800	4.82	
5	8/24/88	Operating Gallery, North Wall at Cell 15	3	15,360	6,300	4.91	
6	8/24/88	Operating Gallery, North Wall at Cell 15	3	15,360	6,300	4.91	
7	8/24/88	Operating Gallery, Shielding Wall at Cell 15	7	15,730	6,500	4.95	
8	8/24/88	Operating Gallery, Shielding Wall at Cell 15	7	15,730	6,500	4.95	
9	8/24/88	Operating Gallery, Shielding Wall at Cell 15	7	15,730	6,500	4.95	
10	8/24/88	Operating Gallery, North Wall at Cell 11	3	15,360	6,300	4.91	

NO.	DATE	LOCATION	THICKNESS (FEET)	VELOCITY (FT/SEC)	COMPRESSIVE STRENGTH (PSI)	ELASTIC MODULUS (10 PSI)	COMMENTS
11	8/24/88	Operating Gallery, North Wall at Cell 11	3	15,360	6,300	4.91	
12	8/24/88	Operating Gallery, Shielding Wall at Cell 11	7	14,670	5,800	4.82	
13	8/24/88	Operating Gallery, Shielding Wall at Cell 11	7	15,360	6,300	4.91	
14	8/24/88	Operating Gallery, North Wall at Cell 9	3	15,360	6,300	4.91	
15	8/24/88	Operating Gallery, North Wall at Cell 9	3	15,010	5,800	4.82	
16	8/24/88	Operating Gallery, Shielding Wall at Cell 9	7	15,360	6,300	4.91	
17	8/24/88	Operating Gallery, Shielding Wall at Cell 9	7	15,360	6,300	4.91	
18	8/24/88	Operating Gallery, North Wall at Cell 5	3	15,730	6,500	4.95	
19	8/24/88	Operating Gallery, North Wall at Cell 5	3	15,360	6,300	4.91	
20	8/24/88	Operating Gallery, Shielding Wall at Cell 5	7	15,730	6,500	4.95	
21	8/24/88	Operating Gallery, Shielding Wall at Cell 5	7	15,360	6,300	4.91	

NO.	DATE	LOCATION	THICKNESS (FEET)	VELOCITY (FT/SEC)	COMPRESSIVE STRENGTH (PSI)	ELASTIC MODULUS (10 PSI)	COMMENTS
22	8/25/88	Electrical Gallery, Shielding Wall at Cell 25	9	15,430	6,300	4.91	
23	8/25/88	Electrical Gallery, Shielding Wall at Cell 25	9	14,670	5,800	4.82	
24	8/25/88	Electrical Gallery, North Wall at Cell 25	3	15,010	5,800	4.82	
25	8/25/88	Electrical Gallery, North Wall at Cell 25	3	14,670	5,800	4.82	
26	8/25/88	Electrical Gallery, Base Slab at Cell 25	6	14,670	5,800	4.82	
27	8/25/88	Electrical Gallery, Base Slab at Cell 25	6	14,340	5,200	4.70	
28	8/25/88	Electrical Gallery, Shielding Wall at Cell 23	9	14,670	5,800	4.82	
29	8/25/88	Electrical Gallery, Shielding Wall at Cell 23	9	14,670	5,800	4.82	
30	8/25/88	Electrical Gallery, Base Slab at Cell 23	6	14,020	4,800	4.59	
31	8/25/88	Electrical Gallery, Base Slab at Cell 23	6	14,020	4,800	4.59	
32	8/25/88	Electrical Gallery, North Wall at Cell 23	3	14,670	5,800	4.82	

NO.	DATE	LOCATION	(FEET)	[illegible]	COMPRESSIVE STRENGTH (PSI)	ELASTIC MODULUS (10 PSI)	COMMENTS
33	8/25/88	Electrical Gallery, North Wall at Cell 23	3	14,670	5,800	4.82	
34	8/25/88	Electrical Gallery, Shielding Wall at Cell 22	9	15,360	6,300	4.91	
35	8/25/88	Electrical Gallery, Shielding Wall at Cell 22	9	14,670	5,800	4.82	
36	8/25/88	Electrical Gallery, Base Slab at Cell 22	6	15,010	5,800	4.82	
37	8/25/88	Electrical Gallery, Base Slab at Cell 22	6	15,010	5,800	4.82	
38	8/25/88	Electrical Gallery, North Wall at Cell 22	3	15,010	5,800	4.82	
39	8/25/88	Electrical Gallery, North Wall at Cell 22	3	15,010	5,800	4.82	

TABLE 2c PULSE ECHO, 90° BEAM TRANSDUCER, 221-B BUILDING ROOF

NO.	DATE	LOCATION	THICKNESS (FEET)	VELOCITY (FT/SEC)	COMPRESSIVE STRENGTH (PSI)	ELASTIC MODULUS (10 PSI)	COMMENTS
1A	8/27/88	East End of Roof (See Key Plan Attached)	77	14,080	4,800	4.59	Multiple Reflections from Open Joints in the North Wall
2A	8/27/8	East End of Roof (See Key Plan Attached)	77	14,490	5,200	4.70	Multiple Reflections from Open Joints in the North Wall
3A	8/27/88	East End of Roof (See Key Plan Attached)	77	14,950	5,200	4.70	Multiple Reflections from Open Joints in the North Wall
4A	8/27/88	East End of Roof (See Key Plan Attached)	77	14,490	5,200	4.70	Multiple Reflections from Open Joints in the North Wall
5A	8/27/88	East End of Roof (See Key Plan Attached)	77	14,490	5,200	4.70	Multiple Reflections from Open Joints in the North Wall
6A	8/27/88	East End of Roof (See Key Plan Attached)	77	14,710	5,800	4.82	Multiple Reflections from Open Joints in the North Wall
7A	8/27/88	East End of Roof (See Key Plan Attached)	77	14,490	5,200	4.70	Multiple Reflections from Open Joints in the North Wall
8A	8/27/88	East End of Roof (See Key Plan Attached)	77	14,290	5,200	4.70	Multiple Reflections from Open Joints in the North Wall
9A	8/27/88	East End of Roof (See Key Plan Attached)	77	14,710	5,800	4.82	Multiple Reflections from Open Joints in the North Wall
10A	8/27/88	East End of Roof (See Key Plan Attached)	77	14,290	5,200	4.70	Multiple Reflections from Open Joints in the North Wall
11A	8/27/88	East End of Roof (See Key Plan Attached)	77	14,490	5,200	4.70	Multiple Reflections from Open Joints in the North Wall
1B	8/27/88	East End of Roof (See Key Plan Attached)	3	14,710	5,800	4.82	

NO	DATE	LOCATION	THICKNESS (FEET)	VELOCITY (FT/SEC)	COMPRESSIVE STRENGTH (PSI)	ELASTIC MODULUS (10 PSI)	COMMENTS
2B	8/27/88	East End of Roof (See Key Plan Attached)	3	14,290	5,200	4.70	
3B	8/27/88	East End of Roof (See Key Plan Attached)	3	14,490	5,200	4.70	
4B	8/27/88	East End of Roof (See Key Plan Attached)	3	14,290	5,200	4.70	
5B	8/27/88	East End of Roof (See Key Plan Attached)	3	14,290	5,200	4.70	
6B	8/27/88	East End of Roof (See Key Plan Attached)	3	14,490	5,200	4.70	
7B	8/27/88	East End of Roof (See Key Plan Attached)	3	14,290	5,200	4.70	
8B	8/27/88	East End of Roof (See Key Plan Attached)	3	14,290	5,200	4.70	
9B	8/27/88	East End of Roof (See Key Plan Attached)	3	14,490	5,200	4.70	
10B	8/27/88	East End of Roof (See Key Plan Attached)	3	14,710	5,800	4.82	
11B	8/27/88	East End of Roof (See Key Plan Attached)	3	14,290	5,200	4.70	
1C	8/27/88	East End of Roof (See Key Plan Attached)	3	14,080	4,800	4.59	
2C	8/27/88	East End of Roof (See Key Plan Attached)	3	13,700	4,800	4.59	

NO.	DATE	LOCATION	THICKNESS (FEET)	VELOCITY (FT/SEC)	COMPRESSIVE STRENGTH (PSI)	ELASTIC MODULUS (10 PSI)	COMMENTS
3C	8/27/88	East End of Roof (See Key Plan Attached)	3	13,330	4,600	4.39	
4C	8/27/88	East End of Roof (See Key Plan Attached)	3	13,700	4,800	4.59	
5C	8/27/88	East End of Roof (See Key Plan Attached)	3	13,160	4,600	4.39	
6C	8/27/88	East End of Roof (See Key Plan Attached)	3	13,700	4,800	4.59	
7C	8/27/88	East End of Roof (See Key Plan Attached)	3	13,510	4,600	4.39	
8C	8/27/88	East End of Roof (See Key Plan Attached)	3	13,990	4,800	4.59	
9C	8/27/88	East End of Roof (See Key Plan Attached)	3	13,700	4,800	4.59	
10C	8/27/88	East End of Roof (See Key Plan Attached)	3	13,990	4,800	4.59	
11C	8/27/88	East End of Roof (See Key Plan Attached)	3	13,700	4,800	4.59	
1D	8/27/88	East End of Roof (See Key Plan Attached)	3	14,290	5,200	4.70	
2D	8/27/88	East End of Roof (See Key Plan Attached)	3	15,150	5,800	4.82	
3D	8/27/88	East End of Roof (See Key Plan Attached)	3	14,490	5,200	4.70	
4D	8/27/88	East End of Roof (See Key Plan Attached)	3	14,490	5,200	4.70	

NO	DATE	LOCATION	THICKNESS (FEET)	VELOCITY (FT/SEC)	COMPRESSIVE STRENGTH (PSI)	ELASTIC MODULUS (10 PSI)	COMMENTS
5D	8/27/88	East End of Roof (See Key Plan Attached)	3	14,490	5,200	4.70	
6D	8/27/88	East End of Roof (See Key Plan Attached)	3	14,490	5,200	4.70	
7D	8/27/88	East End of Roof (See Key Plan Attached)	3	14,710	5,800	4.82	
8D	8/27/88	East End of Roof (See Key Plan Attached)	3	14,490	5,200	4.70	
9D	8/27/88	East End of Roof (See Key Plan Attached)	3	14,490	5,200	4.70	
10D	8/27/88	East End of Roof (See Key Plan Attached)	3	14,710	5,800	4.82	
11D	8/27/88	East End of Roof (See Key Plan Attached)	3	14,490	5,200	4.70	
12D	8/27/88	East End of Roof (See Key Plan Attached)	3	14,490	5,200	4.70	
1E	8/27/88	East End of Roof (See Key Plan Attached)	77	14,490	5,200	4.70	Multiple Reflections from Open Joints in South Wall
2E	8/27/88	East End of Roof (See Key Plan Attached)	77	14,490	5,200	4.70	Multiple Reflections from Open Joints in South Wall
3E	8/27/88	East End of Roof (See Key Plan Attached)	77	14,710	5,800	4.82	Multiple Reflections from Open Joints in South Wall
4E	8/27/88	East End of Roof (See Key Plan Attached)	77	14,710	5,800	4.82	Multiple Reflections from Open Joints in South Wall

NO.	DATE	LOCATION	THICKNESS (FEET)	VELOCITY (FT/SEC)	COMPRESSIVE STRENGTH (PSI)	ELASTIC MODULUS (10 PSI)	COMMENTS
5E	8/27/88	East End of Roof (See Key Plan Attached)	77	14,490	5,200	4.70	Multiple Reflections from Open Joints in South Wall
6E	8/27/88	East End of Roof (See Key Plan Attached)	77	14,930	5,800	4.82	Multiple Reflections from Open Joints in South Wall
7E	8/27/88	East End of Roof (See Key Plan Attached)	77	14,710	5,800	4.82	Multiple Reflections from Open Joints in South Wall
8E	8/27/88	East End of Roof (See Key Plan Attached)	77	14,930	5,800	4.82	Multiple Reflections from Open Joints in South Wall
9E	8/27/88	East End of Roof (See Key Plan Attached)	77	14,490	5,200	4.70	Multiple Reflections from Open Joints in South Wall
10E	8/27/88	East End of Roof (See Key Plan Attached)	77	14,290	5,200	4.70	Multiple Reflections from Open Joints in South Wall
11E	8/27/88	East End of Roof (See Key Plan Attached)	77	14,710	5,800	4.82	Multiple Reflections from Open Joints in South Wall
1A	8/27/88	West End of Roof (See Key Plan Attached)	77	14,710	5,800	4.82	Multiple Reflections from Open Joints in North Wall
2A	8/27/88	West End of Roof (See Key Plan Attached)	77	14,290	5,200	4.70	Multiple Reflections from Open Joints in North Wall
3A	8/27/88	West End of Roof (See Key Plan Attached)	77	14,710	5,800	4.82	Multiple Reflections from Open Joints in North Wall
4A	8/27/88	West End of Roof (See Key Plan Attached)	77	14,490	5,200	4.70	Multiple Reflections from Open Joints in North Wall
5A	8/27/88	West End of Roof (See Key Plan Attached)	77	14,290	5,200	4.70	Multiple Reflections from Open Joints in North Wall

NO.	DATE	LOCATION	THICKNESS (FEET)	VELOCITY (FT/SEC)	COMPRESSIVE STRENGTH (PSI)	ELASTIC MODULUS (10 PSI)	COMMENTS
6A	8/27/88	West End of Roof (See Key Plan Attached)	77	14,290	5,200	4.70	Multiple Reflections from Open Joints in North Wall
1B	8/27/88	West End of Roof (See Key Plan Attached)	3	14,710	5,800	4.82	
2B	8/27/88	West End of Roof (See Key Plan Attached)	3	14,290	5,200	4.70	
3B	8/27/88	West End of Roof (See Key Plan Attached)	3	14,490	5,200	4.70	
4B	8/27/88	West End of Roof (See Key Plan Attached)	3	14,710	5,800	4.82	
5B	8/27/88	West End of Roof (See Key Plan Attached)	3	14,080	5,200	4.70	
6B	8/27/88	West End of Roof (See Key Plan Attached)	3	14,290	5,200	4.70	
1C	8/27/88	West End of Roof (See Key Plan Attached)	3	14,290	5,200	4.70	
2C	8/27/88	West End of Roof (See Key Plan Attached)	3	14,490	5,200	4.70	
3C	8/27/88	West End of Roof (See Key Plan Attached)	3	14,710	5,800	4.82	
4C	8/27/88	West End of Roof (See Key Plan Attached)	3	14,490	5,200	4.70	
5C	8/27/88	West End of Roof (See Key Plan Attached)	3	14,290	5,200	4.70	
6C	8/27/88	West End of Roof (See Key Plan Attached)	3	14,490	5,200	4.70	

NO.	DATE	LOCATION	THICKNESS (FEET)	VELOCITY (FT/SEC)	COMPRESSIVE STRENGTH (PSI)	ELASTIC MODULUS (10 PSI)	COMMENTS
1D	8/27/88	West End of Roof (See Key Plan Attached)	3	14,710	5,800	4.82	
2D	8/27/88	West End of Roof (See Key Plan Attached)	3	14,290	5,200	4.70	
3D	8/27/88	West End of Roof (See Key Plan Attached)	3	14,710	5,800	4.82	
4D	8/27/88	West End of Roof (See Key Plan Attached)	3	14,290	5,200	4.70	
5D	8/27/88	West End of Roof (See Key Plan Attached)	3	14,490	5,200	4.70	
6D	8/27/88	West End of Roof (See Key Plan Attached)	3	14,490	5,200	4.70	
1E	8/27/88	West End of Roof (See Key Plan Attached)	77	14,290	5,200	4.70	Multiple Reflections from Open Joints in South Wall
2E	8/27/88	West End of Roof (See Key Plan Attached)	77	14,490	5,200	4.70	Multiple Reflections from Open Joints in South Wall
3E	8/27/88	West End of Roof (See Key Plan Attached)	77	14,710	5,800	4.82	Multiple Reflections from Open Joints in South Wall
4E	8/27/88	West End of Roof (See Key Plan Attached)	77	14,490	5,200	4.70	Multiple Reflections from Open Joints in South Wall
5E	8/27/88	West End of Roof (See Key Plan Attached)	77	14,290	5,200	4.70	Multiple Reflections from Open Joints in South Wall
6E	8/27/88	West End of Roof (See Key Plan Attached)	77	14,490	5,200	4.70	Multiple Reflections from Open Joints in South Wall

TABLE 3a - PENETRATING RADAR NDT
221-B BUILDING NORTH WALL
ON EXTERIOR SURFACE

DATE	TEST LOCATION/DESCRIPTION	RESULTS/REMARKS
8/22/88	Section 8, At Pipe Gallery Floor Level (Elevation 698)	Vertical Bars 18" O.C., Each Face (EF), Unspliced
8/22/88	Section 8, 40" Above Pipe Gallery Floor Level	Vertical Bars 18" O.C., EF, Unspliced
8/22/88	Section 8, 30" Below Pipe Gallery Floor Level	Vertical Bars 18" O.C., EF, Unspliced
8/22/88	Section 8, The Operating Gallery Floor Level (Elevation 712)	Vertical Bars 18" O.C., EF, Spliced, Splices Extend 3' to 4' Above and Below Construction Joint at Gallery Floor Level
8/22/88	Section 8, 3' Below Underside of Crane Gallery Floor Slab (Elevation 721)	Vertical Bars, 18" O.C., EF, Unspliced
8/22/88	Section 8, Underside of Crane Gallery Floor Slab (Elevation 724)	Vertical Bars 18" O.C., EF, Unspliced
8/22/88	Section 8, Mid-Depth of Crane Gallery Slab	Vertical Bars 18" O.C., Detected on Outer Face Only, Unspliced
8/22/88	Section 8, 1' Below Topside of Crane Gallery Floor Slab	Vertical Bars, 18" O.C., Detected on Outer Face Only, Spliced
8/22/88	Section 8, Above the Crane Gallery Slab (Elevation 728)	Vertical Bars, 18" O.C., EF, Spliced
8/22/88	Section 8, At Joint at Crane Rail Level (Elevation 737.67)	Vertical Bars 18" O.C. (Average) EF, 10 of 12 Bars Detected EF are Spliced
8/22/88	Section 8, 1' Below Crane Rail Level	Same as at Crane Rail Level
8/22/88	Section 8, 2' Below Crane Rail Level	Vertical Bars, 18" O.C. EF, Unspliced
8/23/88	Section 2, 2' Below Underside of Crane Gallery Floor Slab	Vertical Bars 18" O.C. EF, Spliced

TABLE 3a - PENETRATING RADAR NDT
221-B BUILDING NORTH WALL
ON EXTERIOR SURFACE

DATE	TEST LOCATION/DESCRIPTION	RESULTS/REMARKS
8/23/88	Section 2, 3' Below Underside of Crane Gallery Floor Slab	Vertical Bars 18" O.C. (Possibly Closer) EF, Unspliced
8/23/88	Section 2, Mid Depth of Crane Gallery Floor Slab	Vertical Bars 18" O.C. Detected 2 Layers, Unspliced
8/23/88	Section 2, 1' Above Underside of Crane Gallery Floor Slab	Vertical Bars 18" O.C. Detected 2 Layers, Spliced
8/23/88	Section 2, 1' Below Joint at Crane Rail Level	Vertical Bars 24" O.C. (Possibly Closer) EF, Spliced
8/23/88	Section 2, 1' Above Joint at Crane Rail Level	Vertical Bars 24" O.C. (Possibly Closer) EF, Spliced
8/23/88	Section 2, 3' Above Joint at Crane Rail Level	Vertical Bars 24" O.C. (Possibly Closer) EF, Unspliced
8/23/88	Section 2, 1' Below Joint at Roof Slab (Elevation 750.67)	Vertical Bars 24" O.C. EF, Spliced
8/23/88	Section 2, 1' Above Joint at Roof Slab (Elevation 750.67)	Vertical Bars 24" O.C. Two Layers Detected, Spliced
8/23/88	Section 2, 2' Above Joint at Roof Slab	Same as 1' Above this Joint, but
8/24/88	Section 12, 3' Below Joint at Roof Slab	Vertical Bars, 24" O.C. (Possibly Closer) EF, Spliced
8/24/88	Section 12, 5' Below Joint at Roof Slab	Vertical Bars, 24" O.C. (Possibly Closer) EF, About Half the Bars are Spliced
8/24/88	Section 12, 7' Below Joint at Roof Slab	Vertical Bars, 24" O.C. (Possibly Closer) EF, Some Splices Detected
8/25/88	Section 2, 2' Above Topside of Crime Gallery Floor Slab	Vertical Bars, 18" O.C. EF, Unspliced
8/25/88	Section 2, At Topside of Crane Gallery Floor Slab (Elevation 728)	Vertical Bars 18" O.C. EF, Unspliced
8/23/88	Section 2, 3' Below Joint at Roof Slab (Elevation 750.67)	Same as 1' Below this joint, but not all Bars Spliced

TABLE 3a - PENETRATING RADAR NDT
221-B BUILDING NORTH WALL
ON EXTERIOR SURFACE

DATE	TEST LOCATION/DESCRIPTION	RESULTS/REMARKS
8/25/88	Section 2, 2' Below Topside of Crane Gallery Floor Slab	Vertical Bars, 18" O.C. Two Layers Detected, Unspliced
8/25/88	Section 16, At Pour Line 30" Above Grade (Elevation 695)	Vertical Bars, 18" O.C. EF, Unspliced
8/25/88	Section 16, 1' Below Pipe Gallery Floor Level	Vertical Bars, 18" O.C. EF, Unspliced
8/25/88	Section 16, Mid Depth of Crane Gallery Slab	Vertical Bars, 18" O.C. Two Layers Detected, Unspliced
8/25/88	Section 16, At Topside of Crane Gallery Slab (Elevation 723)	Vertical Bars, 18" O.C. EF, Unspliced
8/25/88	Section 16, 2' Below Joint at Crane Rail Level	Vertical Bars 24" O.C. (Possibly Closer) EF, Spliced
8/25/88	Section 16, 2' Above Joint at Crane Rail Level	Vertical Bars 24" O.C. EF, Unspliced
8/25/88	Section 16, 2' Below Joint at Roof Slab	Vertical Bars 24" O.C. EF, Spliced
8/25/88	Section 16, At Roof Slab to Wall Joint (Elevation 750.67)	Vertical Bars 24" O.C. EF, Spliced
8/25/88	Section 16, 2' Below Underside of Crane Gallery Floor Slab	Vertical Bars 24" O.C. EF. Unspliced
8/25/88	Section 16, 2' Above Operating Gallery Floor Level	Vertical Bars 24" O.C. EF, Spliced
8/25/88	Section 16, 4' Below Operating Gallery Floor Level	Vertical Bars 18" O.C. EF, 2 of 5 Bars Detected Spliced
8/25/88	Section 16, 2' Above Pipe Gallery Floor Level	Vertical Bars 18" O.C. EF, Unspliced
8/22/88	Section 8, At Roof Slab to Wall Joint (Elevation 750.67)	Vertical Bars 18" O.C. EF, Spliced
8/22/88	Section 8, 2' Above Roof Slab to Wall Joint	Vertical Bars 18" O.C. 2 Layers, Spliced
8/22/88	Section 8, 2' Below Roof Slab to Wall Joint	Vertical Bars 18" O.C. EF, Spliced

TABLE 3b - PENETRATING RADAR NDT
221-B BUILDING SOUTH WALL
ON EXTERIOR SURFACE

DATE	TEST LOCATION/DESCRIPTION	RESULTS/REMARKS
8/23/88	Section 8, At Joint at Top of Hot Pipe Trench (Elevation 707), 2 Tests	Vertical Bars 18" O.C. EF, Unspliced
8/23/88	Section 8, 3' Below Joint at Bottom of Hot Pipe Trench	No Vertical Reinforcement Bars
8/23/88	Section 8, 3' Below Joint at Top of Hot Pipe Trench	Vertical Bars 18" O.C. EF, Spliced
8/23/88	Section 8, 5' Below Joint at Top of Hot Pipe Trench	Vertical Bars 18" O.C. EF, Unspliced
8/23/88	Section 8, 6' to 8' Above Joint at Top of Hot Pipe Trench	Same as 5' Below This Joint
8/23/88	Section 8, 1' Above Joint at Crane Rail Level	Vertical Bars 18" O.C. EF, 10 of 14 Bars Detected are Spliced
8/23/88	Section 8, 2' Below Joint at Crane Rail Level	Vertical Bars 18" O.C. EF, Spliced
8/23/88	Section 8, 3' Above Joint at Crane Rail Level	Vertical Bars 18" O.C. EF, Unspliced
8/23/88	Section 8, 2' Above Joint at Crane Rail Level	Vertical Bars 18" O.C. EF, 8 of 14 Bars Detected are Spliced
8/23/88	Section 8, 1-1/2' Below Roof to Wall Joint	Vertical Bars 24" O.C. EF, Spliced (Drawing W69333 and W69566 Show Bars 24" O.C. Inside and Bars 8-1/2" O.C. Outside All Unspliced)
8/23/88	Section 8, 1' Above Roof to Wall Joint	Vertical Bars 18" O.C. 2 Layers, Spliced (Drawings W69333 and W69566 Show Bars 24" O.C. Inside and Bars 8-1/2" O.C. Outside All Unspliced)
8/23/88	Section 8, 2' Below Top of Roof Slab	Vertical Bars 18" O.C., Front Face Only Detected, Unspliced
8/25/88	Section 8, 2' Above Joint 3' to 4' Above Canyon Deck	Vertical Bars 18" O.C. EF, Unspliced

TABLE 3b - PENETRATING RADAR NDT
221-B BUILDING SOUTH WALL
ON EXTERIOR SURFACE

DATE	TEST LOCATION/DESCRIPTION	RESULTS/REMARKS
8/25/88	Section 3, On Joint 3' to 4' Above Canyon Deck	Vertical Bars 18" O.C. EF, Unspliced
8/25/88	Section 18, At joint At Bottom of Hot Pipe Trench (Elevation 701)	Vertical Bars 18" O.C., Front Face Only Detected, Unspliced (Drawings W69333 and W69566 Show No Reinforcing)
8/25/88	Section 18, 2' Above Joint at Bottom of Hot Pipe Trench	Vertical Bars, 24" O.C., Front Face Unspliced (Drawings Show Unspliced Dowels 17" O.C., Which Could Be Embedded to this Level)
8/25/88	Section 18, At Top of Hot Pipe Trench	Vertical Bars, 24" O.C. (Possibly Closer) Front Face Only Detected, Spliced (Drawings Show Spliced Bars 17" O.C. Front Face and Unspliced Bars 4-1/2" O.C. Back Face
8/25/88	Section 18, 4' Below Top of Hot Pipe Trench	Vertical Bars, 24" O.C. (Possibly Closer) Front Face Only, Spliced (should Be the Same Results as Test 2' Above Bottom of Hot Pipe Trench Which Detected Unspliced Bars. A Possible Explanation for this is that the Test at the Bottom of the Trench Shows Reinforcement Not on Drawings. Thus, there could be Spliced Vertical Bars at this Level.
8/25/88	Section 18, 3' Above Top of Hot Pipe Trench	Vertical Bars 24" O.C. (Possibly Closer) Front Face Only Detected, Unspliced
8/25/88	Section 18, 2' Above Top of Hot Pipe Trench	Vertical Bars 24" O.C. (Possibly Closer) Front Face Only Detected, Spliced

TABLE 3b - PENETRATING RADAR NDT
221-B BUILDING SOUTH WALL
ON EXTERIOR SURFACE

DATE	TEST LOCATION/DESCRIPTION	RESULTS/REMARKS
8/25/88	Section 18, 3' to 4' Above Canyon Deck Level	Vertical Bars 18" O.C. EF, Spliced
8/25/88	Section 18, 2' Below Crane Rail Level	Vertical Bars 18" O.C. EF, Spliced
8/25/88	Section 18, 2' Above Crane Rail Level	Vertical Bars 18" O.C. EF, Spliced
8/25/88	Section 18, 2' Above Roof to Wall Joint	Vertical Bars 24" O.C. (Possibly Closer) EF, Spliced (Different Than Shown by Drawings. See Section 8 Tests for This Area.)
8/25/88	Section 18, AT Roof to Wall Joint	Vertical Bars Same as 2' Above This Joint
8/25/88	Section 18, 2' Below Roof to Wall Joint	Vertical Bars Same as 2' Above This Joint
8/25/88	Section 16, At Bottom of Hot Pipe Trench	Vertical Bars 24" O.C., Front Face Only Detected, Unspliced (Drawings Show No Reinforcement at This Level)
8/25/88	Section 16, 2' Below Top of Hot Pipe Trench	Vertical Bars 24" O.C. (Possibly Closer) Front Face Only Detected, Unspliced
8/25/88	Section 16, At Top of Hot Pipe Trench	Vertical Bars, 24" O.C. (Possibly Closer) Front Face Only Detected, Unspliced
8/25/88	Section 16, 2' Below Crane Rail Level	Vertical Bars 24" O.C. (Possibly Closer) EF, Spliced
8/25/88	Section 16, 2' Above Crane Rail Level	Vertical Bars 24" O.C. (Possibly Closer) EF, Spliced
8/25/88	Section 16, 2' Above Roof to Wall Joint	Vertical Bars 24" O.C. (Possibly Closer) 2 Layers, Spliced (Different Than Shown By Drawings. See Section 8 Tests for This Area.)

TABLE 3b - PENETRATING RADAR NDT
221-B BUILDING SOUTH WALL
ON EXTERIOR SURFACE

DATE	TEST LOCATION/DESCRIPTION	RESULTS/REMARKS
8/25/88	Section 16, 2' Below Roof to Wall Joint	Vertical Bars Same as 2' Above This Joint
8/25/88	Section 7, 2' Above Roof to Wall Joint	Vertical Bars Same as Section 16 Tests for This Area
8/25/88	Section 7, 2' Below Roof to Wall Joint	Vertical Bars Same as Section 16 Tests for This Area
8/25/88	Section 7, 3' Above Crane Rail Level	Vertical Bars 24" O.C. (Possibly Closer) EF, 50% of Detected Bars Spliced
8/25/88	Section 7, 3' Below Crane Rail Level	Vertical Bars 24" O.C. (Possibly Closer) EF, 25% of Detected Bars Spliced
8/25/88	Section 7, 6' to 7' Above Canyon Deck Level	Vertical Bars 24" O.C. (Possibly Closer) EF, Unspliced
8/25/88	Section 7, 3' to 4' Above Canyon Deck Level	Vertical Bars 24" O.C. (Possibly Closer) EF, Unspliced
8/25/88	Section 7, 3' Above Top of Hot Pipe Trench	Vertical Bars 24" O.C. (Possibly Closer) Front Face Only Detected, Unspliced (Drawings Show Splices at This Level)
8/25/88	Section 7, 2' Below Top of Hot Pipe Trench	Vertical Bars 24" O.C. (Possibly Closer) Front Face Only Detected, Unspliced
8/25/88	Section 7, 2' Above Bottom of Hot Pipe Trench	Vertical Bars 24" O.C. (Possibly Closer) Front Face Only Detected, 30% of Bars Detected are Spliced (Drawing Show No Bars)
8/25/88	Section 7, Bottom of Hot Pipe Trench	Vertical Bars 24" O.C. (Possibly Closer) Front Face Only Detected, 40% of Bars Detected are Spliced (Drawings Show No Bars This Level)

TABLE 3c - PENETRATING RADAR NDT
221-B BUILDING ROOF
SECTIONS 12 AND 13

DATE	TEST LOCATION/DESCRIPTION	RESULTS/REMARKS
8/24/88	1' From North Edge of Roof 30' E-W Test To Detect N-S Bars	2 Layers of Spliced N-S Bars 18" O.C. (Drawings W69333 and W69566 Show Bars Unspliced)
8/24/88	4' From North Edge of Roof 30' E-W Test To Detect N-S Bars	Layer of Wire Fabric Top Face and 2 Layers of Spliced N-S Bars 18" O.C. (Drawings W69333 and W69566 Show Bars Unspliced and No Wire Fabric)
8/24/88	6' From North Edge of Roof, 30' E-W Test To Detect N-S Bars	Layers of Wire Fabric Top Face, 2 Layers of Unspliced N-S Bars 24" O.C. (Drawings W69333 and W69566 Show Bars at 17" O.C. and No Wire Fabric)
8/24/88	5' From North Edge of Roof, 30' E-W Test To Detect N-S Bars	Layer of Wire Fabric Top Face, 2 Layers of Spliced N-S Bars 17" O.C. (Drawings W69333 and W69566 Show Unspliced Bars and No Wire Fabric)
8/24/88	10' From North Edge of Roof, 30' E-W Test To Detect N-S Bars	Layer of Wire Mesh Top Face, No Top N-S Bars Detected, Bottom Layer of N-S Bars Detected, but Unable to Determine Spacing (Drawings W69333 and W69566 Show 2 Layers of N-S Bars and No Wire Fabric)
8/24/88	7-1/2' From North Edge of Roof, 30' E-W Test To Detect N-S Bars	Layer of Wire Mesh Top Face, 2 Layers of Unspliced N-S Bars, 24" to 36" O.C. (Drawings W69333 and W69566 Show N-S Bars 17" O.C. and No Wire Fabric)
8/24/88	Mid Span of Roof, 30' E-W Test To Detect N-S Bars	Bottom Layer of N-S Bars Unspliced 24" O.C. (Drawings W#69333 and W69566 Show Bottom N-S Bars 17" O.C.)
8/24/88	3' North of Mid Span, 30' E-W Test To Detect N-S Bars	Same as at Mid Span

TABLE 3c - PENETRATING RADAR NDT
221-B BUILDING ROOF
SECTIONS 12 AND 13

DATE	TEST LOCATION/DESCRIPTION	RESULTS/REMARKS
8/24/88	6' North of Mid Span, 30' E-W Test To Detect N-S Bars	Same as at Mid Span
8/24/88	N-S Test Across Roof to Detect E-W Bars	Bottom Layer of E-W Bars 24" O.C. Across Full Width, Top Face Has E-W Bars 24" O.C. Extending 14' Inward From North and South Edges. No Top E-W Steel in Center 32' of Roof Slab

TABLE 3d - PENETRATING RADAR NDT
221-B BUILDING GALLERIES

DATE	TEST LOCATION/DESCRIPTION	RESULTS/REMARKS
8/24/88	Operating Gallery at Cell 16 On Shielding Wall 1' Above Construction Joint	Vertical Bars 18" O.C. Front Face Only Detected, Unspliced
8/24/88	Operating Gallery Floor Next to Shielding Wall at Cell 16	N-S Bars 12" O.C. Top and Bottom, Unspliced, Wire Fabric at Top Face
8/24/88	Operating Gallery Floor on E-W Centerline at Cell 16	N-S Bars 12" O.C. Top and Bottom Faces, Unspliced
8/24/88	Operating Gallery at Cells 9 and 10, On Shielding Wall 5' Above Floor	Vertical Bars 18" O.C. Front Face Only Detected, Unspliced
8/24/88	Operating Gallery at Cells 9 and 10, On Shielding Wall 2' Above Floor	Vertical Bars 18" O.C. (Possibly Closer) Front Face Only Detected, Unspliced
8/24/88	Operating Gallery at Cells 9 and 10, On Shielding Wall 1' Above Floor	Same at 2' Above Floor
8/24/88	Operating Gallery Floor Slab 1' From Shielding Wall at Cells 9 and 10	N-S Bars 8" O.C., Top and Bottom, Some Spliced
8/24/88	Operating Gallery at Cells 5 and 6, On Shielding Wall 5' Above Floor	Vertical Bars 24" O.C. (Possibly Closer) Front Face Only Detected, Unspliced
8/24/88	Operating Gallery at Cells 5 and 6, On Shielding Wall Above Possible Construction Joint 2' Above Floor	Vertical Bars 18" O.C. Front Face Only Detected, Unspliced
8/24/88	Operating Gallery at Cells 5 and 6, On Shielding Wall 1' Above Floor	Vertical Bars 24" O.C. (Possibly Closer) Front Face Only Detected, Unspliced
8/24/88	Operating Gallery Floor Slab 1' From Shielding Wall at Cells 5 and 6	N-S Bars 12" O.C. Top and Bottom, Unspliced
8/25/88	Electrical Gallery at Cell 22, On Shielding Wall at Base	Vertical Bars 24" O.C. Front Face Only Detected, Unspliced

TABLE 3d - PENETRATING RADAR NDT
221-B BUILDING GALLERIES

DATE	TEST LOCATION/DESCRIPTION	RESULTS/REMARKS
8/25/88	Electrical Gallery at Cell 22. On Shielding Wall 5' Above Floor	No Vertical Bars Detected
8/25/88	Electrical Gallery at Cell 22, On North Wall 2' Above Floor	Vertical Bars 18" O.C. EF, Unspliced
8/25/88	Electrical Gallery at Cell 22, On North Wall at Base	Vertical Bars 18" O.C. EF, Spliced
8/25/88	Electrical Gallery at Cell 23, On Shielding Wall at Base	Vertical Bars 24" O.C. Front Face Only Detected, Unspliced
8/25/88	Electrical Gallery at Cell 23, On Shielding Wall 5' Above Floor	No Vertical Bars Detected
8/25/88	Electrical Gallery at Cell 25, On Shielding Wall at Base	Vertical Bars 24" O.C. Front Face Only Detected, Unspliced
8/25/88	Electrical Gallery at Cell 25, On North Wall at Base	Vertical Bars 24" O.C. EF, Spliced
8/25/88	Electrical Gallery at Cell 23, On North Wall 5' Above Floor	Vertical Bars 24" O.C. EF, Unspliced
8/25/88	Electrical Gallery at Cell 23, On Shielding Wall 2' Above Floor	Vertical Bars 24" O.C. Front Face Only Detected, Unspliced
8/25/88	Electrical Gallery at Cell 23, AT E-W Centerline of Base Floor	Wire Mesh on top Face Detected, No N-S Bars Detected
8/25/88	Electrical Gallery at Cell 23, On Base Floor 1' From Shielding Wall	Same as E-W Centerline of Base Floor
8/25/88	Electrical Gallery By the Compressor Floor Mounts On Base Floor	N-S Bars 10" O.C. Under Wire Mesh Detected on Top Face

WESTINGHOUSE HANFORD COMPANY **Survey Report**

Document No: WHC-SD-WM-SA-005
Title: B Plant Canyon Structure Seismic Evaluation
Date: December 20, 1989

To: [redacted]
Engineering Analysis Group

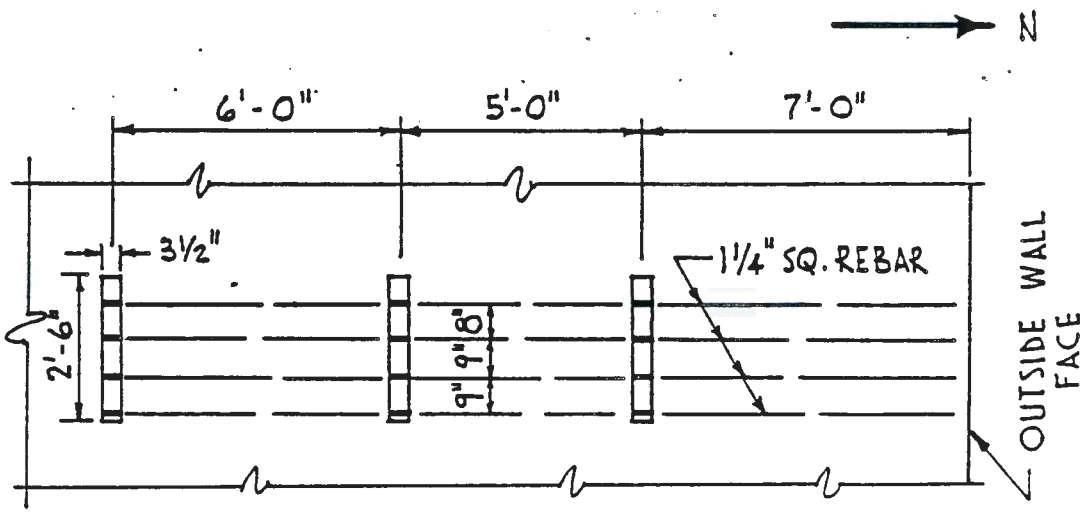
From: C. R. Cruz S6-81
B Plant Design Engineering

Description of Work:

On November 9, 1989, Richard Clayton and Carlos R. Cruz met at the roof of B Plant Building 221-B to measure the negative reinforcement (top rebars) spacing and their length in the North-South direction.

Three trenches were open exposing four (4) adjacent top rebars. The trenches, opened in the East-West direction, were located in a manner to follow the same rebar running from the external wall toward the mid-span of the roof slab.

This survey is confirming the measured spacing and length of the 1-1/4" sq. rebar with the details of Construction Drawing No. W69333 approved in 1943.



EXPOSED REBARS IN TRENCHES
SCALE : 1/4" = 1'-0"

Cog Engineer: C. R. Cruz
B Plant Design Eng.

Cog Eng. Manager: Dale F. Saleman
B Plant Design Eng.

Date: 12-20-89

Date: 12-20-89

Witness: R. E. Clayton
Richard E. Clayton QA

Date: 12/20/89

APPENDIX B

TYPICAL SSI (FLUSH) INPUT LISTING

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  1:    1    1
  2:221-B PLANT CANYON HORIZONTAL BLUME, 0.2g, 7%, 10 SEC
  3:  198   24    0  274  262   23    1    1   19    0
  4:    1    2
  5: BOTH LEFT
  6: 2048 2000      .005             .20
  7:HOR
  8:       20.    4
  9:        3.    4
 10:        6.    8
 11:       12.   16
 12:       20.   32
 13:    2    0    8    3    5    0
 14:    0
 15:       20.
 16:    0
 17:  .02       .05       .07
 18:  202    010101    000001
 19:   57    010101    000001
 20:   51    010101    000001
 21:   49    010101    000001
 22:   47    010101    000001
 23:   45    010101    000001
 24:   43    010101    000001
 25:   39    010101    000001
 26:    1    1    2   21   20 1  1    0.2000     110.0     1111.      460.    0.0320
 27:    2    2    3   22   21 2  1    0.2000     110.0     1111.      345.    0.0620
 28:    3    3    4   23   22 3  1    0.2000     110.0     1111.      273.    0.0880
 29:    4    4    5   24   23 4  1    0.2000     110.0     1111.      227.    0.1060
 30:    5    5    6   25   24 5  1    0.2400     120.0     4513.     1580.    0.0500
 31:    6    6    7   26   25 6  1    0.2400     120.0     4513.     1426.    0.0600
 32:    7    7    8   27   26 7  1    0.2400     120.0     4513.     1254.    0.0760
 33:    8    8    9   28   27 8  1    0.2400     120.0     4513.     1124.    0.0870
 34:    9    9   10   29   28 9  1    0.2900     120.0     5371.     1351.    0.0860
 35:   10   10   11   30   2910  1    0.2900     120.0     5371.     1255.    0.0930
 36:   11   11   12   31   3011  1    0.2900     120.0     5371.     1175.    0.0990
 37:   12   12   13   32   3112  1    0.2900     120.0     5371.     1116.    0.1050
 38:   13   13   14   33   3213  1    0.2900     120.0     5371.     1068.    0.I100
 39:   14   14   15   34   3314  1    0.3600     125.0    18780.     6613.    0.0490
 40:   15   15   16   35   3415  1    0.3600     125.0    18780.     6514.    0.0510
 41:   16   16   17   36   3516  1    0.3600     125.0    18780.     6415.    0.0520
 42:   17   17   18   37   3617  1    0.3600     125.0    18780.     6324.    0.0540
 43:   18   18   19   38   3718  1    0.3600     125.0    18780.     6240.    0.0550
 44:   19   19  262  263   3819  1    0.3600     125.0    18780.     6158.    0.0560
 45:   20   20   21   54   53 1  1    0.2000     110.0     1111.      460.    0.0320
 46:   21   21   22   55   54 2  1    0.2000     110.0     1111.      345.    0.0620
 47:   22   22   23   56   55 3  1    0.2000     110.0     1111.      273.    0.0880
 48:   23   23   24   51   56 4  1    0.2000     110.0     1111.      227.    0.1060
 49:   24   24   25   57   51 5  1    0.2400     120.0     4513.     1580.    0.0500
 50:   25   25   26   58   57 6  1    0.2400     120.0     4513.     1426.    0.0600
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51:	26	26	27	59	58 7	1	0.2400	120.0	4513.	1254.	0.0760
52:	27	27	28	60	59 8	1	0.2400	120.0	4513.	1124.	0.0870
53:	28	28	29	61	60 9	1	0.2900	120.0	5371.	1351.	0.0860
54:	29	29	30	62	6110	1	0.2900	120.0	5371.	1255.	0.0930
55:	30	30	31	63	6211	1	0.2900	120.0	5371.	1175.	0.0990
56:	31	31	32	64	6312	1	0.2900	120.0	5371.	1116.	0.1050
57:	32	32	33	65	6413	1	0.2900	120.0	5371.	1068.	0.1100
58:	33	33	34	66	6514	1	0.3600	125.0	18780.	6613.	0.0490
59:	34	34	35	67	6615	1	0.3600	125.0	18780.	6514.	0.0510
60:	35	35	36	68	6716	1	0.3600	125.0	18780.	6415.	0.0520
61:	36	36	37	69	6817	1	0.3600	125.0	18780.	6324.	0.0540
62:	37	37	38	70	6918	1	0.3600	125.0	18780.	6240.	0.0550
63:	38	38	263	264	7019	1	0.3600	125.0	18780.	6158.	0.0560
64:	39	57	58	73	72 6	1	0.2400	120.0	4513.	1426.	0.0600
65:	40	58	59	74	73 7	1	0.2400	120.0	4513.	1254.	0.0760
66:	41	59	60	75	74 8	1	0.2400	120.0	4513.	1124.	0.0870
67:	42	60	61	76	75 9	1	0.2900	120.0	5371.	1351.	0.0860
68:	43	61	62	77	7610	1	0.2900	120.0	5371.	1255.	0.0930
69:	44	62	63	78	7711	1	0.2900	120.0	5371.	1175.	0.0990
70:	45	63	64	79	7812	1	0.2900	120.0	5371.	1116.	0.1050
71:	46	64	65	80	7913	1	0.2900	120.0	5371.	1068.	0.1100
72:	47	65	66	81	8014	1	0.3600	125.0	18780.	6613.	0.0490
73:	48	66	67	82	8115	1	0.3600	125.0	18780.	6514.	0.0510
74:	49	67	68	83	8216	1	0.3600	125.0	18780.	6415.	0.0520
75:	50	68	69	84	8317	1	0.3600	125.0	18780.	6324.	0.0540
76:	51	69	70	85	8418	1	0.3600	125.0	18780.	6240.	0.0550
77:	52	70	264	265	8519	1	0.3600	125.0	18780.	6158.	0.0560
78:	53	72	73	97	96 6	1	0.2400	120.0	4513.	1426.	0.0600
79:	54	73	74	98	97 7	1	0.2400	120.0	4513.	1254.	0.0760
80:	55	74	75	99	98 8	1	0.2400	120.0	4513.	1124.	0.0870
81:	56	75	76	100	99 9	1	0.2900	120.0	5371.	1351.	0.0860
82:	57	76	77	101	10010	1	0.2900	120.0	5371.	1255.	0.0930
83:	58	77	78	102	10111	1	0.2900	120.0	5371.	1175.	0.0990
84:	59	78	79	103	10212	1	0.2900	120.0	5371.	1116.	0.1050
85:	60	79	80	104	10313	1	0.2900	120.0	5371.	1068.	0.1100
86:	61	80	81	105	10414	1	0.3600	125.0	18780.	6613.	0.0490
87:	62	81	82	106	10515	1	0.3600	125.0	18780.	6514.	0.0510
88:	63	82	83	107	10616	1	0.3600	125.0	18780.	6415.	0.0520
89:	64	83	84	108	10717	1	0.3600	125.0	18780.	6324.	0.0540
90:	65	84	85	109	10818	1	0.3600	125.0	18780.	6240.	0.0550
91:	66	85	265	266	10919	1	0.3600	125.0	18780.	6158.	0.0560
92:	67	96	97	112	111 6	1	0.2400	120.0	4513.	1426.	0.0600
93:	68	97	98	113	112 7	1	0.2400	120.0	4513.	1254.	0.0760
94:	69	98	99	114	113 8	1	0.2400	120.0	4513.	1124.	0.0870
95:	70	99	100	115	114 9	1	0.2900	120.0	5371.	1351.	0.0860
96:	71	100	101	116	11510	1	0.2900	120.0	5371.	1255.	0.0930
97:	72	101	102	117	11611	1	0.2900	120.0	5371.	1175.	0.0990
98:	73	102	103	118	11712	1	0.2900	120.0	5371.	1116.	0.1050
99:	74	103	104	119	11813	1	0.2900	120.0	5371.	1068.	0.1100
100:	75	104	105	120	11914	1	0.3600	125.0	18780.	6613.	0.0490

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101:	76	105	106	121	12015	1	0.3600	125.0	18780.	6514.	0.0510
102:	77	106	107	122	12116	1	0.3600	125.0	18780.	6415.	0.0520
103:	78	107	108	123	12217	1	0.3600	125.0	18780.	6324.	0.0540
104:	79	108	109	124	12318	1	0.3600	125.0	18780.	6240.	0.0550
105:	80	109	266	267	12419	1	0.3600	125.0	18780.	6158.	0.0560
106:	81	111	112	127	126 6	1	0.2400	120.0	4513.	1426.	0.0600
107:	82	112	113	128	127 7	1	0.2400	120.0	4513.	1254.	0.0760
108:	83	113	114	129	128 8	1	0.2400	120.0	4513.	1124.	0.0870
109:	84	114	115	130	129 9	1	0.2900	120.0	5371.	1351.	0.0860
110:	85	115	116	131	13010	1	0.2900	120.0	5371.	1255.	0.0930
111:	86	116	117	132	13111	1	0.2900	120.0	5371.	1175.	0.0990
112:	87	117	118	133	13212	1	0.2900	120.0	5371.	1116.	0.1050
113:	88	118	119	134	13313	1	0.2900	120.0	5371.	1068.	0.1100
114:	89	119	120	135	13414	1	0.3600	125.0	18780.	6613.	0.0490
115:	90	120	121	136	13515	1	0.3600	125.0	18780.	6514.	0.0510
116:	91	121	122	137	13616	1	0.3600	125.0	18780.	6415.	0.0520
117:	92	122	123	138	13717	1	0.3600	125.0	18780.	6324.	0.0540
118:	93	123	124	139	13818	1	0.3600	125.0	18780.	6240.	0.0550
119:	94	124	267	268	13919	1	0.3600	125.0	18780.	6158.	0.0560
120:	95	126	127	142	141 6	1	0.2400	120.0	4513.	1426.	0.0600
121:	96	127	128	143	142 7	1	0.2400	120.0	4513.	1254.	0.0760
122:	97	128	129	144	143 8	1	0.2400	120.0	4513.	1124.	0.0870
123:	98	129	130	145	144 9	1	0.2900	120.0	5371.	1351.	0.0860
124:	99	130	131	146	14510	1	0.2900	120.0	5371.	1255.	0.0930
125:	100	131	132	147	14611	1	0.2900	120.0	5371.	1175.	0.0990
126:	101	132	133	148	14712	1	0.2900	120.0	5371.	1116.	0.1050
127:	102	133	134	149	14813	1	0.2900	120.0	5371.	1068.	0.1100
128:	103	134	135	150	14914	1	0.3600	125.0	18780.	6613.	0.0490
129:	104	135	136	151	15015	1	0.3600	125.0	18780.	6514.	0.0510
130:	105	136	137	152	15116	1	0.3600	125.0	18780.	6415.	0.0520
131:	106	137	138	153	15217	1	0.3600	125.0	18780.	6324.	0.0540
132:	107	138	139	154	15318	1	0.3600	125.0	18780.	6240.	0.0550
133:	108	139	268	269	15419	1	0.3600	125.0	18780.	6158.	0.0560
134:	109	141	142	164	163 6	1	0.2400	120.0	4513.	1426.	0.0600
135:	110	142	143	165	164 7	1	0.2400	120.0	4513.	1254.	0.0760
136:	111	143	144	166	165 8	1	0.2400	120.0	4513.	1124.	0.0870
137:	112	144	145	167	166 9	1	0.2900	120.0	5371.	1351.	0.0860
138:	113	145	146	168	16710	1	0.2900	120.0	5371.	1255.	0.0930
139:	114	146	147	169	16811	1	0.2900	120.0	5371.	1175.	0.0990
140:	115	147	148	170	16912	1	0.2900	120.0	5371.	1116.	0.1050
141:	116	148	149	171	17013	1	0.2900	120.0	5371.	1068.	0.1100
142:	117	149	150	172	17114	1	0.3600	125.0	18780.	6613.	0.0490
143:	118	150	151	173	17215	1	0.3600	125.0	18780.	6514.	0.0510
144:	119	151	152	174	17316	1	0.3600	125.0	18780.	6415.	0.0520
145:	120	152	153	175	17417	1	0.3600	125.0	18780.	6324.	0.0540
146:	121	153	154	176	17518	1	0.3600	125.0	18780.	6240.	0.0550
147:	122	154	269	270	17619	1	0.3600	125.0	18780.	6158.	0.0560
148:	123	163	164	179	178 6	1	0.2400	120.0	4513.	1426.	0.0600
149:	124	164	165	180	179 7	1	0.2400	120.0	4513.	1254.	0.0760
150:	125	165	166	181	180 8	1	0.2400	120.0	4513.	1124.	0.0870

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151:	126	166	167	182	181 9	1	0.2900	120.0	5371.	1351.	0.0860
152:	127	167	168	183	18210	1	0.2900	120.0	5371.	1255.	0.0930
153:	128	168	169	184	18311	1	0.2900	120.0	5371.	1175.	0.0990
154:	129	169	170	185	18412	1	0.2900	120.0	5371.	1116.	0.1050
155:	130	170	171	186	18513	1	0.2900	120.0	5371.	1068.	0.1100
156:	131	171	172	187	18614	1	0.3600	125.0	18780.	6613.	0.0490
157:	132	172	173	188	18715	1	0.3600	125.0	18780.	6514.	0.0510
158:	133	173	174	189	18816	1	0.3600	125.0	18780.	6415.	0.0520
159:	134	174	175	190	18917	1	0.3600	125.0	18780.	6324.	0.0540
160:	135	175	176	191	19018	1	0.3600	125.0	18780.	6240.	0.0550
161:	136	176	270	271	19119	1	0.3600	125.0	18780.	6158.	0.0560
162:	137	178	179	211	210 6	1	0.2400	120.0	4513.	1426.	0.0600
163:	138	179	180	212	211 7	1	0.2400	120.0	4513.	1254.	0.0760
164:	139	180	181	213	212 8	1	0.2400	120.0	4513.	1124.	0.0870
165:	140	181	182	214	213 9	1	0.2900	120.0	5371.	1351.	0.0860
166:	141	182	183	215	21410	1	0.2900	120.0	5371.	1255.	0.0930
167:	142	183	184	216	21511	1	0.2900	120.0	5371.	1175.	0.0990
168:	143	184	185	217	21612	1	0.2900	120.0	5371.	1116.	0.1050
169:	144	185	186	218	21713	1	0.2900	120.0	5371.	1068.	0.1100
170:	145	186	187	219	21814	1	0.3600	125.0	18780.	6613.	0.0490
171:	146	187	188	220	21915	1	0.3600	125.0	18780.	6514.	0.0510
172:	147	188	189	221	22016	1	0.3600	125.0	18780.	6415.	0.0520
173:	148	189	190	222	22117	1	0.3600	125.0	18780.	6324.	0.0540
174:	149	190	191	223	22218	1	0.3600	125.0	18780.	6240.	0.0550
175:	150	191	271	272	22319	1	0.3600	125.0	18780.	6158.	0.0560
176:	151	206	207	225	224 1	1	0.2000	110.0	1111.	460.	0.0320
177:	152	207	208	226	225 2	1	0.2000	110.0	1111.	345.	0.0620
178:	153	208	209	227	226 3	1	0.2000	110.0	1111.	273.	0.0880
179:	154	209	204	228	227 4	1	0.2000	110.0	1111.	227.	0.1060
180:	155	204	210	229	228 5	1	0.2400	120.0	4513.	1580.	0.0500
181:	156	210	211	230	229 6	1	0.2400	120.0	4513.	1426.	0.0600
182:	157	211	212	231	230 7	1	0.2400	120.0	4513.	1254.	0.0760
183:	158	212	213	232	231 8	1	0.2400	120.0	4513.	1124.	0.0870
184:	159	213	214	233	232 9	1	0.2900	120.0	5371.	1351.	0.0860
185:	160	214	215	234	23310	1	0.2900	120.0	5371.	1255.	0.0930
186:	161	215	216	235	23411	1	0.2900	120.0	5371.	1175.	0.0990
187:	162	216	217	236	23512	1	0.2900	120.0	5371.	1116.	0.1050
188:	163	217	218	237	23613	1	0.2900	120.0	5371.	1068.	0.1100
189:	164	218	219	238	23714	1	0.3600	125.0	18780.	6613.	0.0490
190:	165	219	220	239	23815	1	0.3600	125.0	18780.	6514.	0.0510
191:	166	220	221	240	23916	1	0.3600	125.0	18780.	6415.	0.0520
192:	167	221	222	241	24017	1	0.3600	125.0	18780.	6324.	0.0540
193:	168	222	223	242	24118	1	0.3600	125.0	18780.	6240.	0.0550
194:	169	223	272	273	24219	1	0.3600	125.0	18780.	6158.	0.0560
195:	170	224	225	244	243 1	1	0.2000	110.0	1111.	460.	0.0320
196:	171	225	226	245	244 2	1	0.2000	110.0	1111.	345.	0.0620
197:	172	226	227	246	245 3	1	0.2000	110.0	1111.	273.	0.0880
198:	173	227	228	247	246 4	1	0.2000	110.0	1111.	227.	0.1060
199:	174	228	229	248	247 5	1	0.2400	120.0	4513.	1580.	0.0500
200:	175	229	230	249	248 6	1	0.2400	120.0	4513.	1426.	0.0600

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201:  176  230  231  250  249 7  1   0.2400   120.0   4513.   1254.   0.0760
202:  177  231  232  251  250 8  1   0.2400   120.0   4513.   1124.   0.0870
203:  178  232  233  252  251 9  1   0.2900   120.0   5371.   1351.   0.0860
204:  179  233  234  253  25210   1   0.2900   120.0   5371.   1255.   0.0930
205:  180  234  235  254  25311   1   0.2900   120.0   5371.   1175.   0.0990
206:  181  235  236  255  25412   1   0.2900   120.0   5371.   1116.   0.1050
207:  182  236  237  256  25513   1   0.2900   120.0   5371.   1068.   0.1100
208:  183  237  238  257  25614   1   0.3600   125.0  18780.   6613.   0.0490
209:  184  238  239  258  25715   1   0.3600   125.0  18780.   6514.   0.0510
210:  185  239  240  259  25816   1   0.3600   125.0  18780.   6415.   0.0520
211:  186  240  241  260  25917   1   0.3600   125.0  18780.   6324.   0.0540
212:  187  241  242  261  26018   1   0.3600   125.0  18780.   6240.   0.0550
213:  188  242  273  274  26119   1   0.3600   125.0  18780.   6158.   0.0560
214:  189   51   57   72   71 5  0   0.2000   150.0 260000. 260000.   0.0500
215:  190   71   72   96   94 5  0   0.2000   150.0 260000. 260000.   0.0500
216:  191   94   96  111  110 5  0   0.2000   150.0 260000. 260000.   0.0500
217:  192  110  111  126  125 5  0   0.2000   150.0 260000. 260000.   0.0500
218:  193  125  126  141  140 5  0   0.2000   150.0 260000. 260000.   0.0500
219:  194  140  141  163  161 5  0   0.2000   150.0 260000. 260000.   0.0500
220:  195  161  163  178  177 5  0   0.2000   150.0 260000. 260000.   0.0500
221:  196  177  178  210  204 5  0   0.2000   150.0 260000. 260000.   0.0500
222:  197   90   92  159  157 0  0   0.2000    48.0  83000.  83000.   0.0500
223:  198   92   94  161  159 0  0   0.2000    48.0  83000.  83000.   0.0500
224:  199   39   40   41   42 0  0   0.2000   150.0 260000. 260000.   0.0500
225:  3.50      1.4       0.833
226:  200   41   42   43   44 0  0   0.2000   150.0 260000. 260000.   0.0500
227:  3.00     0.100      0.833
228:  201   43   44   45   46 0  0   0.2000   150.0 260000. 260000.   0.0500
229:  5.00      4.00      0.833
230:  202   45   46   47   48 0  0   0.2000   150.0 260000. 260000.   0.0500
231:  3.00      0.90      0.833
232:  203   47   48   49   50 0  0   0.2000   150.0 260000. 260000.   0.0500
233:  3.00      0.90      0.833
234:  204   49   50   51   52 0  0   0.2000   150.0 260000. 260000.   0.0500
235:  3.00      0.90      0.833
236:  205   39   40   86   87 0  0   0.2000   150.0 260000. 260000.   0.0500
237:  3.50      1.40      0.833
238:  206   45   46   88   89 0  0   0.2000   150.0 260000. 260000.   0.0500
239:  4.00      2.00      0.833
240:  207   47   48   90   91 0  0   0.2000   150.0 260000. 260000.   0.0500
241:  1.00     0.033      0.833
242:  208   49   50   92   93 0  0   0.2000   150.0 260000. 260000.   0.0500
243:  1.00     0.033      0.833
244:  209   88   89   90   91 0  0   0.2000   150.0 260000. 260000.   0.0500
245:  7.00      11.4      0.833
246:  210   90   91   92   93 0  0   0.2000   150.0 260000. 260000.   0.0500
247:  9.00      24.3      0.833
248:  211   92   93   94   95 0  0   0.2000   150.0 260000. 260000.   0.0500
249:  9.00      24.3      0.833
250:  212   86   87  155  156 0  0   0.2000   150.0 260000. 260000.   0.0500
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251:  3.00      0.90     0.833
252:  213  157  158  159  160 0  0    0.2000     150.0   260000.   260000.    0.0500
253:  6.00      7.20     0.833
254:  214  159  160  161  162 0  0    0.2000     150.0   260000.   260000.    0.0500
255:  7.00      11.4     0.833
256:  215  155  156  192  193 0  0    0.2000     150.0   260000.   260000.    0.0500
257:  3.50      1.40     0.833
258:  216  159  160  202  203 0  0    0.2000     150.0   260000.   260000.    0.0500
259:  7.00      11.4     0.833
260:  217  192  193  194  195 0  0    0.2000     150.0   260000.   260000.    0.0500
261:  3.50      1.40     0.833
262:  218  194  195  196  197 0  0    0.2000     150.0   260000.   260000.    0.0500
263:  3.00     0.100     0.833
264:  219  196  197  198  199 0  0    0.2000     150.0   260000.   260000.    0.0500
265:  5.00      4.00     0.833
266:  220  198  199  200  201 0  0    0.2000     150.0   260000.   260000.    0.0500
267:  5.00      4.00     0.833
268:  221  200  201  202  203 0  0    0.2000     150.0   260000.   260000.    0.0500
269:  8.00      17.0     0.833
270:  222  202  203  204  205 0  0    0.2000     150.0   260000.   260000.    0.0500
271:  5.00      4.00     0.833
272:    1     SEED AND IDRISS (1972)  --  SAND
273:1.000 .984 .934 .826 .656 .443 .246 .115 .049 .049 .049
274:  0.5  0.8  1.7  3.2  5.6 10.0 15.5 21.0 24.6 24.8 24.6
275:    1     -22.0      22.0    0    0.0000
276:    2     -22.0      18.0    0    0.0000
277:    3     -22.0      14.0    0    0.0000
278:    4     -22.0      10.0    0    0.0000
279:    5     -22.0       6.0    0    0.0000
280:    6     -22.0       0.0    0    0.0000
281:    7     -22.0     -10.0    0    0.0000
282:    8     -22.0     -20.0    0    0.0000
283:    9     -22.0     -30.0    0    0.0000
284:   10     -22.0     -40.0    0    0.0000
285:   11     -22.0     -50.0    0    0.0000
286:   12     -22.0     -60.0    0    0.0000
287:   13     -22.0     -70.0    0    0.0000
288:   14     -22.0     -80.0    0    0.0000
289:   15     -22.0     -90.0    0    0.0000
290:   16     -22.0    -100.0    0    0.0000
291:   17     -22.0    -110.0    0    0.0000
292:   18     -22.0    -120.0    0    0.0000
293:   19     -22.0    -130.0    0    0.0000
294:   20     -11.0      22.0    0    0.0000
295:   21     -11.0      18.0    0    0.0000
296:   22     -11.0      14.0    0    0.0000
297:   23     -11.0      10.0    0    0.0000
298:   24     -11.0       6.0    0    0.0000
299:   25     -11.0       0.0    0    0.0000
300:   26     -11.0     -10.0    0    0.0000
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301:	27	-11.0	-20.0	0	0.0000
302:	28	-11.0	-30.0	0	0.0000
303:	29	-11.0	-40.0	0	0.0000
304:	30	-11.0	-50.0	0	0.0000
305:	31	-11.0	-60.0	0	0.0000
306:	32	-11.0	-70.0	0	0.0000
307:	33	-11.0	-80.0	0	0.0000
308:	34	-11.0	-90.0	0	0.0000
309:	35	-11.0	-100.0	0	0.0000
310:	36	-11.0	-110.0	0	0.0000
311:	37	-11.0	-120.0	0	0.0000
312:	38	-11.0	-130.0	0	0.0000
313:	39	0.0	75.5	0	0.0000
314:	40	0.0	75.5	4	0.0000
315:	41	0.0	60.3	0	0.0000
316:	42	0.0	60.3	4	0.0000
317:	43	0.0	60.0	0	9.4
318:	44	0.0	60.0	4	0.0000
319:	45	0.0	48.5	0	0.0000
320:	46	0.0	48.5	4	0.0000
321:	47	0.0	34.0	0	0.0000
322:	48	0.0	34.0	4	0.0000
323:	49	0.0	20.0	0	0.0000
324:	50	0.0	20.0	4	0.0000
325:	51	0.0	6.0	0	0.0000
326:	52	0.0	6.0	4	0.0000
327:	53	0.0	22.0	0	0.0000
328:	54	0.0	18.0	0	0.0000
329:	55	0.0	14.0	0	0.0000
330:	56	0.0	10.0	0	0.0000
331:	57	0.0	0.0	0	0.0000
332:	58	0.0	-10.0	0	0.0000
333:	59	0.0	-20.0	0	0.0000
334:	60	0.0	-30.0	0	0.0000
335:	61	0.0	-40.0	0	0.0000
336:	62	0.0	-50.0	0	0.0000
337:	63	0.0	-60.0	0	0.0000
338:	64	0.0	-70.0	0	0.0000
339:	65	0.0	-80.0	0	0.0000
340:	66	0.0	-90.0	0	0.0000
341:	67	0.0	-100.0	0	0.0000
342:	68	0.0	-110.0	0	0.0000
343:	69	0.0	-120.0	0	0.0000
344:	70	0.0	-130.0	0	0.0000
345:	71	8.5	6.0	0	0.0000
346:	72	8.5	0.0	0	0.0000
347:	73	8.5	-10.0	0	0.0000
348:	74	8.5	-20.0	0	0.0000
349:	75	8.5	-30.0	0	0.0000
350:	76	8.5	-40.0	0	0.0000

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351:	77	8.5	-50.0	0	0.0000
352:	78	8.5	-60.0	0	0.0000
353:	79	8.5	-70.0	0	0.0000
354:	80	8.5	-80.0	0	0.0000
355:	81	8.5	-90.0	0	0.0000
356:	82	8.5	-100.0	0	0.0000
357:	83	8.5	-110.0	0	0.0000
358:	84	8.5	-120.0	0	0.0000
359:	85	8.5	-130.0	0	0.0000
360:	86	17.0	75.5	0	0.0000
361:	87	17.0	75.5	4	0.0000
362:	88	17.0	48.5	0	0.0000
363:	89	17.0	48.5	4	0.0000
364:	90	17.0	34.0	0	10.5
365:	91	17.0	34.0	4	0.0000
366:	92	17.0	20.0	0	0.0000
367:	93	17.0	20.0	4	0.0000
368:	94	17.0	6.0	0	0.0000
369:	95	21.0	6.0	4	0.0000
370:	96	17.0	0.0	0	0.0000
371:	97	17.0	-10.0	0	0.0000
372:	98	17.0	-20.0	0	0.0000
373:	99	17.0	-30.0	0	0.0000
374:	100	17.0	-40.0	0	0.0000
375:	101	17.0	-50.0	0	0.0000
376:	102	17.0	-60.0	0	0.0000
377:	103	17.0	-70.0	0	0.0000
378:	104	17.0	-80.0	0	0.0000
379:	105	17.0	-90.0	0	0.0000
380:	106	17.0	-100.0	0	0.0000
381:	107	17.0	-110.0	0	0.0000
382:	108	17.0	-120.0	0	0.0000
383:	109	17.0	-130.0	0	0.0000
384:	110	25.3	6.0	0	0.0000
385:	111	25.3	0.0	0	0.0000
386:	112	25.3	-10.0	0	0.0000
387:	113	25.3	-20.0	0	0.0000
388:	114	25.3	-30.0	0	0.0000
389:	115	25.3	-40.0	0	0.0000
390:	116	25.3	-50.0	0	0.0000
391:	117	25.3	-60.0	0	0.0000
392:	118	25.3	-70.0	0	0.0000
393:	119	25.3	-80.0	0	0.0000
394:	120	25.3	-90.0	0	0.0000
395:	121	25.3	-100.0	0	0.0000
396:	122	25.3	-110.0	0	0.0000
397:	123	25.3	-120.0	0	0.0000
398:	124	25.3	-130.0	0	0.0000
399:	125	33.5	6.0	0	0.0000
400:	126	33.5	0.0	0	0.0000

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401:	127	33.5	-10.0	0	0.0000
402:	128	33.5	-20.0	0	0.0000
403:	129	33.5	-30.0	0	0.0000
404:	130	33.5	-40.0	0	0.0000
405:	131	33.5	-50.0	0	0.0000
406:	132	33.5	-60.0	0	0.0000
407:	133	33.5	-70.0	0	0.0000
408:	134	33.5	-80.0	0	0.0000
409:	135	33.5	-90.0	0	0.0000
410:	136	33.5	-100.0	0	0.0000
411:	137	33.5	-110.0	0	0.0000
412:	138	33.5	-120.0	0	0.0000
413:	139	33.5	-130.0	0	0.0000
414:	140	41.8	6.0	0	0.0000
415:	141	41.8	0.0	0	0.0000
416:	142	41.8	-10.0	0	0.0000
417:	143	41.8	-20.0	0	0.0000
418:	144	41.8	-30.0	0	0.0000
419:	145	41.8	-40.0	0	0.0000
420:	146	41.8	-50.0	0	0.0000
421:	147	41.8	-60.0	0	0.0000
422:	148	41.8	-70.0	0	0.0000
423:	149	41.8	-80.0	0	0.0000
424:	150	41.8	-90.0	0	0.0000
425:	151	41.8	-100.0	0	0.0000
426:	152	41.8	-110.0	0	0.0000
427:	153	41.8	-120.0	0	0.0000
428:	154	41.8	-130.0	0	0.0000
429:	155	50.0	75.5	0	0.0000
430:	156	50.0	75.5	4	0.0000
431:	157	50.0	34.0	0	15.9
432:	158	50.0	34.0	4	0.0000
433:	159	50.0	20.0	0	0.0000
434:	160	50.0	20.0	4	0.0000
435:	161	50.0	6.0	0	0.0000
436:	162	50.0	6.0	4	0.0000
437:	163	50.0	0.0	0	0.0000
438:	164	50.0	-10.0	0	0.0000
439:	165	50.0	-20.0	0	0.0000
440:	166	50.0	-30.0	0	0.0000
441:	167	50.0	-40.0	0	0.0000
442:	168	50.0	-50.0	0	0.0000
443:	169	50.0	-60.0	0	0.0000
444:	170	50.0	-70.0	0	0.0000
445:	171	50.0	-80.0	0	0.0000
446:	172	50.0	-90.0	0	0.0000
447:	173	50.0	-100.0	0	0.0000
448:	174	50.0	-110.0	0	0.0000
449:	175	50.0	-120.0	0	0.0000
450:	176	50.0	-130.0	0	0.0000

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451:	177	57.5	6.0	0	0.0000
452:	178	57.5	0.0	0	0.0000
453:	179	57.5	-10.0	0	0.0000
454:	180	57.5	-20.0	0	0.0000
455:	181	57.5	-30.0	0	0.0000
456:	182	57.5	-40.0	0	0.0000
457:	183	57.5	-50.0	0	0.0000
458:	184	57.5	-60.0	0	0.0000
459:	185	57.5	-70.0	0	0.0000
460:	186	57.5	-80.0	0	0.0000
461:	187	57.5	-90.0	0	0.0000
462:	188	57.5	-100.0	0	0.0000
463:	189	57.5	-110.0	0	0.0000
464:	190	57.5	-120.0	0	0.0000
465:	191	57.5	-130.0	0	0.0000
466:	192	65.0	75.5	0	0.0000
467:	193	65.0	75.5	4	0.0000
468:	194	65.0	60.3	0	0.0000
469:	195	65.0	60.3	4	0.0000
470:	196	65.0	60.0	0	9.4
471:	197	65.0	60.0	4	0.0000
472:	198	65.0	48.5	0	0.0000
473:	199	65.0	48.5	4	0.0000
474:	200	65.0	34.0	0	5.4
475:	201	65.0	34.0	4	0.0000
476:	202	65.0	20.0	0	0.0000
477:	203	65.0	20.0	4	0.0000
478:	204	65.0	6.0	0	0.0000
479:	205	65.0	6.0	4	0.0000
480:	206	65.0	22.0	0	0.0000
481:	207	65.0	18.0	0	0.0000
482:	208	65.0	14.0	0	0.0000
483:	209	65.0	10.0	0	0.0000
484:	210	65.0	0.0	0	0.0000
485:	211	65.0	-10.0	0	0.0000
486:	212	65.0	-20.0	0	0.0000
487:	213	65.0	-30.0	0	0.0000
488:	214	65.0	-40.0	0	0.0000
489:	215	65.0	-50.0	0	0.0000
490:	216	65.0	-60.0	0	0.0000
491:	217	65.0	-70.0	0	0.0000
492:	218	65.0	-80.0	0	0.0000
493:	219	65.0	-90.0	0	0.0000
494:	220	65.0	-100.0	0	0.0000
495:	221	65.0	-110.0	0	0.0000
496:	222	65.0	-120.0	0	0.0000
497:	223	65.0	-130.0	0	0.0000
498:	224	76.0	22.0	0	0.0000
499:	225	76.0	18.0	0	0.0000
500:	226	76.0	14.0	0	0.0000

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501:  227      76.0      10.0    0    0.0000
502:  228      76.0       6.0    0    0.0000
503:  229      76.0       0.0    0    0.0000
504:  230      76.0     -10.0    0    0.0000
505:  231      76.0     -20.0    0    0.0000
506:  232      76.0     -30.0    0    0.0000
507:  233      76.0     -40.0    0    0.0000
508:  234      76.0     -50.0    0    0.0000
509:  235      76.0     -60.0    0    0.0000
510:  236      76.0     -70.0    0    0.0000
511:  237      76.0     -80.0    0    0.0000
512:  238      76.0     -90.0    0    0.0000
513:  239      76.0    -100.0    0    0.0000
514:  240      76.0    -110.0    0    0.0000
515:  241      76.0    -120.0    0    0.0000
516:  242      76.0    -130.0    0    0.0000
517:  243      87.0      22.0    0    0.0000
518:  244      87.0      18.0    0    0.0000
519:  245      87.0      14.0    0    0.0000
520:  246      87.0      10.0    0    0.0000
521:  247      87.0       6.0    0    0.0000
522:  248      87.0       0.0    0    0.0000
523:  249      87.0     -10.0    0    0.0000
524:  250      87.0     -20.0    0    0.0000
525:  251      87.0     -30.0    0    0.0000
526:  252      87.0     -40.0    0    0.0000
527:  253      87.0     -50.0    0    0.0000
528:  254      87.0     -60.0    0    0.0000
529:  255      87.0     -70.0    0    0.0000
530:  256      87.0     -80.0    0    0.0000
531:  257      87.0     -90.0    0    0.0000
532:  258      87.0    -100.0    0    0.0000
533:  259      87.0    -110.0    0    0.0000
534:  260      87.0    -120.0    0    0.0000
535:  261      87.0    -130.0    0    0.0000
536:  262     -22.0    -140.0    0    0.0000
537:  263     -11.0    -140.0    0    0.0000
538:  264       0.0    -140.0    0    0.0000
539:  265       8.5    -140.0    0    0.0000
540:  266      17.0    -140.0    0    0.0000
541:  267      25.3    -140.0    0    0.0000
542:  268      33.5    -140.0    0    0.0000
543:  269      41.8    -140.0    0    0.0000
544:  270      50.0    -140.0    0    0.0000
545:  271      57.5    -140.0    0    0.0000
546:  272      65.0    -140.0    0    0.0000
547:  273      76.0    -140.0    0    0.0000
548:  274      87.0    -140.0    0    0.0000
549:COMM CONTROL MOTION - HORIZONTAL, ZPA=0.2G, 2000 POINTS, DT=0.005 SEC
550: 0.014141 0.015267 0.015951 0.016336 0.016758 0.016979 0.016954 0.016629
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551:	0.016387	0.014176	0.012741	0.012053	0.012072	0.013171	0.014876	0.017093
552:	0.01984	0.021099	0.023141	0.026073	0.029939	0.037493	0.045393	0.05311
553:	0.06014	0.06091	0.059508	0.055398	0.049001	0.037907	0.026378	0.014272
554:	0.001441	-0.00677	-0.01338	-0.01761	-0.01990	-0.01439	-0.00808	-0.00104
555:	0.006429	0.012848	0.018841	0.024301	0.029027	0.034387	0.038556	0.041552
556:	0.043204	0.042491	0.039895	0.03584	0.031054	0.026087	0.021089	0.016132
557:	0.01135	0.006611	0.002235	-0.00184	-0.00566	-0.00886	-0.01144	-0.01315
558:	-0.01381	-0.01283	-0.00985	-0.00415	0.004511	0.016791	0.030787	0.045693
559:	0.060681	0.073881	0.085265	0.094298	0.10078	0.10586	0.10828	0.10854
560:	0.10743	0.099773	0.091325	0.082144	0.072774	0.060798	0.049628	0.039169
561:	0.029597	0.022669	0.017903	0.015289	0.014354	0.017219	0.02086	0.024616
562:	0.027679	0.030691	0.032532	0.033329	0.033026	0.029921	0.026439	0.02358
563:	0.021906	0.023391	0.025428	0.027969	0.03118	0.035398	0.039848	0.044269
564:	0.048323	0.053083	0.056118	0.057932	0.059805	0.045853	0.030447	0.012098
565:	-0.00802	-0.04041	-0.07013	-0.09856	-0.12732	-0.13763	-0.14449	-0.14655
566:	-0.14507	-0.13217	-0.11847	-0.10416	-0.08990	-0.07835	-0.06819	-0.05979
567:	-0.05395	-0.04765	-0.04442	-0.04291	-0.04212	-0.04422	-0.04824	-0.05424
568:	-0.06112	-0.06946	-0.07723	-0.08476	-0.09199	-0.09783	-0.10186	-0.10388
569:	-0.10425	-0.10403	-0.10263	-0.10052	-0.09864	-0.09453	-0.09178	-0.09016
570:	-0.08947	-0.08805	-0.08727	-0.08651	-0.08492	-0.08225	-0.07819	-0.07344
571:	-0.06886	-0.06435	-0.06082	-0.05857	-0.05807	-0.05861	-0.05987	-0.06021
572:	-0.05828	-0.05260	-0.04369	-0.03127	-0.01547	0.002165	0.020401	0.037552
573:	0.052543	0.065438	0.074942	0.080607	0.082711	0.081845	0.080291	0.079037
574:	0.078263	0.078916	0.080944	0.085248	0.091849	0.098656	0.10578	0.11357
575:	0.12335	0.13698	0.15169	0.16498	0.17556	0.18212	0.18122	0.17632
576:	0.17065	0.16412	0.15822	0.15447	0.15272	0.2	0.14403	0.13623
577:	0.13238	0.13297	0.13592	0.13886	0.14099	0.14301	0.1462	0.15176
578:	0.15391	0.15342	0.15132	0.14713	0.14372	0.09985	0.05871	0.015343
579:	-0.03387	-0.05317	-0.07290	-0.0917	-0.11191	-0.10793	-0.10694	-0.10617
580:	-0.1034	-0.11177	-0.11725	-0.12081	-0.1245	-0.11521	-0.10683	-0.09761
581:	-0.08761	-0.08534	-0.08618	-0.08861	-0.08937	-0.08298	-0.07344	-0.06224
582:	-0.0501	-0.04108	-0.03075	-0.01980	-0.00955	0.001083	0.010458	0.019357
583:	0.027549	0.032723	0.034824	0.035142	0.036391	0.039454	0.045406	0.052987
584:	0.060168	0.068784	0.074023	0.078624	0.087285	0.076087	0.066732	0.053456
585:	0.035166	-0.01344	-0.05908	-0.10375	-0.15238	-0.14338	-0.13559	-0.12458
586:	-0.11021	-0.11389	-0.11867	-0.12308	-0.1247	-0.10939	-0.09127	-0.07275
587:	-0.05666	-0.04892	-0.04437	-0.03996	-0.03384	-0.02184	-0.01246	-0.00624
588:	-0.00062	-0.01846	-0.03492	-0.05171	-0.06869	-0.08951	-0.10701	-0.12281
589:	-0.13979	-0.13467	-0.12981	-0.12317	-0.11463	-0.1114	-0.10978	-0.11091
590:	-0.11487	-0.11704	-0.1195	-0.12092	-0.12082	-0.11817	-0.11247	-0.102
591:	-0.08590	-0.06542	-0.04249	-0.01931	0.002564	0.022328	0.038801	0.051288
592:	0.059384	0.062803	0.062503	0.059657	0.055638	0.052055	0.049549	0.048618
593:	0.048914	0.048999	0.048277	0.046563	0.04408	0.040725	0.035995	0.030222
594:	0.024863	0.013962	0.005742	0.000264	-0.00218	-0.00194	0.001463	0.006745
595:	0.012477	0.016899	0.020495	0.022402	0.021659	0.02228	0.020458	0.016544
596:	0.010334	0.006712	0.000955	-0.00629	-0.01483	-0.02664	-0.04011	-0.05471
597:	-0.06936	-0.08042	-0.08842	-0.09207	-0.09103	-0.08632	-0.07788	-0.06579
598:	-0.05034	-0.03170	-0.01282	0.004337	0.018346	0.027584	0.032927	0.035129
599:	0.035029	0.033055	0.028724	0.022628	0.016595	-0.00261	-0.01996	-0.03684
600:	-0.05421	-0.06420	-0.07293	-0.08025	-0.08700	-0.08468	-0.08129	-0.07542

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601:	-0.06649	-0.05902	-0.04980	-0.03985	-0.03013	-0.01718	-0.00521	0.005792
602:	0.015197	0.020207	0.022028	0.021871	0.021967	0.025485	0.031382	0.038908
603:	0.04692	0.053524	0.059644	0.065705	0.071684	0.076125	0.07762	0.076248
604:	0.074536	0.05535	0.039579	0.025241	0.009967	0.010209	0.009576	0.008196
605:	0.005200	0.006306	0.006404	0.007003	0.008499	0.003900	-0.00044	-0.00319
606:	-0.00263	0.011082	0.028327	0.047776	0.067487	0.076787	0.083788	0.08993
607:	0.096717	0.11244	0.12395	0.12937	0.13129	0.080407	0.031112	-0.01958
608:	-0.07339	-0.08886	-0.09833	-0.10028	-0.09909	-0.08579	-0.07621	-0.06714
609:	-0.05513	-0.04665	-0.03730	-0.03029	-0.02751	-0.02119	-0.01464	-0.00384
610:	0.012131	0.029471	0.043533	0.052974	0.060981	0.036901	0.015012	-0.00773
611:	-0.03294	-0.03904	-0.04177	-0.04020	-0.03673	-0.02186	-0.00852	0.004418
612:	0.0179	0.024227	0.02967	0.032661	0.031634	0.032906	0.029738	0.023559
613:	0.015677	0.003860	-0.00842	-0.01999	-0.02933	-0.03323	-0.03310	-0.02856
614:	-0.01972	-0.01149	-0.00233	0.005643	0.011447	0.00577	-0.00184	-0.01129
615:	-0.02212	-0.01983	-0.01591	-0.00953	-0.00127	0.001995	0.003935	0.003403
616:	-0.00011	-0.00307	-0.00871	-0.01671	-0.02671	-0.03925	-0.05089	-0.05927
617:	-0.06291	-0.05969	-0.05316	-0.04473	-0.03569	-0.02868	-0.02342	-0.02022
618:	-0.01865	-0.01930	-0.02127	-0.02470	-0.02913	-0.04095	-0.05198	-0.06186
619:	-0.07035	-0.07519	-0.07830	-0.08020	-0.08141	-0.08123	-0.07968	-0.07628
620:	-0.07098	-0.05606	-0.03957	-0.02218	-0.00506	0.007921	0.019003	0.027953
621:	0.034438	0.041506	0.046225	0.049089	0.049908	0.046512	0.040442	0.03343
622:	0.027883	0.027035	0.029172	0.03389	0.041106	0.04952	0.061157	0.07639
623:	0.094819	0.11441	0.13263	0.14769	0.15966	0.14614	0.12965	0.10874
624:	0.083204	0.068622	0.05417	0.040987	0.028477	0.025148	0.022598	0.022282
625:	0.024985	0.027227	0.030343	0.032935	0.034565	0.030174	0.026041	0.022168
626:	0.017938	0.016762	0.015419	0.014815	0.015315	0.022082	0.028856	0.035255
627:	0.041109	0.042755	0.042888	0.04091	0.03676	0.034526	0.031992	0.030062
628:	0.029073	0.027056	0.026716	0.028752	0.033201	0.041554	0.050064	0.057733
629:	0.063946	0.066209	0.066508	0.065519	0.064557	0.067024	0.07117	0.076589
630:	0.082474	0.086258	0.08989	0.093516	0.097018	0.1021	0.10684	0.1117
631:	0.11675	0.11539	0.11311	0.1109	0.11093	0.11773	0.12728	0.13713
632:	0.14465	0.14301	0.13694	0.12797	0.1187	0.10605	0.093288	0.078541
633:	0.06236	0.019662	-0.01860	-0.05337	-0.08754	-0.07648	-0.06428	-0.04955
634:	-0.03395	-0.02829	-0.02663	-0.02676	-0.02495	-0.02062	-0.01378	-0.00713
635:	-0.00266	-0.01363	-0.02645	-0.03979	-0.05227	-0.05946	-0.06618	-0.07424
636:	-0.08426	-0.09859	-0.11135	-0.122	-0.13157	-0.12284	-0.11394	-0.10477
637:	-0.09614	-0.09254	-0.08991	-0.08686	-0.08244	-0.07230	-0.06257	-0.05487
638:	-0.05070	-0.05323	-0.05960	-0.06801	-0.07609	-0.07743	-0.07401	-0.06453
639:	-0.04932	-0.03246	-0.01348	0.006791	0.027902	0.051105	0.071285	0.086202
640:	0.094841	0.095445	0.092598	0.089683	0.089377	0.091582	0.094163	0.095724
641:	0.097514	0.066759	0.037868	0.008212	-0.02363	-0.02982	-0.03268	-0.03088
642:	-0.02619	-0.01290	-0.00030	0.011912	0.02407	0.031598	0.037897	0.041589
643:	0.041339	0.042843	0.043216	0.045616	0.050674	0.05447	0.055657	0.054355
644:	0.053227	0.054563	0.059149	0.066133	0.074023	0.083818	0.092539	0.10203
645:	0.11488	0.11069	0.10537	0.094796	0.079889	0.032174	-0.01139	-0.05277
646:	-0.09617	-0.09225	-0.08867	-0.08276	-0.07531	-0.07619	-0.08054	-0.08780
647:	-0.09560	-0.0972	-0.09481	-0.08883	-0.08180	-0.07279	-0.06595	-0.05875
648:	-0.04846	-0.05334	-0.05919	-0.06945	-0.08405	-0.10085	-0.11564	-0.12816
649:	-0.14011	-0.1329	-0.12606	-0.11887	-0.11139	-0.11235	-0.11335	-0.11386
650:	-0.11353	-0.10542	-0.09608	-0.08561	-0.07526	-0.06986	-0.06785	-0.06855

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651:	-0.07000	-0.06852	-0.06568	-0.06155	-0.05614	-0.05042	-0.04323	-0.03466
652:	-0.02544	-0.02164	-0.02115	-0.02528	-0.03327	-0.0521	-0.07075	-0.08837
653:	-0.10451	-0.10893	-0.11035	-0.10883	-0.10528	-0.09990	-0.09443	-0.08957
654:	-0.08596	-0.08424	-0.08316	-0.08184	-0.08008	-0.07212	-0.06414	-0.05577
655:	-0.04678	-0.04120	-0.03565	-0.03027	-0.02551	-0.01614	-0.00953	-0.00476
656:	0.000692	-0.01313	-0.02575	-0.03988	-0.05661	-0.07366	-0.08937	-0.10374
657:	-0.11873	-0.11218	-0.1066	-0.09993	-0.09102	-0.09302	-0.09389	-0.09401
658:	-0.09315	-0.08085	-0.06618	-0.04918	-0.03115	-0.01855	-0.00758	0.002513
659:	0.012931	0.027089	0.040969	0.053502	0.063995	0.070227	0.074561	0.077967
660:	0.081409	0.083471	0.08483	0.084933	0.08422	0.074272	0.064652	0.055241
661:	0.046218	0.039919	0.034246	0.02816	0.020858	0.013536	0.006871	0.001973
662:	-0.00074	0.006960	0.017568	0.031079	0.046541	0.060089	0.073063	0.084823
663:	0.094677	0.10454	0.11114	0.11448	0.11474	0.11085	0.10493	0.098458
664:	0.092931	0.090137	0.088987	0.089124	0.090173	0.090831	0.091976	0.094029
665:	0.09732	0.10146	0.10549	0.10904	0.11265	0.10442	0.095895	0.086295
666:	0.076029	0.065527	0.056226	0.047249	0.037597	0.030555	0.024269	0.019299
667:	0.015221	0.019518	0.024206	0.029277	0.034105	0.03714	0.038996	0.040187
668:	0.040992	0.041947	0.04165	0.040298	0.038535	0.030978	0.022871	0.013961
669:	0.004804	-0.00452	-0.01291	-0.02097	-0.02932	-0.03415	-0.03787	-0.03968
670:	-0.03964	-0.03615	-0.03151	-0.02565	-0.01864	-0.01339	-0.00809	-0.00335
671:	0.000392	0.004383	0.007077	0.008398	0.008426	0.009130	0.009417	0.009633
672:	0.009852	0.010095	0.010663	0.011791	0.013383	0.017079	0.021072	0.025641
673:	0.030691	0.035853	0.040536	0.045243	0.0508	0.056804	0.062874	0.068234
674:	0.072837	0.0692	0.06468	0.058743	0.051496	0.044146	0.036834	0.029293
675:	0.021075	0.011098	0.001494	-0.00726	-0.01536	-0.01307	-0.01022	-0.00669
676:	-0.00300	-0.00103	-0.00018	0.000041	0.000295	-0.00094	-0.00323	-0.00733
677:	-0.01308	-0.02691	-0.04092	-0.05483	-0.06841	-0.07458	-0.07880	-0.08052
678:	-0.07994	-0.07680	-0.07201	-0.06527	-0.05633	-0.04545	-0.03340	-0.02113
679:	-0.00959	0.001179	0.010516	0.018765	0.026148	0.031664	0.035157	0.03643
680:	0.036136	0.028058	0.019568	0.010576	0.001349	-0.00488	-0.00978	-0.01332
681:	-0.01592	-0.01624	-0.01575	-0.01430	-0.01202	-0.00633	-0.00027	0.005914
682:	0.01182	0.016294	0.019841	0.022758	0.025442	0.026338	0.026868	0.026897
683:	0.026664	0.025366	0.024709	0.024764	0.025334	0.028922	0.032531	0.035888
684:	0.038603	0.039665	0.039326	0.037465	0.034086	0.029761	0.024158	0.017529
685:	0.010091	0.001852	-0.00691	-0.01580	-0.02425	-0.03476	-0.04464	-0.05383
686:	-0.06169	-0.06890	-0.07346	-0.07573	-0.07622	-0.07318	-0.06844	-0.06242
687:	-0.05615	-0.04639	-0.03798	-0.03097	-0.02535	-0.02369	-0.02349	-0.02461
688:	-0.02698	-0.02992	-0.03417	-0.03948	-0.04539	-0.05167	-0.05795	-0.06407
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690:	-0.03941	-0.03561	-0.03135	-0.02759	-0.02486	-0.01820	-0.01204	-0.00625
691:	-0.00109	0.003697	0.007425	0.010325	0.012843	0.013481	0.014247	0.015016
692:	0.015737	0.017693	0.02044	0.024309	0.029109	0.034502	0.039644	0.044201
693:	0.048098	0.052596	0.056387	0.059295	0.061179	0.061862	0.062094	0.062243
694:	0.062316	0.063372	0.064123	0.064845	0.065809	0.066497	0.067618	0.069378
695:	0.071833	0.078101	0.084593	0.091415	0.09854	0.10109	0.1018	0.1002
696:	0.097194	0.084165	0.070865	0.05623	0.039816	0.024856	0.010722	-0.00210
697:	-0.01430	-0.01793	-0.02136	-0.024	-0.02568	-0.02752	-0.02880	-0.02932
698:	-0.02891	-0.02591	-0.02220	-0.01773	-0.01256	-0.01176	-0.01154	-0.01224
699:	-0.01353	-0.01728	-0.02140	-0.02643	-0.03245	-0.03848	-0.04404	-0.04905
700:	-0.05389	-0.05438	-0.05431	-0.05339	-0.05193	-0.04783	-0.04361	-0.03900

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701:	-0.03417	-0.03035	-0.02748	-0.02551	-0.02415	-0.02287	-0.02204	-0.02130
702:	-0.02009	-0.01861	-0.01603	-0.01206	-0.00647	-0.00039	0.006403	0.013296
703:	0.020023	0.020572	0.020168	0.018274	0.01506	0.011525	0.008080	0.004551
704:	0.000417	-0.00091	-0.00252	-0.00405	-0.00572	-0.00562	-0.00659	-0.00868
705:	-0.01162	-0.01857	-0.02548	-0.03204	-0.03804	-0.04040	-0.04160	-0.04147
706:	-0.04025	-0.03825	-0.03596	-0.03334	-0.03021	-0.02626	-0.02216	-0.01825
707:	-0.01477	-0.01221	-0.01017	-0.00857	-0.00743	-0.00615	-0.00562	-0.00574
708:	-0.00624	-0.00939	-0.01278	-0.01629	-0.01954	-0.02382	-0.02735	-0.03055
709:	-0.03375	-0.03589	-0.03753	-0.03849	-0.03892	-0.03456	-0.02954	-0.02373
710:	-0.01754	-0.01140	-0.00619	-0.00164	0.002728	0.004317	0.005331	0.005769
711:	0.006400	0.002951	0.001074	0.000612	0.001348	0.006142	0.011729	0.017398
712:	0.022383	0.026039	0.028443	0.029454	0.028987	0.028981	0.028317	0.027437
713:	0.026411	0.026246	0.026071	0.026206	0.026748	0.027034	0.027339	0.027707
714:	0.028357	0.0313	0.034996	0.03965	0.045328	0.051169	0.057603	0.064293
715:	0.07084	0.077453	0.083191	0.088041	0.092148	0.093507	0.094159	0.094174
716:	0.093704	0.090788	0.087033	0.082189	0.076541	0.072163	0.068415	0.065311
717:	0.062382	0.06216	0.062407	0.064006	0.067308	0.072247	0.077339	0.082138
718:	0.086884	0.083255	0.079661	0.075602	0.070739	0.071412	0.071295	0.070537
719:	0.069362	0.062592	0.0552	0.046848	0.037748	0.028864	0.020659	0.012938
720:	0.005016	0.000381	-0.00426	-0.00828	-0.01162	-0.01648	-0.02196	-0.02838
721:	-0.03546	-0.04042	-0.04491	-0.04883	-0.05226	-0.05588	-0.05865	-0.06028
722:	-0.06079	-0.05902	-0.05658	-0.05366	-0.05041	-0.0478	-0.04481	-0.04158
723:	-0.03867	-0.03059	-0.02373	-0.01756	-0.01167	-0.00887	-0.00739	-0.00706
724:	-0.00674	-0.01457	-0.02161	-0.02860	-0.03561	-0.04030	-0.04336	-0.04500
725:	-0.04613	-0.04374	-0.04129	-0.03841	-0.03505	-0.02845	-0.02186	-0.01541
726:	-0.00927	-0.00682	-0.00518	-0.00440	-0.00448	-0.00341	-0.00325	-0.00388
727:	-0.00515	-0.00845	-0.01210	-0.01589	-0.01952	-0.02197	-0.02422	-0.02655
728:	-0.02920	-0.03296	-0.03683	-0.04039	-0.04326	-0.04538	-0.04690	-0.04810
729:	-0.04916	-0.05123	-0.05345	-0.05622	-0.05987	-0.06281	-0.06649	-0.07071
730:	-0.07526	-0.07881	-0.08129	-0.08181	-0.07991	-0.07493	-0.06779	-0.05886
731:	-0.04884	-0.03832	-0.02851	-0.01987	-0.01261	-0.00659	-0.00249	-0.00024
732:	0.000672	-0.00152	-0.00395	-0.00625	-0.00801	-0.00855	-0.00786	-0.00594
733:	-0.00306	-0.00057	0.002212	0.00536	0.009155	0.014183	0.019574	0.024668
734:	0.028872	0.030557	0.030886	0.029947	0.028133	0.027382	0.026915	0.026747
735:	0.026391	0.022266	0.017537	0.012948	0.009414	0.011728	0.015408	0.0199
736:	0.024624	0.026691	0.029055	0.032383	0.036813	0.045991	0.053356	0.058106
737:	0.061153	0.041923	0.022146	0.000590	-0.02298	-0.03574	-0.04667	-0.05541
738:	-0.06323	-0.06385	-0.06400	-0.06258	-0.05924	-0.05490	-0.05034	-0.04667
739:	-0.04472	-0.04221	-0.04112	-0.04072	-0.04087	-0.04217	-0.04473	-0.04812
740:	-0.05149	-0.05323	-0.05393	-0.05360	-0.05256	-0.05181	-0.05127	-0.05123
741:	-0.05190	-0.05301	-0.05491	-0.05713	-0.05889	-0.05970	-0.05842	-0.05427
742:	-0.04689	-0.03655	-0.02457	-0.01213	-0.00012	0.00738	0.012905	0.015822
743:	0.01617	0.013755	0.010217	0.006000	0.001470	-0.00082	-0.00180	-0.00102
744:	0.001088	0.006478	0.011612	0.016534	0.021608	0.024645	0.027565	0.030163
745:	0.032853	0.033613	0.035518	0.037889	0.039692	0.045337	0.050486	0.055492
746:	0.059876	0.064431	0.067768	0.070851	0.074233	0.076867	0.078498	0.0796
747:	0.0819	0.087804	0.097086	0.1086	0.11982	0.13014	0.13569	0.13769
748:	0.13872	0.12383	0.1067	0.085081	0.060124	0.012221	-0.03154	-0.07146
749:	-0.10949	-0.10279	-0.09266	-0.07816	-0.06102	-0.05634	-0.05396	-0.05312
750:	-0.05186	-0.04482	-0.03665	-0.02884	-0.0226	-0.03161	-0.04115	-0.04994

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754: 0.009244 0.015969  0.02593 0.040236  0.05842  0.07673 0.093955  0.10917
755:  0.12307  0.11644   0.1067 0.091541 0.070847 0.049975   0.0298 0.012654
756: -0.00079 0.000932 0.005904 0.013904 0.024355 0.024144 0.022504 0.017131
757: 0.007116 -0.00226 -0.01408 -0.02731 -0.04134 -0.05819 -0.07352 -0.08570
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761: -0.05400 -0.04640 -0.03490 -0.02035 -0.00452 0.012612 0.028989 0.045797
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763: -0.02080 -0.01728 -0.01071 -0.00053 0.011237 0.016062 0.018338 0.018401
764: 0.017227 0.017891 0.017939 0.016807 0.014011 0.010818 0.008321 0.008513
765:  0.01194 0.021353 0.031507 0.041981   0.0527 0.060793 0.066634  0.06992
766: 0.072254 0.056813 0.041671 0.024753 0.005082 -0.00654 -0.01628 -0.02283
767: -0.02723 -0.01923 -0.01105 -0.00221 0.007303 0.010202 0.011305 0.009725
768: 0.005525 0.001819 -0.00243 -0.00631 -0.00944 -0.01241 -0.01425 -0.01438
769: -0.01256 -0.00616 0.001047 0.008402 0.015478 0.020231 0.024472 0.028513
770: 0.032727 0.037288 0.042218 0.047633 0.053572 0.057638 0.061176 0.063692
771: 0.064925 0.060608 0.053696 0.043918 0.032264 0.019275 0.007336 -0.00313
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779: 0.029333 0.038224 0.046418 0.053729 0.059815 0.065411 0.070334 0.074779
780: 0.078061 0.081753 0.083301 0.083662 0.083697 0.083398 0.082539 0.081405
781: 0.080635 0.080847 0.081717 0.083482 0.086621 0.090481 0.095105 0.099959
782:  0.10508  0.10042 0.095925 0.091082 0.085759 0.078881 0.071588 0.063644
783: 0.055429 0.046404 0.038935 0.032806  0.02736 0.032727 0.038975 0.046021
784: 0.052783 0.056981 0.057948 0.055408  0.05014  0.03291 0.014721 -0.00465
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786: -0.03995 -0.03358 -0.02688 -0.02030 -0.01415 -0.00620 0.001416 0.008986
787: 0.016261 0.019097  0.02036 0.020307 0.019463 0.018825 0.017145 0.014755
788:  0.01265 0.005708 -0.00050 -0.00638 -0.01156 -0.01718 -0.02121 -0.02460
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795: -0.04495 -0.03877 -0.03244 -0.02657 -0.02158 -0.01569 -0.01094 -0.00709
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798: 0.072342 0.079718 0.086291 0.091277 0.094522 0.095728 0.096315 0.096697
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804:
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APPENDIX C

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APPENDIX D

NONLINEAR ANALYSIS DETAILS

D1 BIAX2 Results

D2 Nonlinear Model Details

D3 Time History Postprocessing Results

APPENDIX D1

BIAX2 RESULTS

B-PLANT CANYON

CONCRETE SECTION EVALUATIONS USING THE BIAX2 COMPUTER PROGRAM

Prepared by: L. G. Price

Reviewed by: G. R. Wagenblast 2-3-89

CONTENTS:

C.1 Description of the BIAX2 Computer Program

C.2 User Inputs to the Computer Program

C.3 Application to the B-Plant Structural Evaluation

C.4 Modification and Verification

B-PLANT CANYON
CONCRETE SECTION EVALUATIONS USING THE BIAX2 COMPUTER PROGRAM

C.1 Description of the BIAX2 Computer Program

The BIAX2 computer program was developed at the University of California to evaluate the flexural behavior of reinforced concrete cross sections under axial and bending loads. The cross section and steel distribution can be asymmetric. Both uniaxial and biaxial bending can be accommodated. Material properties are input as stress-strain relationships and account for non-linear material behavior under monotonic loading. Concrete tensile strength can be used and crack propagation based on static equilibrium across the section can be predicted. Concrete material properties can be defined for both confined and unconfined concrete.

C.2 User Inputs to the Computer Program

The user inputs geometry, material properties, axial load and assumed compressive strain at the outermost edge. Assuming that plane sections remain plane and that equilibrium requirements must be met, the program computes bending moment and curvature for these conditions. The original program was written to tabulate data for plotting bending moment-versus-axial force interaction curves for a concrete section, and for plotting bending moment-versus-average curvature curves for constant axial loads.

C.3 Modifications and Verification

The version of BIAX2 used for these calculations is saved as NEWBX2. NEWBX2 is an IBM-PC FORTRAN executable file. This version contains minor changes in the fortran code that allow plotting of moment versus steel strain and moment versus neutral axis location. These changes were made by Westinghouse with assistance from the program developer John Wallace. Verification to date includes checking the program results against hand calculations for very simple geometries and a direct comparison to a different computer program (RCCOLA) which was developed independently and also calculates non-linear concrete section capacities. The test problem incorporated all features used in the B-Plant section evaluations. The RCCOLA analysis verified the BIAX2 results. The differences in the capacity calculations were consistent with the limits imposed by different calculation procedures and variations in the material property curve fitting.

C.4 Application to the B-Plant Structural Evaluation

The BIAX2 program was used to determine the ultimate strength capacity of the B-Plant cold joints for use in the non-linear structural analysis. The concrete tensile strength was set to zero and the axial load was set to the dead weight load on each section. The BIAX2 predictions were based solely on the strength of unconfined concrete. The steel and concrete stress-strain relationships used for these evaluations are shown in

Figures C-2 and C-3. Figures C-4 and C-5 show moment versus tensile steel strain plots for the cold joint at the north wall at the roof. The section plots are TR5P which evaluates the section with the outside steel in tension. The MIN5P plot evaluates the section with the inside steel in tension.

Results of all the BIAX2 cold-joint capacity evaluations (Mu) are listed in Table C-1. This table also compares the BIAX2 capacity values to the rigid concrete model, F*d/2 + Mu, capacities from Table B-1 and ACI code allowables for concrete sections with similar reinforcement. These results indicate that for the extremely lightly reinforced sections (ie. tensile steel area (As) less than 0.6 square inches), the capacity is dictated by the ultimate strength of the tensile steel acting across the full section width. Therefore the Table B-1 capacities are conservative for the extremely lightly reinforced sections. It should be noted that the steel ratios for these sections are below ACI minimums. These allowables are shown to compare the BIAX2 capacity values to the ACI values used in previous seismic evaluations of the building capacity.

The evaluations for cold joints with greater reinforcement show that the distance from the tensile steel to the neutral axis of the section decreases with increasing steel ratios. The concrete compressive strength was found to limit the ultimate capacity for the sections with more steel reinforcement. Therefore, the stronger section capacities should be based on the BIAX2 predictions. The capacity values to be used for the non-linear and limit analyses are indicated in Table C-1 with an (*) asterick.

TABLE C-1 CONSTRUCTION JOINT CAPACITIES FROM BIAX2

File	Location	Dead Load,k	Width (in)	As,in2	Compression Zone,in	Mu,in-k	Table B-1 Mu+Fd/2	ACI Allow.
	North Wall @ Roof							
TR5P	- Outside	15.7	45.0	2.206	3.6	5.42*	6.19	3.54
MIN5P	- Inside	15.7	45.0	0.10	2.1	0.72	0.58*	0.43
	South Wall @ Roof							
TR5P	- Outside	16.1	45.0	2.206	3.6	5.42*	6.20	3.55
MIN5P	- Inside	16.1	45.0	0.10	2.1	0.72	0.60*	0.44
	North Wall @ Crane							
	- Outside	22.9	36.0	0.219			0.66*	0.49
	- Inside	22.9	36.0	0.10			0.56*	0.44
	South Wall @ Crane							
	- Outside	23.3	36.0	0.219			0.67*	0.50
	- Inside	23.3	36.0	0.10			0.57*	0.44
	N. W., Abv Cr Gal Fl							
ACGMIN	- Outside	33.9	60.0	0.527	2.2	2.92	2.87*	1.92
ACGMAX	- Inside	33.9	60.0	1.500	3.1	6.26*	6.41	3.88
	S. W., 10′ Abv Deck							
10ADMIN	- Outside	34.2	60.0	0.311	2.3	2.18	2.09*	1.49
10ADMAX	- Inside	34.2	60.0	2.667	4.7	9.43*	10.67	6.24
	S. W., 3′ Abv Deck							
3ADMIN	- Outside	44.2	60.0	0.311	2.4	2.45	2.37*	1.74
3ADMAX	- Inside	44.2	60.0	4.167	6.4	12.44*	16.41	9.52
	S. W., T. of Pipe T.							
TTMIN	- Outside	55.0	60.0	0.311	2.5	2.74	2.67*	2.01
TTMAX	- Inside	55.0	60.0	4.167	6.6	12.49*	16.71	9.71
	S. W., B. of Pipe T.							
	- Outside	61.1	102.0	0.000		--	2.99*	2.70
BTMAX	- Inside	61.1	102.0	2.885	6.2	18.80*	21.37	12.87

* Capacity values used for the non-linear and limit analyses

Figure C-1 BIAX2 COLD JOINT EVALUATION LOCATIONS

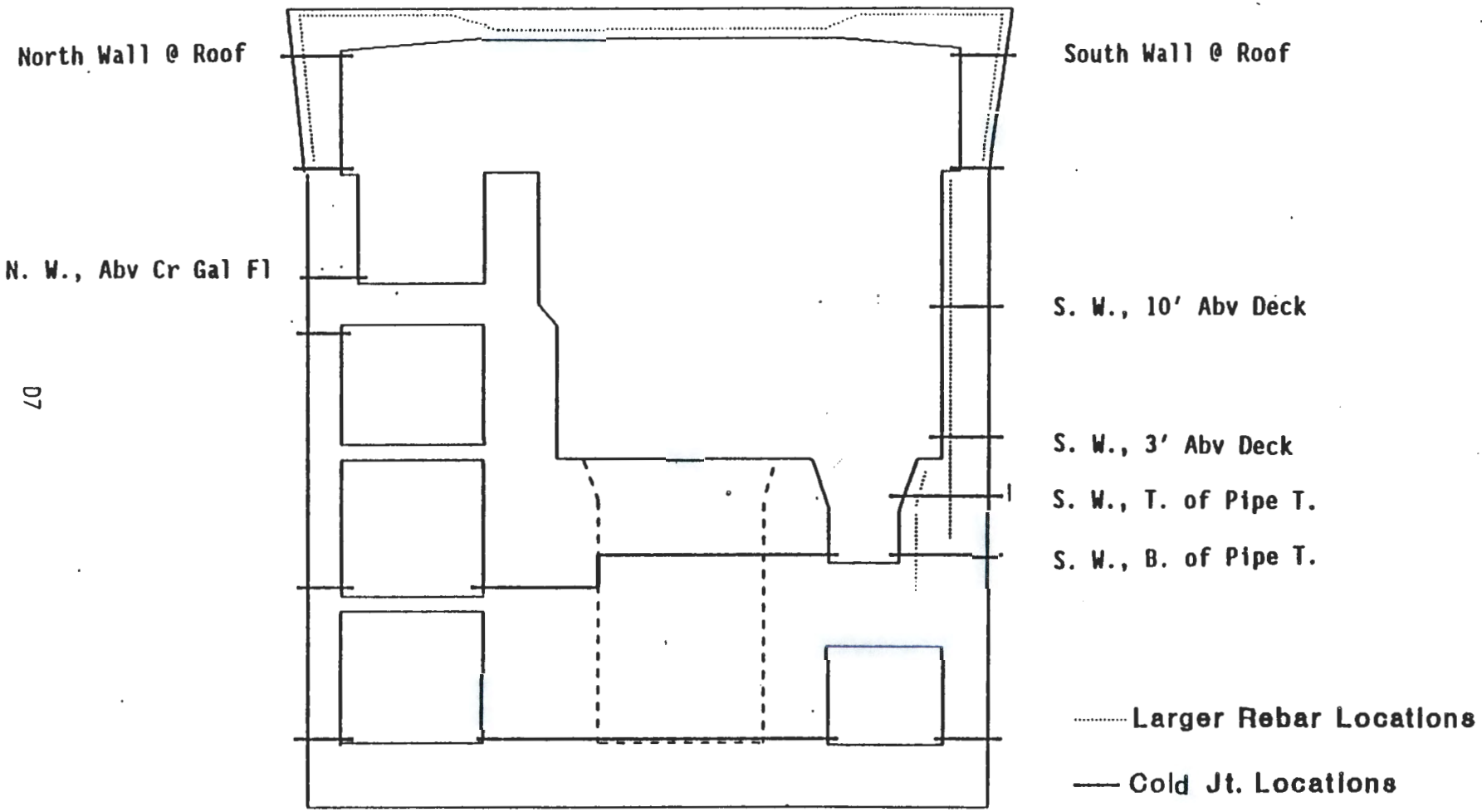
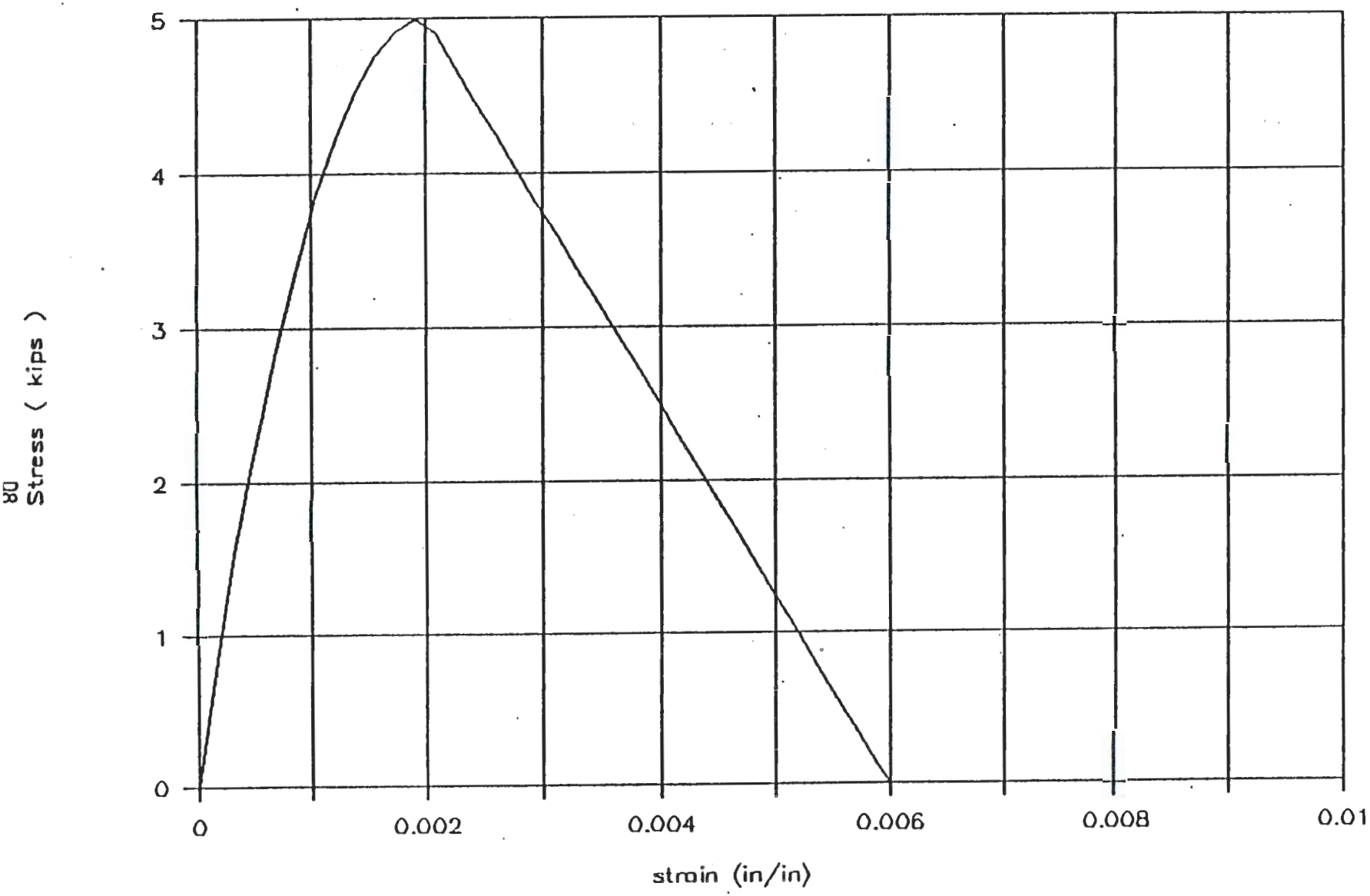


Figure C.2 - Concrete stress-strain data f'c=5000*



* A more conservative concrete strength value of 4800 psi was used in the final time history calcs.

Figure C.3 - BIAX2 steel stress-strain data

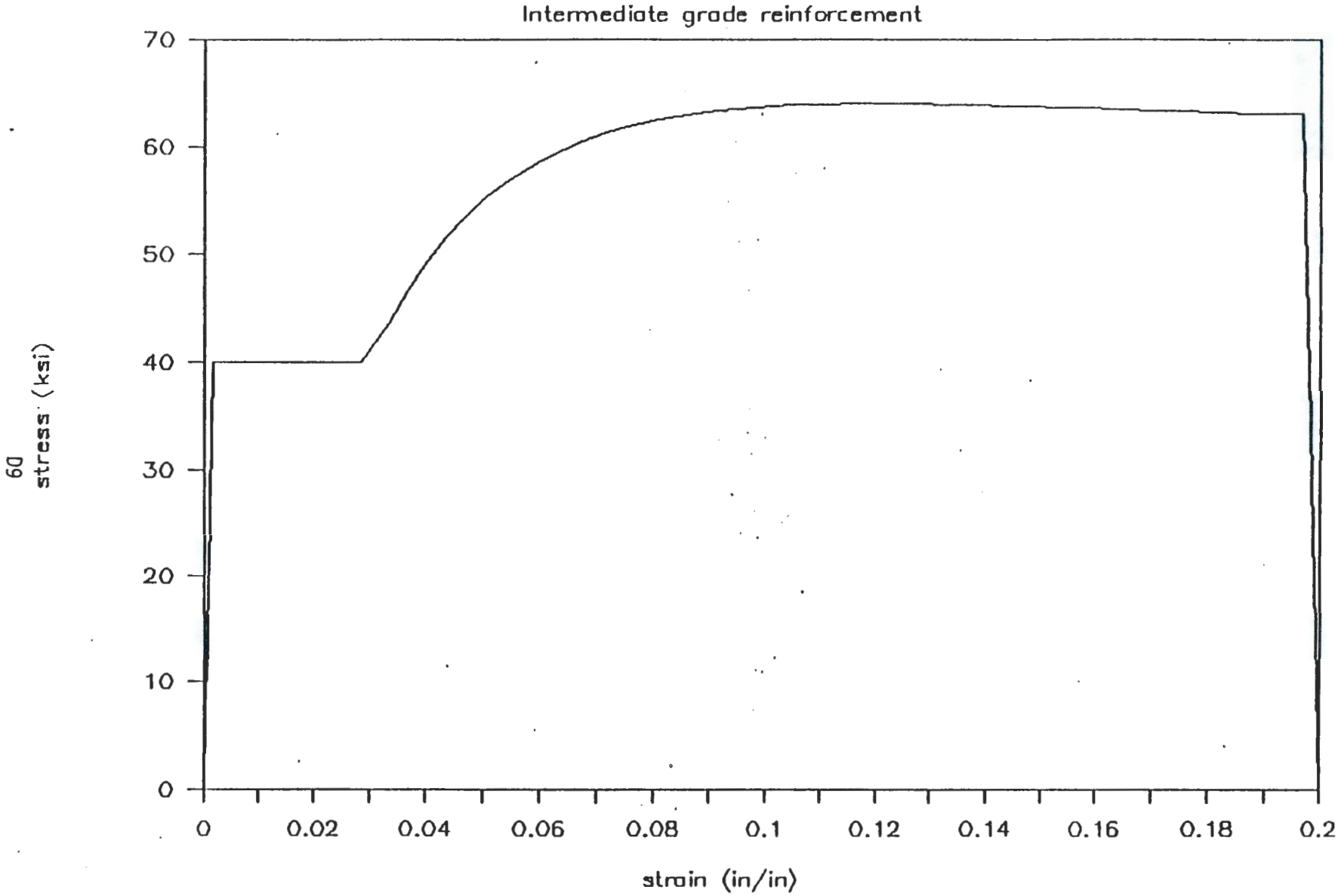


Figure C.4 - Biax2 — Kent Conc. f'c=5000

min steel(.10,2.21 sq.in.) D=45.

Data Set
MIN5P

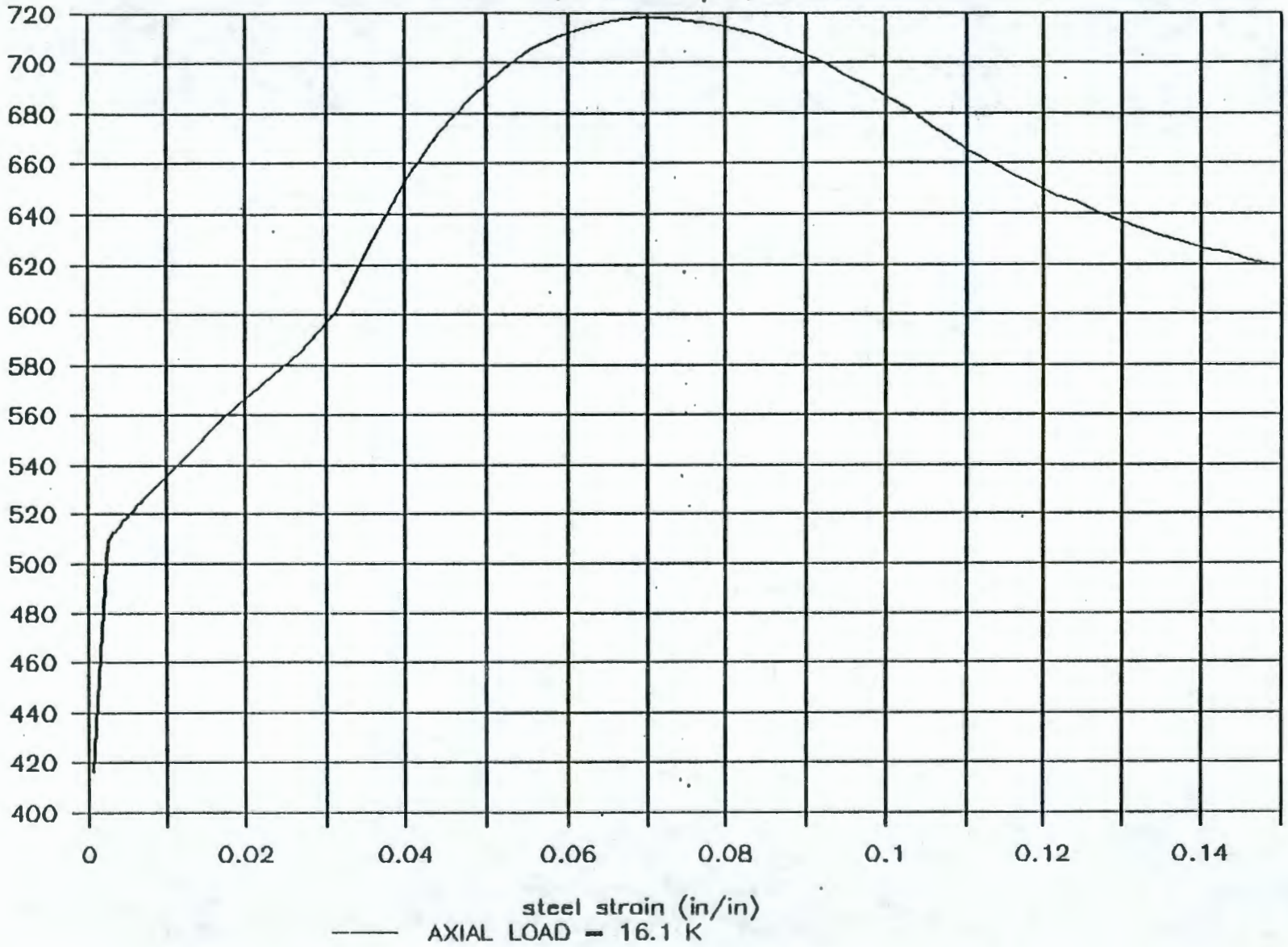
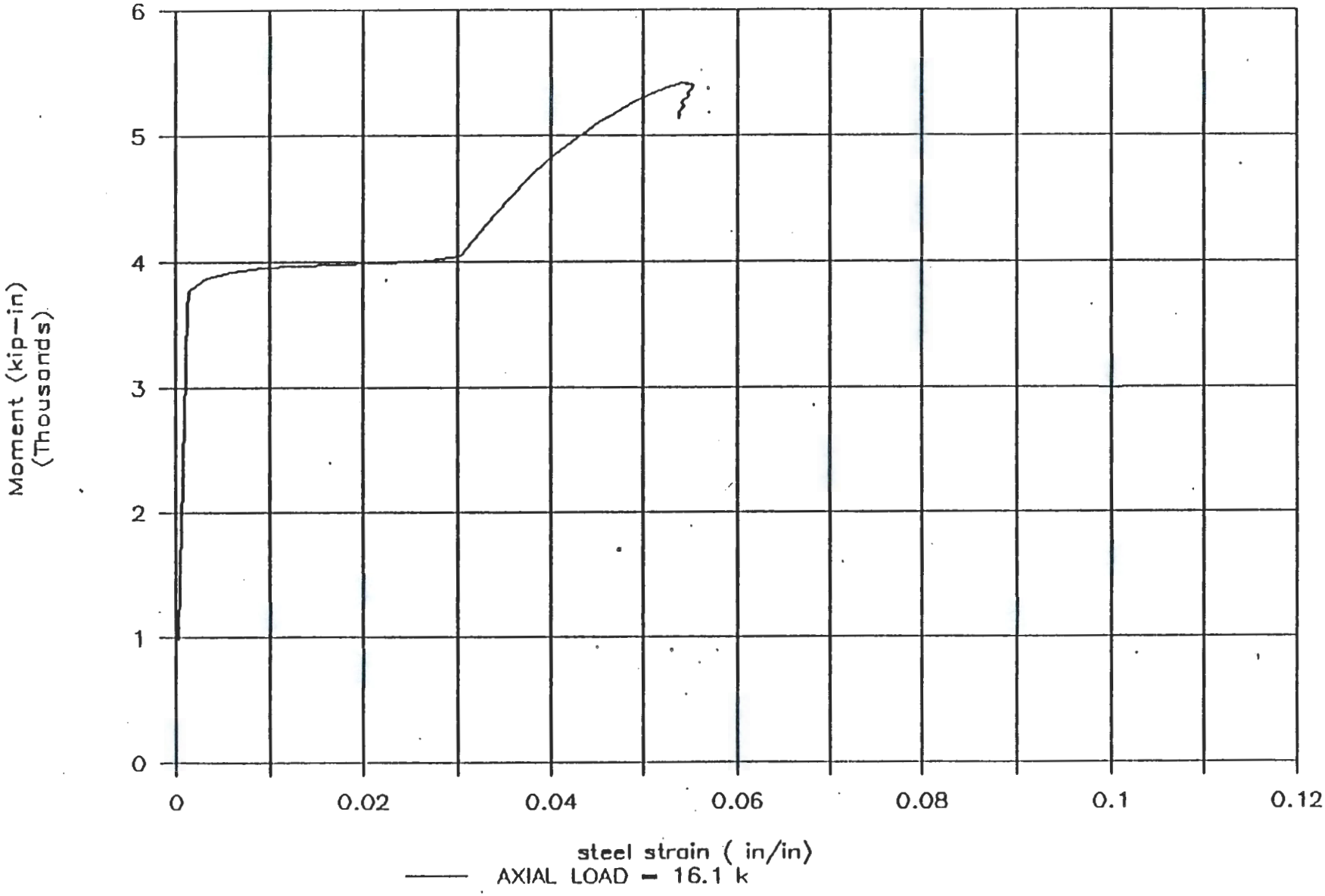


Figure C.5 - Biax2 – Kent Conc. f'c=5000

max steel (2.21,.1,sq.in.) D=45.

Data Set
TR5P



APPENDIX D2

NONLINEAR MODEL DETAILS

D2-1 Node and Element Plots

D2-2 Substructure Creation Input

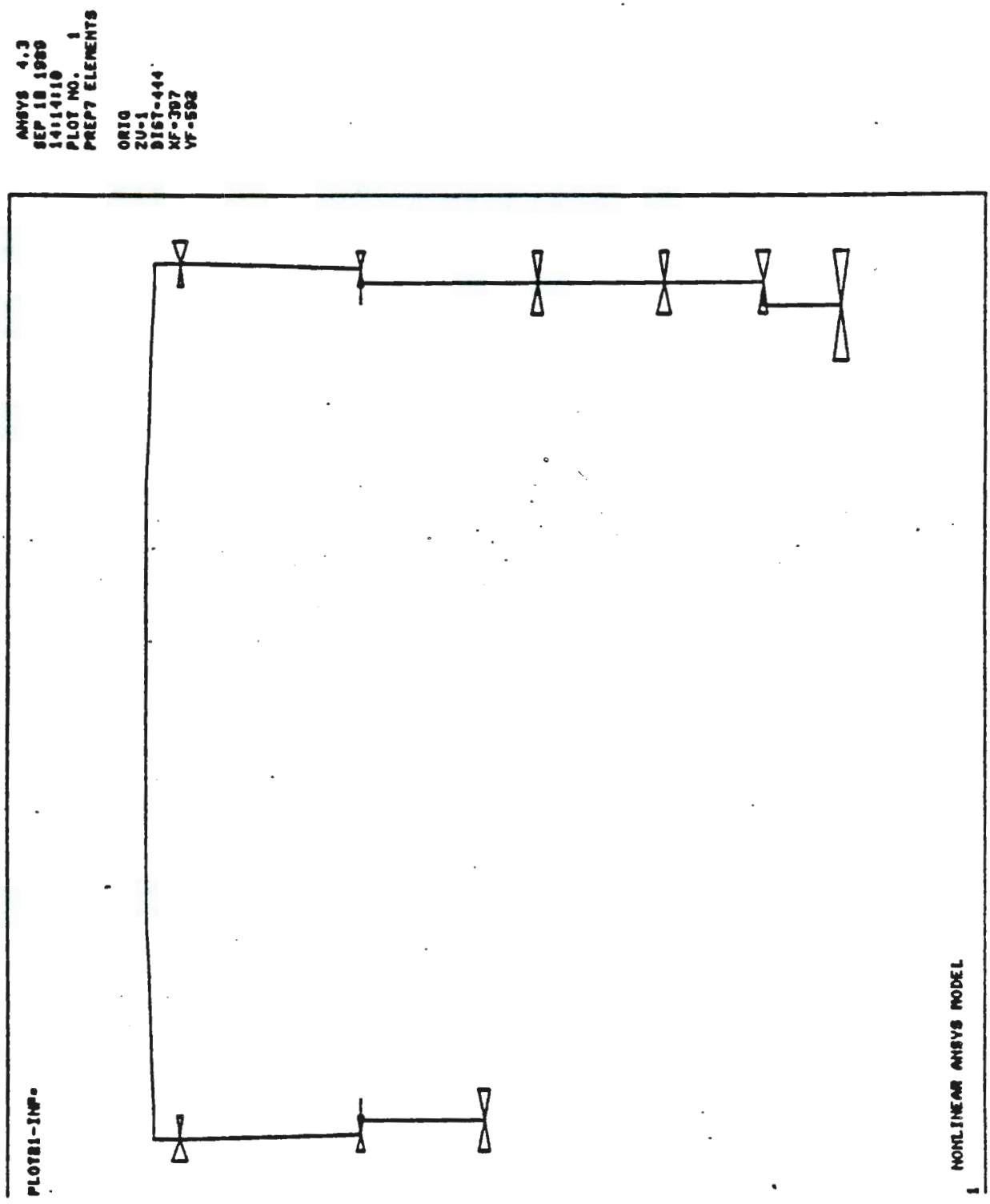
D2-3 Static Capacity Run Input

D2-4 Typical Time History Input

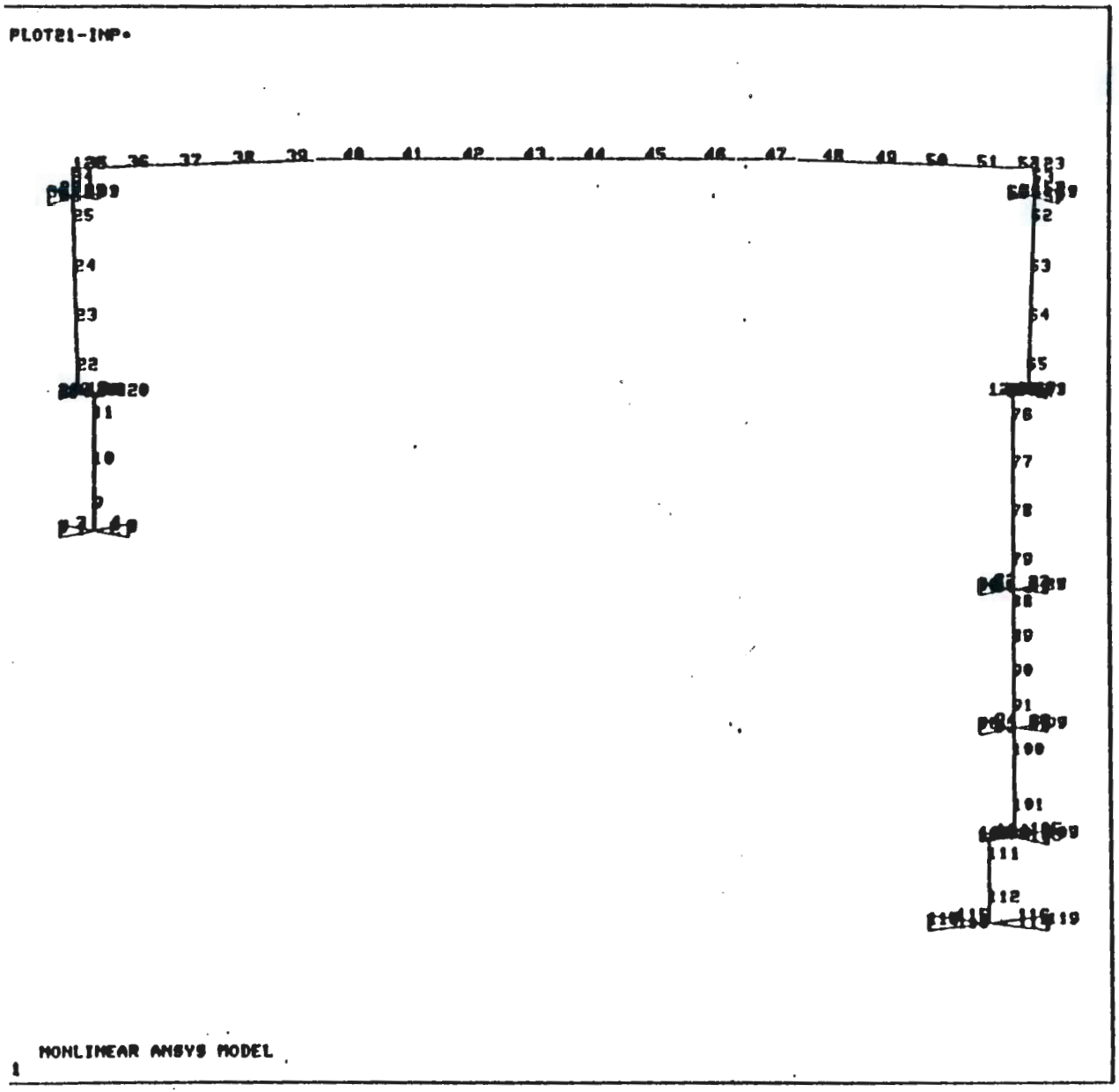
D2-1 Node and Element Plots

Nonlinear Finite Element Model

(Without Substructure)



Model Element Numbers



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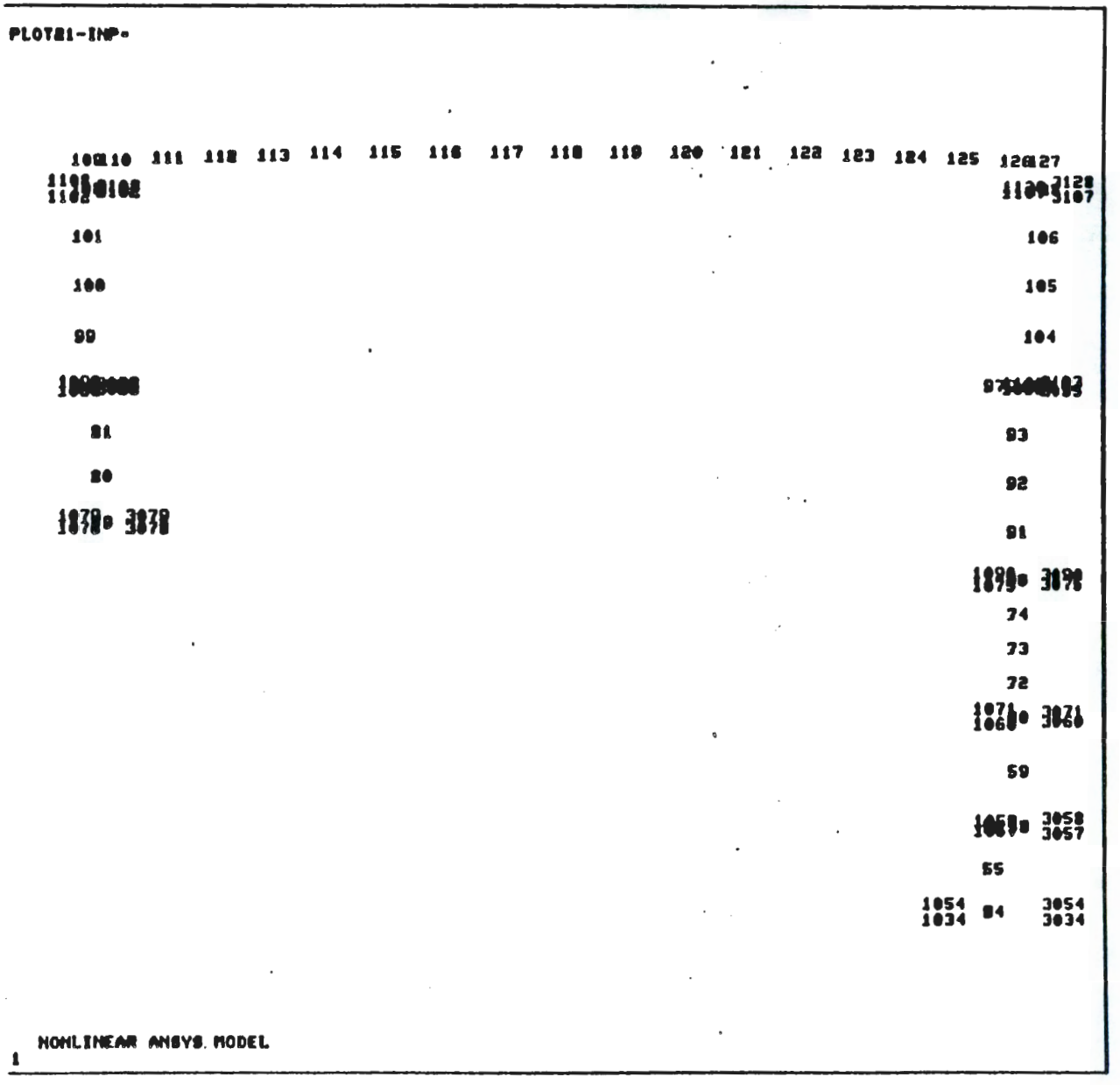

D2-2 Substructure Creation Input

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 3:# @$-lM 1.0Mw
 4:# @$-lT 1:00
 5:# @$
 6:set -x
 7:ja
 8:md
 9:mkdir /tmp/bplant
10:cd /tmp/bplant
11:rm output
12:nasa /w/w91968/bplnl/substr >>output
13:cat >input <<'eof'
14:/prep7
15:/title, generation of super-element no. 1 - lower canyon structure
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 94:,1078,3.,606.
 95:,3078,57.,606.
 96:,79,30.000,606.00
 97:,1079,3.,606.
 98:,3079,57.,606.
 99:,80,30.000,643.00
100:,81,30.000,680.00
101:,82,30.000,717.00
102:,83,18.000,717.00
103:,1083,3.,717.
104:,3083,33.,717.
105:,84,60.000,582.00
106:,85,204.00,582.00
107:,86,246.00 ,558.00
108:,87,240.00,582.00
109:,88,240.00,606.00
110:,89,240.00 ,717.00
111:,90,764.00,558.00
```

```
113:,3090,791.,558.
114:,91,764.00,597.75
115:,92,764.00,637.50
116:,93,764.00,677.25
117:,94,764.00,717.00
118:,95,776.00,717.00
119:,1095,761.,717.
120:,3095,791.,717.
121:,96,48.000,717.00
122:,97,746.00,717.00
123:,98,18.000,717.00
124:,1098,3.,717.
125:,3098,33.,717.
126:,99,16.875,757.25
127:,100,15.750,797.50
128:,101,14.625,837.75
129:,102,13.500,878.00
130:,1102,-6.5,878.
131:,3102,33.,878.
132:,103,776.00,717.00
133:,1103,761.,717.
134:,3103,791.,717.
135:,104,777.12,757.25
136:,105,778.25,797.50
137:,106,779.37,837.75
138:,107,780.50,878.00
139:,1107,761.,878.
140:,3107,800.,878.
141:,108,13.500,878.00
142:,1108,-6.5,878.
143:,3108,33.,878.
144:,109,13.500,902.00
145:,110,36.000,902.00
146:,111,78.000,903.50
147:,112,120.00,905.00
148:,113,162.00,906.50
149:,114,204.00,908.00
150:,115,252.25,908.00
151:,116,300.50,908.00
152:,117,348.75,908.00
153:,118,397.00,908.00
154:,119,445.25,908.00
155:,120,493.50,908.00
156:,121,541.75,908.00
157:,122,590.00,908.00
158:,123,632.00,906.50
159:,124,674.00,905.00
160:,125,716.00,903.50
161:,126,758.00,902.00
162:,127,780.50,902.00
163:,128,780.50,878.00
164:,1128,761.,878.
165:,3128,800.,878.
166:DENS,1,.00022465     *normal 150 pcf concrete
167:DENS,2,.00007863     *35% for shear walls
```

```
169:EX,1,4.00E6          *4800 psi concrete
170:EX,2,1.40E6          *35% for shear walls
171:EX,3,4.00E6          *4800 psi concrete
172:ET,1,42,,,3          *solid
173:ET,2,54,,,,,,1       *beam
174:ET,3,21,,,4          *gen mass
175:ET,4,14,,1           *ux spring
176:ET,5,14,,2           *uy spring
177:ET,6,14,,6           *rotation Z spring
178:ET,7,40,,,2          *uy spring-gap
179:ET,8,39,,1,6         *Non-linear rotation
180:mat,1
181:type,1
182:real,1
183:e,1,2,19,9
184:,2,3,23,19
185:,3,4,30,23
186:mat,2
187:e,19,23,24,20
188:e,20,24,25,21
189:,21,25,26,45
190:,45,26,51,46
191:,46,51,52,47
192:,47,52,53,48
193:mat,3
194:type,2
195:real,2
196:e,1,9
197:mat,1
198:e,9,10
199:,10,11
200:,11,12
201:,12,13
202:,13,35
203:mat,3
204:real,3
205:e,2,19
206:mat,1
207:e,19,20
208:,20,21
209:,21,45
210:mat,3
211:real,4
212:e,3,23
213:mat,1
214:e,23,24
215:,24,25
216:real,17
217:e,25,26
218:mat,3
219:real,5
220:e,4,30
221:mat,1
222:e,30,31
223:,31,32
```

```
225:e,32,33
226:mat,3
227:real,19
228:e,13,16
229:mat,1
230:real,6
231:e,16,17
232:mat,3
233:real,19
234:e,17,45
235:,26,28
236:mat,1
237:real,4
238:e,28,29
239:mat,3
240:real,19
241:e,29,33
242:mat,1
243:real,2
244:e,35,36
245:,36,37
246:,37,38
247:,38,39
248:,39,61
249:real,3
250:e,45,46
251:,46,47
252:,47,48
253:real,4
254:e,48,66
255:real,17
256:e,26,51
257:real,4
258:e,51,52
259:,52,53
260:real,18
261:e,33,34
262:mat,3
263:real,19
264:e,39,42
265:mat,1
266:real,6
267:e,42,43
268:mat,3
269:real,19
270:e,43,48
271:mat,1
272:real,2
273:e,61,62
274:,62,63
275:,63,64
276:,64,76
277:real,4
278:e,66,67
279:,67,68
```

```
281:,69,86
282:real,19
283:e,76,77
284:,77,78
285:mat,3
286:real,19
287:e,77,84
288:mat,1
289:real,8
290:e,84,85
291:mat,3
292:real,19
293:e,85,87
294:mat,1
295:real,19
296:e,86,87
297:,87,88
298:real,5
299:e,88,89
300:rsize,12
301:r,1,12.
302:r,2,432.00,46656.,18.000,18.000
303:r,3,1296.0,0.12597E+07,54.000,54.000
304:r,4,1008.0,0.59270E+06,42.000,42.000
305:r,5,720.00,0.21600E+06,30.000,30.000
306:r,6,144.00,1728.0,6.0000,6.0000
307:r,7,1224.0,0.10612E+07,51.000,51.000
308:r,8,576.00,0.11059E+06,24.000,24.000
309:r,9,432.00,46656.,18.000,18.000,459.00,55962.
310:rmore,19.125,19.125
311:r,10,459.00,55962.,19.125,19.125,486.00,66430.
312:rmore,20.250,20.250
313:r,11,486.00,66430.,20.250,20.250,513.00,78128.
314:rmore,21.375,21.375
315:r,12,513.00,78128.,21.375,21.375,540.00,91125.
316:rmore,22.500,22.500
317:r,13,540.00,91125.,22.500,22.500,513.00,78128.
318:rmore,21.375,21.375
319:r,14,513.00,78128.,21.375,21.375,486.00,66430.
320:rmore,20.250,20.250
321:r,15,486.00,66430.,20.250,20.250,459.00,55962.
322:rmore,19.125,19.125
323:r,16,459.00,55962.,19.125,19.125,432.00,46656.
324:rmore,18.000,18.000
325:r,17,1008.0,0.10000E+10,10.000,10.000        *rigid link
326:r,18,1224.0,0.10000E+11,10.000,10.000        *rigid link
327:r,19,720.00,0.10000E+10,10.000,10.000        *rigid link
328:c***  define master degrees of freedom
329:m,1,ux,,,uy,rotz
330:m,4,ux,,,uy,rotz
331:m,24,ux,,,uy
332:m,45,ux,,,uy
333:m,34,ux,,,uy,rotz
334:m,78,ux,,,uy,rotz
335:AFWRIT
```

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```
/INPUT,27
FINISH
eof
ansys <input >>output
lsf -f | nasa >>output
lsf -f
mv FILE08 save8
cfs store bplant/save8
ja -st | nasa | tee -a >>output
nprint -c -rR32 output
rm FILE* fort.* core
```

D2-3 Static Capacity Run Input

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```
 1:/PREP7
 2:/title,"B PLANT CANYON NONLINEAR MODEL, SOUTH ACCEL."
 3:KAN,0
 4:n,34,743.00,282.00
 5:,1034,694.5,275.55
 6:,3034,791.5,275.55
 7:,54,743.00,282.00
 8:,1054,694.5,288.45
 9:,3054,791.5,288.45
10:,55,743.00,318.00
11:,56,743.00,354.00
12:,57,764.00,354.00
13:,1057,736.5,350.15
14:,3057,791.5,347.55
15:,58,764.00,354.00
16:,1058,736.5,357.85
17:,3058,791.5,360.45
18:,59,764.00,399.00
19:,60,764.00,444.00
20:,1060,736.5,437.55
21:,3060,791.5,440.15
22:,71,764.00,444.00
23:,1071,736.5,450.45
24:,3071,791.5,447.85
25:,72,764.00,472.50
26:,73,764.00,501.00
27:,74,764.00,529.50
28:,75,764.00,558.00
29:,1075,736.5,552.85
30:,3075,791.5,554.15
31:,78,30.000,606.00
32:,1078,2.5,600.81
33:,3078,57.5,600.85
34:,79,30.000,606.00
35:,1079,2.5,611.19
36:,3079,57.5,611.15
37:,80,30.000,643.00
38:,81,30.000,680.00
39:,82,30.000,717.00
40:,83,18.000,717.00
41:,1083,2.5,713.73
42:,3083,33.5,714.38
43:,90,764.00,558.00
44:,1090,736.5,563.15
45:,3090,791.5,561.85
46:,91,764.00,597.75
47:,92,764.00,637.50
48:,93,764.00,677.25
49:,94,764.00,717.00
50:,95,776.00,717.00
51:,1095,760.5,714.38
52:,3095,791.5,713.74
53:,96,48.000,717.00
54:,97,746.00,717.00
```

```
 55:,98,18.000,717.00
 56:,1098,2.5,720.26
```



```
 57:,3098,33.5,719.62
 58:,99,16.875,757.25
 59:,100,15.750,797.50
 60:,101,14.625,837.75
 61:,102,13.500,878.00
 62:,1102,-6.5,871.15
 63:,3102,33.5,875.38
 64:,103,776.00,717.00
 65:,1103,760.5,719.62
 66:,3103,791.5,720.26
 67:,104,777.12,757.25
 68:,105,778.25,797.50
 69:,106,779.37,837.75
 70:,107,780.50,878.00
 71:,1107,760.5,875.38
 72:,3107,800.5,871.55
 73:,108,13.500,878.00
 74:,1108,-6.5,884.45
 75:,3108,33.5,880.62
 76:,109,13.500,902.00
 77:,110,36.000,902.00
 78:,111,78.000,903.50
 79:,112,120.00,905.00
 80:,113,162.00,906.50
 81:,114,204.00,908.00
 82:,115,252.25,908.00
 83:,116,300.50,908.00
 84:,117,348.75,908.00
 85:,118,397.00,908.00
 86:,119,445.25,908.00
 87:,120,493.50,908.00
 88:,121,541.75,908.00
 89:,122,590.00,908.00
 90:,123,632.00,906.50
 91:,124,674.00,905.00
 92:,125,716.00,903.50
 93:,126,758.00,902.00
 94:,127,780.50,902.00
 95:,128,780.50,878.00
 96:,1128,760.5,880.62
 97:,3128,800.5,884.45
 98:C*****   MATERIAL PROPERTIES
 99:C*** CONCRETE = MAT1
100:DENS,1,.00022465     *normal 150 pcf concrete
101:EX,1,4.00E6          *4800 psi concrete
102:C*** Rebar & Rigid Links = MAT2
103:DENS,2,1E-9          *low density for rigid links & rebar
104:KNL,1
```

```
105:EX,2,29.E6
106:NL,2,13,10
107:NL,2,19,0.,100.
108:NL,2,25,40000.,40000.
109:NL,2,31,1.0E5,1.0E5
110:C*** Gap Ele = MAT3
111:MU,3,0.0            *Gap Element Friction
112:C***  Element Types
```



```
113:ET,1,3   * Beam Element
114:ET,2,21,,,4          *gen mass
115:ET,3,12              *2-D Interface
116:ET,4,1               *elastic/plastic truss
117:C*****   REAL CONSTANTS
118:rsize,12
119:r,1,,1.E9,,1.0   * spring/gap element
120:r,2,432.00,46656.,36.0    * 36" beam
121:r,3,1296.0,0.12597E+07,108.0    * 108" beam
122:r,4,1008.0,0.59270E+06,84.0    * 84 " beam
123:r,5,720.00,0.21600E+06,60.0    * 60" beam
124:r,6,144.00,1728.0,12.0    * 12" beam
125:r,7,1224.0,0.10612E+07,102.0    * 102" beam
126:r,8,576.00,0.11059E+06,48.0    * 48" beam
127:r,9,445.5,51309,37.13   * 36"/38.25" tap. beam
128:r,10,472.5,61196,39.38   * 38.25"/40.5" tap. beam
129:r,11,499.5,72279,20.81   * 40.5"/42.75" tap. beam
130:r,12,526.5,84626,21.94   * 42.75"/45.0" tap. beam
131:r,13,526.5,84626,21.94   * 45.0"/42.75" tap. beam
132:r,14,499.5,72279,20.81   * 42.75"-40.5" tap. beam
133:r,15,472.5,61196,39.38   * 40.5"/38.25" tap. beam
134:r,16,445.5,51309,37.13   * 38.25"-36.0" tap. beam
135:r,17,1.E3,1.E7,1.,1.       *rigid link
136:C***  Rebar Element Areas
137:r,18,.527   * N. Wall above Cr. G. Flr, outside steel
138:r,19,1.50   * N. Wall above Cr. G. Flr, inside steel
139:r,20,0.219   * Outside Steel, Crane Level
140:r,21,0.10    * Inside Steel, Crane Level & Wall/Roof Jt.
141:r,22,2.206   * Outside Steel, Wall/Roof Jt.
142:r,23,0.311   * S. Wall Outside Steel, 3' & 10' Above Deck & P. Trench
143:r,24,2.667   * S. Wall Inside Steel, 10' Above Deck
144:r,25,4.167   * S. Wall Inside Steel, 3' Above Deck & T. of P. Trench
145:r,26,2.885   * S. Wall Inside Steel, B. of P. Trench
146:r,27,24.30   * Crane Mass
147:r,28,6.21   * Corner Mass
148:C*****   ELEMENTS
149:C***  Cr. Gallery Flr. Jt.
150:C***  Rigid Links
151:mat,2
152:real,17
153:type,1
154:e,1078,78
```

```
155:,78,3078
156:,1079,79
157:,79,3079
158:C***  Left Rebar
159:type,4
160:real,18
161:e,1078,1079
162:C***  Right Rebar
163:real,19
164:e,3078,3079
165:C***  Gap Elements
166:type,3
167:real,1
168:mat,3
```

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```
169:e,1078,1079
170:,3078,3079
171:C***   Cr. Gallery Wall
172:type,1
173:mat,1
174:real,5
175:e,79,80
176:,80,81
177:,81,82
178:real,17
179:mat,2
180:e,82,83
181:,82,96
182:C***  N. Crane Level Jt.
183:C***  Rigid Links
184:mat,2
185:real,17
186:type,1
187:e,1083,83
188:,83,3083
189:,1098,98
190:,98,3098
191:C***  Left Rebar
192:type,4
193:real,20
194:e,1083,1098
195:C***  Right Rebar
196:real,21
197:e,3083,3098
198:C***  Gap Elements
199:type,3
200:real,1
201:mat,3
202:e,1083,1098
203:,3083,3098
204:C***  N. Wall Above Crane Level
```

```
205:Type,1
206:mat,1
207:real,9
208:e,98,99
209:real,10
210:e,99,100
211:real,11
212:e,100,101
213:real,12
214:e,101,102
215:C***  N. Wall to Roof Jt.
216:C***  Rigid Links
217:mat,2
218:real,17
219:type,1
220:e,1102,102
221:,102,3102
222:,1108,108
223:,108,3108
224:C***  Left Rebar
```

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```
225:type,4
226:real,22
227:e,1102,1108
228:C***  Right Rebar
229:real,21
230:e,3102,3108
231:C***  Gap Elements
232:type,3
233:real,1
234:mat,3
235:e,1102,1108
236:,3102,3108
237:real,19
238:C***  Roof
239:Type,1
240:mat,2
241:real,17
242:e,108,109
243:e,109,110
244:mat,1
245:real,13
246:e,110,111
247:real,14
248:e,111,112
249:real,15
250:e,112,113
251:real,16
252:e,113,114
253:real,2
254:e,114,115
```

```
255:,115,116
256:,116,117
257:,117,118
258:,118,119
259:,119,120
260:,120,121
261:,121,122
262:real,9
263:e,122,123
264:real,10
265:e,123,124
266:real,11
267:e,124,125
268:real,12
269:e,125,126
270:real,17
271:e,126,127
272:e,127,128
273:C***  S. Wall to Roof Jt.
274:C***  Rigid Links
275:mat,2
276:real,17
277:type,1
278:e,1107,107
279:,107,3107
280:,1128,128
```



```
281:,128,3128
282:C***  Left Rebar
283:type,4
284:real,21
285:e,1107,1128
286:C***  Right Rebar
287:real,22
288:e,3107,3128
289:C***  Gap Elements
290:type,3
291:real,1
292:mat,3
293:e,1107,1128
294:,3107,3128
295:C***  S. Wall Above Crane
296:mat,1
297:Type,1
298:real,13
299:e,107,106
300:real,14
301:e,106,105
302:real,15
303:e,105,104
304:real,16
```

```
305:e,104,103
306:C***  S. Crane Level Jt.
307:C***  Rigid Links
308:mat,2
309:real,17
310:type,1
311:e,1095,95
312:,95,3095
313:,1103,103
314:,103,3103
315:C***  Left Rebar
316:type,4
317:real,21
318:e,1095,1103
319:C***  Right Rebar
320:real,20
321:e,3095,3103
322:C***  Gap Elements
323:type,3
324:real,1
325:mat,3
326:e,1095,1103
327:,3095,3103
328:C***  S. Wall Below Crane Level
329:mat,1
330:type,1
331:real,17
332:e,94,95
333:,94,97
334:real,5
335:e,94,93
336:,93,92
```



```
337:,92,91
338:,91,90
339:C***  S. Wall 10' Above Deck Jt.
340:C***  Rigid Links
341:mat,2
342:real,17
343:type,1
344:e,1075,75
345:,75,3075
346:,1090,90
347:,90,3090
348:C***  Left Rebar
349:type,4
350:real,24
351:e,1075,1090
352:C***  Right Rebar
353:real,23
354:e,3075,3090
```

```
355:C***  Gap Elements
356:type,3
357:real,1
358:mat,3
359:e,1075,1090
360:,3075,3090
361:S. Wall, 3' to 10' Above Deck
362:type,1
363:mat,1
364:real,5
365:e,75,74
366:,74,73
367:,73,72
368:,72,71
369:C***  S. Wall 3' Above Deck Jt.
370:C***  Rigid Links
371:mat,2
372:real,17
373:type,1
374:e,1060,60
375:,60,3060
376:,1071,71
377:,71,3071
378:C***  Left Rebar
379:type,4
380:real,25
381:e,1060,1071
382:C***  Right Rebar
383:real,23
384:e,3060,3071
385:C***  Gap Elements
386:type,3
387:real,1
388:mat,3
389:e,1060,1071
390:,3060,3071
391:C***  S. Wall, Deck Level
392:type,1
```



```
393:mat,1
394:real,5
395:e,60,59
396:,59,58
397:C***  S. Wall, Top of Pipe Trench Jt.
398:C***  Rigid Links
399:mat,2
400:real,17
401:type,1
402:e,1057,57
403:,57,3057
404:,1058,58
```

```
405:,58,3058
406:C***  Left Rebar
407:type,4
408:real,25
409:e,1057,1058
410:C***  Right Rebar
411:real,23
412:e,3057,3058
413:C***  Gap Elements
414:type,3
415:real,1
416:mat,3
417:e,1057,1058
418:,3057,3058
419:type,1
420:mat,1
421:real,17
422:e,57,56
423:real,3
424:e,56,55
425:,55,54
426:C***  S. Wall, Bottom of Pipe Trench Jt.
427:C***  Rigid Links
428:mat,2
429:real,17
430:type,1
431:e,1034,34
432:,34,3034
433:,1054,54
434:,54,3054
435:C***  Left Rebar
436:type,4
437:real,26
438:e,1034,1054
439:C***  Right Rebar (None)
440:C***  Gap Elements
441:type,3
442:real,1
443:mat,3
444:e,1034,1054
445:,3034,3054
446:C***  Crane Mass Elements
447:real,27
448:type,2
```



```
449:e,96
450:,97
451:C***  Corner Masses
452:real,28
453:e,109
454:,127
```

```
455:C***  Begin Load Step
456:iter,-10,10
457:cp,1,ux,83,98
458:,2,ux,102,108
459:,3,ux,107,128
460:,4,ux,95,103
461:,5,ux,75,90
462:,6,ux,60,71
463:,7,ux,57,58
464:,8,ux,34,54
465:,9,ux,78,79
466:d,78,all,0.
467:d,34,all,0.
468:acel,,170.  *  Partial Dead Load
469:lwrite
470:iter,-20,20
471:acel,,328.4  * 85% of Dead Load
472:lwrite
473:iter,-20,20
474:acel,-96.6,328.4  * 0.25g hor. acel. south
475:lwrite
476:iter,-20,20
477:acel,-116.,328.4  *  0.3g hor. acel. south
478:lwrite
479:iter,-20,20
480:acel,-135.2,328.4  * 0.35g hor. acel. south
481:lwrite
482:iter,-40,40
483:acel,-154.6,328.4  * 0.4g hor. acel. south
484:lwrite
485:iter,-40,40
486:acel,-173.9,328.4  * 0.45g hor. acel. south
487:lwrite
488:iter,-50,50
489:acel,-193.2,328.4  * 0.5g hor. acel. south
490:lwrite
491:iter,-50,50
492:acel,-212.5,328.4  * 0.55g hor. acel. south
493:lwrite
494:iter,-50,50
495:acel,-231.8,328.4  *  0.6g hor. acel. south
496:lwrite
497:afwrite
498:finish
499:/input,27
500:finish
```

1327$

D2-3 Typical Time History Input

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```
 1:# USER=w91968
 2:# @$-q day
 3:# @$-eo
 4:# @$-lM 1.0Mw
 5:# @$-lT 15:00
 6:# @$
 7:set -x
 8:ja
 9:mkdir /tmp/bplant
10:cd /tmp/bplant
11:rm output
12:nasa /w/w91968/bpn/canyon.sub >>output
13:cat >input <<'eof'
14:/PREP7
15:/title, "Cracked Roof, Substructure, time = 0. to 1.5 sec, 0.2g DBE"
16:kan,4
17:kay,5,2
18:C*** Node Definitions
19:n,34,743.00,282.00
20:,1034,694.5,275.55
21:,3034,791.5,275.55
22:,54,743.00,282.00
23:,1054,694.5,288.45
24:,3054,791.5,288.45
25:,55,743.00,318.00
26:,56,743.00,354.00
27:,57,764.00,354.00
28:,1057,736.5,350.15
29:,3057,791.5,347.55
30:,58,764.00,354.00
31:,1058,736.5,357.85
32:,3058,791.5,360.45
33:,59,764.00,399.00
34:,60,764.00,444.00
35:,1060,736.5,437.55
36:,3060,791.5,440.15
37:,71,764.00,444.00
38:,1071,736.5,450.45
39:,3071,791.5,447.85
40:,72,764.00,472.50
41:,73,764.00,501.00
42:,74,764.00,529.50
43:,75,764.00,558.00
44:,1075,736.5,552.85
45:,3075,791.5,554.15
46:,78,30.000,606.00
47:,1078,2.5,600.81
48:,3078,57.5,600.85
49:,79,30.000,606.00
50:,1079,2.5,611.19
51:,3079,57.5,611.15
52:,80,30.000,643.00
53:,81,30.000,680.00
54:,82,30.000,717.00
55:,83,18.000,717.00
```

```
 57:,3083,33.5,714.38
 58:,90,764.00,558.00
 59:,1090,736.5,563.15
 60:,3090,791.5,561.85
 61:,91,764.00,597.75
 62:,92,764.00,637.50
 63:,93,764.00,677.25
 64:,94,764.00,717.00
 65:,95,776.00,717.00
 66:,1095,760.5,714.38
 67:,3095,791.5,713.74
 68:,96,48.000,717.00
 69:,97,746.00,717.00
 70:,98,18.000,717.00
 71:,1098,2.5,720.26
 72:,3098,33.5,719.62
 73:,99,16.875,757.25
 74:,100,15.750,797.50
 75:,101,14.625,837.75
 76:,102,13.500,878.00
 77:,1102,-6.5,871.15
 78:,3102,33.5,875.38
 79:,103,776.00,717.00
 80:,1103,760.5,719.62
 81:,3103,791.5,720.26
 82:,104,777.12,757.25
 83:,105,778.25,797.50
 84:,106,779.37,837.75
 85:,107,780.50,878.00
 86:,1107,760.5,875.38
 87:,3107,800.5,871.55
 88:,108,13.500,878.00
 89:,1108,-6.5,884.45
 90:,3108,33.5,880.62
 91:,109,13.500,902.00
 92:,110,36.000,902.00
 93:,111,78.000,903.50
 94:,112,120.00,905.00
 95:,113,162.00,906.50
 96:,114,204.00,908.00
 97:,115,252.25,908.00
 98:,116,300.50,908.00
 99:,117,348.75,908.00
100:,118,397.00,908.00
101:,119,445.25,908.00
102:,120,493.50,908.00
103:,121,541.75,908.00
104:,122,590.00,908.00
105:,123,632.00,906.50
106:,124,674.00,905.00
107:,125,716.00,903.50
108:,126,758.00,902.00
109:,127,780.50,902.00
110:,128,780.50,878.00
111:,1128,760.5,880.62
```

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```
113:C*****   MATERIAL PROPERTIES
114:C*** CONCRETE = MAT1
115:DENS,1,.00022465     *normal 150 pcf concrete
116:EX,1,4.00E6          *4800 psi concrete
117:C*** Rebar & Rigid Links = MAT2
118:DENS,2,1E-9          *low density for rigid links & rebar
119:KNL,1
120:EX,2,29.E6
121:NL,2,13,10
122:NL,2,19,0.,100.
123:NL,2,25,40000.,40000.
124:NL,2,31,1.0E5,1.0E5
125:C*** Gap Ele = MAT3
126:MU,3,0.0             *Gap Element Friction
127:C***  Element Types
128:ET,1,3    * Beam Element
129:ET,2,21,,,4          *gen mass
130:ET,3,12              *2-D Interface
131:ET,4,1               *elastic/plastic truss
132:ET,5,50
133:C*****   REAL CONSTANTS
134:rsize,12
135:r,1,,1.E9,,1.0    * spring/gap element
136:r,2,432.00,23380.,36.0     * 36" beam
137:r,3,1296.0,0.12597E+07,108.0     * 108" beam
138:r,4,1008.0,0.59270E+06,84.0     * 84 " beam
139:r,5,720.00,0.21600E+06,60.0     * 60" beam
140:r,6,144.00,1728.0,12.0     * 12" beam
141:r,7,1224.0,0.10612E+07,102.0     * 102" beam
142:r,8,576.00,0.11059E+06,48.0     * 48" beam
143:r,9,445.5,25654,37.13    * 36"/38.25" tap. beam
144:r,10,472.5,30598,39.38    * 38.25"/40.5" tap. beam
145:r,11,499.5,36140,41.62    * 40.5"/42.75" tap. beam
146:r,12,526.5,42313,43.88    * 42.75"/45.0" tap. beam
147:r,13,526.5,84626,43.88    * 45.0"/42.75" tap. beam
148:r,14,499.5,72279,41.62    * 42.75"-40.5" tap. beam
149:r,15,472.5,61196,39.38    * 40.5"/38.25" tap. beam
150:r,16,445.5,51309,37.13    * 38.25"-36.0" tap. beam
151:r,17,1.E3,1.E7,1.,1.        *rigid link
152:C***  Rebar Element Areas
153:r,18,.527    * N. Wall above Cr. G. Flr, outside steel
154:r,19,1.50    * N. Wall above Cr. G. Flr, inside steel
155:r,20,0.219    * Outside Steel, Crane Level
156:r,21,0.10     * Inside Steel, Crane Level & Wall/Roof Jt.
157:r,22,2.206    * Outside Steel, Wall/Roof Jt.
158:r,23,0.311    * S. Wall Outside Steel, 3' & 10' Above Deck & P. Trench
159:r,24,2.667    * S. Wall Inside Steel, 10' Above Deck
160:r,25,4.167    * S. Wall Inside Steel, 3' Above Deck & T. of P. Trench
161:r,26,2.885    * S. Wall Inside Steel, B. of P. Trench
162:r,27,24.30    * Crane Mass
163:r,28,6.21    * Corner Mass
164:r,29,1.0E6    * Base Mass
165:C*****   ELEMENTS
166:C***  Cr. Gallery Flr. Jt.
167:C***  Rigid Links
```

```
169:real,17
170:type,1
171:e,1078,78
172:,78,3078
173:,1079,79
174:,79,3079
175:C***  Left Rebar
176:type,4
177:real,18
178:e,1078,1079
179:C***  Right Rebar
180:real,19
181:e,3078,3079
182:C***  Gap Elements
183:type,3
184:real,1
185:mat,3
186:e,1078,1079
187:,3078,3079
188:C***   Cr. Gallery Wall
189:type,1
190:mat,1
191:real,5
192:e,79,80
193:,80,81
194:,81,82
195:real,17
196:mat,2
197:e,82,83
198:,82,96
199:C***  N. Crane Level Jt.
200:C***  Rigid Links
201:e,1083,83
202:,83,3083
203:,1098,98
204:,98,3098
205:C***  Left Rebar
206:type,4
207:real,20
208:e,1083,1098
209:C***  Right Rebar
210:real,21
211:e,3083,3098
212:C***  Gap Elements
213:type,3
214:real,1
215:mat,3
216:e,1083,1098
217:,3083,3098
218:C***  N. Wall Above Crane Level
219:Type,1
220:mat,1
221:real,16
222:e,98,99
223:real,15
```

```
225:real,14
226:e,100,101
227:real,13
228:e,101,102
229:C***  N. Wall to Roof Jt.
230:C***  Rigid Links
231:mat,2
232:real,17
233:type,1
234:e,1102,102
235:,102,3102
236:,1108,108
237:,108,3108
238:C***  Left Rebar
239:type,4
240:real,22
241:e,1102,1108
242:C***  Right Rebar
243:real,21
244:e,3102,3108
245:C***  Gap Elements
246:type,3
247:real,1
248:mat,3
249:e,1102,1108
250:,3102,3108
251:C***  Roof
252:Type,1
253:mat,2
254:real,17
255:e,108,109
256:e,109,110
257:mat,1
258:real,12
259:e,110,111
260:real,11
261:e,111,112
262:real,10
263:e,112,113
264:real,9
265:e,113,114
266:real,2
267:e,114,115
268:,115,116
269:,116,117
270:,117,118
271:,118,119
272:,119,120
273:,120,121
274:,121,122
275:real,9
276:e,122,123
277:real,10
278:e,123,124
279:real,11
```

```
281:real,12
282:e,125,126
283:real,17
284:mat,2
285:e,126,127
286:e,127,128
287:C***  S. Wall to Roof Jt.
288:C***  Rigid Links
289:e,1107,107
290:,107,3107
291:,1128,128
292:,128,3128
293:C***  Left Rebar
294:type,4
295:real,21
296:e,1107,1128
297:C***  Right Rebar
298:real,22
299:e,3107,3128
300:C***  Gap Elements
301:type,3
302:real,1
303:mat,3
304:e,1107,1128
305:,3107,3128
306:C***  S. Wall Above Crane
307:mat,1
308:Type,1
309:real,13
310:e,107,106
311:real,14
312:e,106,105
313:real,15
314:e,105,104
315:real,16
316:e,104,103
317:C***  S. Crane Level Jt.
318:C***  Rigid Links
319:mat,2
320:real,17
321:type,1
322:e,1095,95
323:,95,3095
324:,1103,103
325:,103,3103
326:C***  Left Rebar
327:type,4
328:real,21
329:e,1095,1103
330:C***  Right Rebar
331:real,20
332:e,3095,3103
333:C***  Gap Elements
334:type,3
335:real,1
```

```
337:e,1095,1103
338:,3095,3103
339:C***  S. Wall Below Crane Level
340:mat,2
341:type,1
342:real,17
343:e,94,95
344:,94,97
345:mat,1
346:real,5
347:e,94,93
348:,93,92
349:,92,91
350:,91,90
351:C***  S. Wall 10' Above Deck Jt.
352:C***  Rigid Links
353:mat,2
354:real,17
355:type,1
356:e,1075,75
357:,75,3075
358:,1090,90
359:,90,3090
360:C***  Left Rebar
361:type,4
362:real,24
363:e,1075,1090
364:C***  Right Rebar
365:real,23
366:e,3075,3090
367:C***  Gap Elements
368:type,3
369:real,1
370:mat,3
371:e,1075,1090
372:,3075,3090
373:S. Wall, 3' to 10' Above Deck
374:type,1
375:mat,1
376:real,5
377:e,75,74
378:,74,73
379:,73,72
380:,72,71
381:C***  S. Wall 3' Above Deck Jt.
382:C***  Rigid Links
383:mat,2
384:real,17
385:type,1
386:e,1060,60
387:,60,3060
388:,1071,71
389:,71,3071
390:C***  Left Rebar
391:type,4
```

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```
393:e,1060,1071
394:C***  Right Rebar
395:real,23
396:e,3060,3071
397:C***  Gap Elements
398:type,3
399:real,1
400:mat,3
401:e,1060,1071
402:,3060,3071
403:C***  S. Wall, Deck Level
404:type,1
405:mat,1
406:real,5
407:e,60,59
408:,59,58
409:C***  S. Wall, Top of Pipe Trench Jt.
410:C***  Rigid Links
411:mat,2
412:real,17
413:type,1
414:e,1057,57
415:,57,3057
416:,1058,58
417:,58,3058
418:C***  Left Rebar
419:type,4
420:real,25
421:e,1057,1058
422:C***  Right Rebar
423:real,23
424:e,3057,3058
425:C***  Gap Elements
426:type,3
427:real,1
428:mat,3
429:e,1057,1058
430:,3057,3058
431:type,1
432:mat,2
433:real,17
434:e,57,56
435:mat,1
436:real,3
437:e,56,55
438:,55,54
439:C***  S. Wall, Bottom of Pipe Trench Jt.
440:C***  Rigid Links
441:mat,2
442:real,17
443:type,1
444:e,1034,34
445:,34,3034
446:,1054,54
447:,54,3054
```

```
449:type,4
450:real,26
451:e,1034,1054
452:C***  Right Rebar (None)
453:C***  Gap Elements
454:type,3
455:real,1
456:mat,3
457:e,1034,1054
458:,3034,3054
459:C***  Crane Mass Elements
460:real,27
461:type,2
462:e,96
463:,97
464:C***  Corner Masses
465:real,28
466:e,109
467:,127
468:C***  Base Mass
469:real,29
470:e,1
471:C***  Lower Canyon Substructure
472:type,5
473:e,1,8
474:dof,ux,uy,rotz
475:C***  Begin Load Step
476:iter,3,3
477:cp,1,ux,83,98
478:,2,ux,102,108
479:,3,ux,107,128
480:,4,ux,95,103
481:,5,ux,75,90
482:,6,ux,60,71
483:,7,ux,57,58
484:,8,ux,34,54
485:,9,ux,78,79
486:cp,10,ux,1,4
487:cp,11,uy,1,4
488:d,1,ux,0.,,,,uy
489:acel,,386.4  * Static Dead Load
490:betad,.000838   * 5% structural damping
491:alphad,1.984
492:postr,2,4,5   * save plas. strains for post pr.
493:kbc,0
494:lwrite
495:iter,1,1   * replace constr. with reac. forces
496:time,.00001
497:ddel,1,ux
498:ddel,1,uy
499:f,1,fx,0.0
500:f,1,fy,0.386745E09
501:lwrite
502:afwrite
503:FINISH
```

```
505:/prep6
506:nsteps,300
507:ntable,10
508:data,2,1,300,1,8  * table 2 = v. acc., n 57
509:(8F9.0)
510:eof
511:cat >>input </w/w91968/bplnl/vacn57.1p5
512:cat >>input <<'eof'
513:data,3,1,300,1,8  * table 3 = h. acc., n 57
514:(8F9.0)
515:eof
516:cat >>input </w/w91968/bplnl/hacn57.1p5
517:cat >>input <<'eof'
518:fill,4,1,300,1,0.386745E+09   * n 57 ver. reac.
519:combin,6,2,,,19657.06  * tab 6 = v. force, n 57
520:combin,6,6,4,,19657.06,1
521:combin,7,3,,,19657.06  * tab 7 = h. force, n 57
522:combin,7,7,,,19657.06
523:fill,1,1,300,,.005,.005  * table 1 = time
524:time,1
525:fill,5,1,300,10,2  *  load step print interval = 10
526:nprint,5
527:nitter,,2
528:prvar,1,2,3,6,7,5
529:fy,1,6
530:fx,1,7
531:LFWRIT
532:FINISH
533:/INPUT,27
534:/input,23
535:FINISH
536:eof
537:cfs get bplant/save8
538:mv save8 FILE08
539:/p/ansys/test/tansys <input >>output
540:lsf -f | nasa >>output
541:lsf -f
542:cfs store bplant/FILE21
543:mv FILE12 save12.1p5
544:mv FILE03 save3.1p5
545:cfs store bplant/save12.1p5
546:cfs store bplant/save3.1p5
547:ja -st | nasa | tee -a >>output
548:nprint -c -rR32 output
549:rm FILE* fort.* core
```

APPENDIX D3

TIME HISTORY POSTPROCESSING RESULTS

Construction Joint Rebar Stress & Plas. Strain Extremes

POST26 SUMMARY OF VARIABLE EXTREME VALUES

VARI	TYPE	IDENTIFIERS		NAME		MINIMUM	AT TIME	MAXIMUM	AT TIME
2	ESTR	5	3	5	SIG	-195.8	1.820	-4.510	1.615
3	ESTR	6	3	6	SIG	-799.1	1.935	0.2102E+05	1.130
4	ESTR	18	3	18	SIG	-0.3987E+05	1.010	0.4079E+05	1.645
5	ESTR	19	3	19	SIG	-0.3987E+05	3.410	0.4037E+05	1.845
6	ESTR	30	3	30	SIG	3238.	1.625	0.2098E+05	1.850
7	ESTR	31	3	31	SIG	-353.8	1.850	-119.4	1.620
8	ESTR	58	3	58	SIG	-443.6	1.650	-175.4	1.145
9	ESTR	59	3	59	SIG	8301.	1.145	0.2687E+05	1.655
10	ESTR	70	3	70	SIG	-201.4	0.8950	-66.89	3.775
11	ESTR	71	3	71	SIG	-0.3976E+05	3.000	0.4033E+05	3.500
12	ESTR	84	3	84	SIG	-59.16	1.165	6052.	1.660
13	ESTR	85	3	85	SIG	-240.3	1.640	-63.92	1.155
14	ESTR	96	3	96	SIG	-120.6	1.765	0.1167E+05	1.625
15	ESTR	97	3	97	SIG	-389.5	1.640	-65.44	1.160
16	ESTR	106	3	106	SIG	-190.5	1.770	0.1840E+05	1.620
17	ESTR	107	3	107	SIG	-310.5	1.610	-35.90	1.160
18	ESTR	117	3	117	SIG	-57.89	4.495	0.1884E+05	1.605

POST26 SUMMARY OF VARIABLE EXTREME VALUES

VARI	TYPE	IDENTIFIERS		NAME		MINIMUM	AT TIME	MAXIMUM	AT TIME
2	ESTR	5	8	5	EPPL	0.0000	10.00	0.0000	10.00
3	ESTR	6	8	6	EPPL	0.0000	10.00	0.0000	10.00
4	ESTR	18	8	18	EPPL	0.0000	0.7850	0.7900E-02	1.700
5	ESTR	19	8	19	EPPL	0.0000	1.065	0.3672E-02	1.905
6	ESTR	30	8	30	EPPL	0.0000	10.00	0.0000	10.00
7	ESTR	31	8	31	EPPL	0.0000	10.00	0.0000	10.00
8	ESTR	58	8	58	EPPL	0.0000	10.00	0.0000	10.00
9	ESTR	59	8	59	EPPL	0.0000	10.00	0.0000	10.00
10	ESTR	70	8	70	EPPL	0.0000	10.00	0.0000	10.00
11	ESTR	71	8	71	EPPL	0.0000	0.7450	0.3281E-02	3.765
12	ESTR	84	8	84	EPPL	0.0000	10.00	0.0000	10.00
13	ESTR	85	8	85	EPPL	0.0000	10.00	0.0000	10.00
14	ESTR	96	8	96	EPPL	0.0000	10.00	0.0000	10.00
15	ESTR	97	8	97	EPPL	0.0000	10.00	0.0000	10.00
16	ESTR	106	8	106	EPPL	0.0000	10.00	0.0000	10.00
17	ESTR	107	8	107	EPPL	0.0000	10.00	0.0000	10.00
18	ESTR	117	8	117	EPPL	0.0000	10.00	0.0000	10.00

Peak Wall Moments, 0.2g DBE

POST26 SUMMARY OF VARIABLE EXTREME VALUES

VARI	TYPE	IDENTIFIERS		NAME	MINIMUM	AT TIME	MAXIMUM	AT TIME
3	ESTR	9	3	9 MOMI	-0.2782E+07	1.080	0.9642E+06	1.615
4	ESTR	10	3	10 MOMI	-0.2045E+07	1.080	0.8070E+06	1.620
5	ESTR	11	3	11 MOMI	-0.1326E+07	1.825	0.6655E+06	1.620
6	ESTR	11	6	11 MOMJ	-0.5405E+06	1.625	0.6457E+06	1.800
7	ESTR	22	3	22 MOMI	-0.5259E+06	1.800	0.6434E+06	1.560
8	ESTR	23	3	23 MOMI	0.1221E+06	1.800	0.8169E+06	0.7900
9	ESTR	24	3	24 MOMI	0.5060E+06	1.705	0.1048E+07	0.7200
10	ESTR	25	3	25 MOMI	0.5603E+06	1.620	0.1546E+07	1.850
11	ESTR	25	6	25 MOMJ	-0.2206E+07	1.850	-0.5739E+06	1.620
12	ESTR	62	3	62 MOMI	0.9987E+06	1.145	0.2791E+07	1.650
13	ESTR	63	3	63 MOMI	0.7868E+06	1.145	0.2258E+07	1.655
14	ESTR	64	3	64 MOMI	0.5601E+06	1.870	0.1703E+07	1.655
15	ESTR	65	3	65 MOMI	0.3160E+06	1.865	0.1155E+07	1.605
16	ESTR	65	6	65 MOMJ	-0.7026E+06	0.8950	-0.4886E+05	3.775
17	ESTR	76	3	76 MOMI	-0.4557E+05	3.775	0.5590E+06	0.7550
18	ESTR	77	3	77 MOMI	-0.2744E+06	3.555	0.1912E+06	0.3250
19	ESTR	78	3	78 MOMI	-0.8777E+06	1.650	0.9135E+05	1.150
20	ESTR	79	3	79 MOMI	-0.1525E+07	1.645	0.8910E+05	1.155
21	ESTR	79	6	79 MOMJ	-0.1099E+06	1.155	0.2186E+07	1.640
22	ESTR	88	3	88 MOMI	-0.2187E+07	1.640	0.1107E+06	1.155
23	ESTR	89	3	89 MOMI	-0.2671E+07	1.640	0.1391E+06	1.160
24	ESTR	90	3	90 MOMI	-0.3163E+07	1.635	0.1770E+06	1.160
25	ESTR	91	3	91 MOMI	-0.3664E+07	1.635	0.2236E+06	1.160
26	ESTR	91	6	91 MOMJ	-0.2785E+06	1.160	0.4176E+07	1.625
27	ESTR	100	3	100 MOMI	-0.4175E+07	1.630	0.2776E+06	1.160
28	ESTR	101	3	101 MOMI	-0.5020E+07	1.615	0.3801E+06	1.160
29	ESTR	101	6	101 MOMJ	-0.5012E+06	1.160	0.5899E+07	1.610
30	ESTR	111	3	111 MOMI	-0.7198E+07	1.610	-0.5540E+06	1.160
31	ESTR	112	3	112 MOMI	-0.7931E+07	1.610	-0.4394E+06	1.160
32	ESTR	112	6	112 MOMJ	0.3013E+06	1.155	0.8689E+07	1.610

Peak Roof Moments, 0.2g DBE

POST26 SUMMARY OF VARIABLE EXTREME VALUES

VARI	TYPE	IDENTIFIERS			NAME	MINIMUM	AT TIME	MAXIMUM	AT TIME
2	ESTR	36	3	36	MOMI	0.3083E+06	1.625	0.2238E+07	1.850
3	ESTR	37	3	37	MOMI	-0.1608E+06	1.630	0.1657E+07	1.850
4	ESTR	38	3	38	MOMI	-0.5574E+06	1.635	0.1152E+07	1.845
5	ESTR	39	3	39	MOMI	-0.8778E+06	1.640	0.7131E+06	1.845
6	ESTR	40	3	40	MOMI	-0.1117E+07	1.645	0.3339E+06	1.845
7	ESTR	41	3	41	MOMI	-0.1299E+07	1.645	-0.5019E+05	1.840
8	ESTR	42	3	42	MOMI	-0.1380E+07	1.650	-0.3444E+06	1.160
9	ESTR	43	3	43	MOMI	-0.1361E+07	1.655	-0.5441E+06	1.145
10	ESTR	44	3	44	MOMI	-0.1245E+07	1.660	-0.6626E+06	3.385
11	ESTR	45	3	45	MOMI	-0.1032E+07	1.670	-0.6699E+06	3.405
12	ESTR	46	3	46	MOMI	-0.8442E+06	4.450	-0.5333E+06	3.430
13	ESTR	47	3	47	MOMI	-0.6600E+06	1.835	-0.2444E+06	1.640
14	ESTR	48	3	48	MOMI	-0.4566E+06	1.830	0.2523E+06	1.645
15	ESTR	49	3	49	MOMI	-0.2251E+06	1.825	0.7475E+06	1.650
16	ESTR	50	3	50	MOMI	0.7357E+05	1.825	0.1315E+07	1.650
17	ESTR	51	3	51	MOMI	0.4460E+06	1.820	0.1954E+07	1.650

POST26 SUMMARY OF VARIABLE EXTREME VALUES

VARI	TYPE	IDENTIFIERS			NAME	MINIMUM	AT TIME	MAXIMUM	AT TIME
2	ESTR	36	6	36	MOMJ	-0.1657E+07	1.850	0.1607E+06	1.630
3	ESTR	37	6	37	MOMJ	-0.1152E+07	1.845	0.5573E+06	1.635
4	ESTR	38	6	38	MOMJ	-0.7131E+06	1.845	0.8777E+06	1.640
5	ESTR	39	6	39	MOMJ	-0.3338E+06	1.845	0.1116E+07	1.645
6	ESTR	40	6	40	MOMJ	0.5005E+05	1.840	0.1299E+07	1.645
7	ESTR	41	6	41	MOMJ	0.3444E+06	1.160	0.1380E+07	1.650
8	ESTR	42	6	42	MOMJ	0.5442E+06	1.145	0.1361E+07	1.655
9	ESTR	43	6	43	MOMJ	0.6623E+06	3.385	0.1245E+07	1.660
10	ESTR	44	6	44	MOMJ	0.6698E+06	3.405	0.1032E+07	1.670
11	ESTR	45	6	45	MOMJ	0.5332E+06	3.430	0.8445E+06	4.450
12	ESTR	46	6	46	MOMJ	0.2445E+06	1.640	0.6600E+06	1.835
13	ESTR	47	6	47	MOMJ	-0.2522E+06	1.645	0.4566E+06	1.830
14	ESTR	48	6	48	MOMJ	-0.7474E+06	1.650	0.2251E+06	1.825
15	ESTR	49	6	49	MOMJ	-0.1315E+07	1.650	-0.7358E+05	1.825
16	ESTR	50	6	50	MOMJ	-0.1954E+07	1.650	-0.4459E+06	1.820
17	ESTR	51	6	51	MOMJ	-0.2670E+07	1.650	-0.8724E+06	1.145

Peak Shear and Normal Forces, 0.2g DBE

POST26 SUMMARY OF VARIABLE EXTREME VALUES

VARI	TYPE	IDENTIFIERS		NAME	MINIMUM	AT TIME	MAXIMUM	AT TIME
2	ESTR	9	1	9 NFOR	0.3311E+05	4.205	0.4581E+05	1.765
3	ESTR	9	2	9 SHRF	-0.1993E+05	1.080	4265.	1.615
4	ESTR	22	1	22 NFOR	0.1902E+05	4.200	0.2765E+05	3.670
5	ESTR	22	2	22 SHRF	-0.1715E+05	1.850	777.8	1.620
6	ESTR	34	1	34 NFOR	0.1316E+05	4.195	0.1977E+05	4.435
7	ESTR	34	2	34 SHRF	-0.1567E+05	1.850	-155.3	1.625
8	ESTR	62	1	62 NFOR	0.1319E+05	1.145	0.2063E+05	1.645
9	ESTR	62	2	62 SHRF	5217.	1.140	0.1321E+05	1.650
10	ESTR	76	1	76 NFOR	0.2821E+05	5.000	0.3819E+05	0.8850
11	ESTR	76	2	76 SHRF	1039.	1.160	0.1559E+05	1.640
12	ESTR	88	1	88 NFOR	0.3687E+05	5.000	0.4911E+05	0.8850
13	ESTR	88	2	88 SHRF	-1031.	1.165	0.1763E+05	1.610
14	ESTR	100	1	100 NFOR	0.4295E+05	4.995	0.5699E+05	0.8850
15	ESTR	100	2	100 SHRF	-2278.	1.160	0.1936E+05	1.600
16	ESTR	111	1	111 NFOR	0.4771E+05	4.990	0.6321E+05	0.8850
17	ESTR	111	2	111 SHRF	-3356.	1.140	0.2060E+05	1.600
18	ESTR	112	4	112 NFOR	-0.7170E+05	0.8850	-0.5524E+05	4.990
19	ESTR	112	5	112 SHRF	-0.2135E+05	1.600	4150.	1.135

POST26 SUMMARY OF VARIABLE EXTREME VALUES

VARI	TYPE	IDENTIFIERS		NAME	MINIMUM	AT TIME	MAXIMUM	AT TIME
20	OPER	20	ABS	SHF/NORF	0.7191E-03	3.475	0.5306	1.130
21	OPER	21	ABS	SHF/NORF	0.5521E-03	1.650	0.7313	1.835
22	OPER	22	ABS	SHF/NORF	0.1066E-01	1.625	0.8900	1.845
23	OPER	23	ABS	SHF/NORF	0.3604	3.050	0.6431	1.655
24	OPER	24	ABS	SHF/NORF	0.3604E-01	1.160	0.4269	1.665
25	OPER	25	ABS	SHF/NORF	0.1053E-03	1.845	0.3803	1.585
26	OPER	26	ABS	SHF/NORF	0.2629E-02	1.825	0.3595	1.590
27	OPER	27	ABS	SHF/NORF	0.2407E-03	1.820	0.3448	1.590
28	OPER	28	ABS	SHF/NORF	0.1537E-02	4.555	0.3135	1.590

Peak Surface Stresses in Roof, 0.2g DBE

POST26 SUMMARY OF VARIABLE EXTREME VALUES

VARI	TYPE	IDENTIFIERS			NAME	MINIMUM	AT TIME	MAXIMUM	AT TIME
2	ESTR	36	7	36	SDPB	-1189.	1.850	-163.1	1.625
3	ESTR	36	8	36	SDMB	156.7	1.625	1131.	1.850
4	ESTR	37	7	37	SDPB	-983.5	1.850	88.02	1.630
5	ESTR	37	8	37	SDMB	-97.16	1.630	924.5	1.845
6	ESTR	38	7	38	SDPB	-771.4	1.845	352.5	1.635
7	ESTR	38	8	38	SDMB	-365.1	1.640	711.7	1.845
8	ESTR	39	7	39	SDPB	-546.6	1.845	627.2	1.640
9	ESTR	39	8	39	SDMB	-643.3	1.640	485.5	1.845
10	ESTR	40	7	40	SDPB	-286.6	1.845	850.1	1.645
11	ESTR	40	8	40	SDMB	-869.1	1.645	227.9	1.840
12	ESTR	41	7	41	SDPB	10.63	1.840	989.3	1.645
13	ESTR	41	8	41	SDMB	-1011.	1.645	-66.65	1.840
14	ESTR	42	7	42	SDPB	240.2	1.160	1049.	1.650
15	ESTR	42	8	42	SDMB	-1075.	1.650	-290.1	1.160
16	ESTR	43	7	43	SDPB	395.5	1.145	1033.	1.655
17	ESTR	43	8	43	SDMB	-1062.	1.655	-442.2	1.140
18	ESTR	44	7	44	SDPB	488.9	1.145	942.2	1.660
19	ESTR	44	8	44	SDMB	-974.3	1.660	-529.4	3.385
20	ESTR	45	7	45	SDPB	496.9	3.405	777.3	1.670
21	ESTR	45	8	45	SDMB	-811.9	1.670	-534.6	3.405
22	ESTR	46	7	46	SDPB	390.3	3.430	627.3	4.450
23	ESTR	46	8	46	SDMB	-672.6	4.450	-430.9	3.430
24	ESTR	47	7	47	SDPB	168.7	1.640	487.4	1.835
25	ESTR	47	8	47	SDMB	-528.8	1.835	-207.7	1.640
26	ESTR	48	7	48	SDPB	-204.1	1.645	311.8	1.830
27	ESTR	48	8	48	SDMB	-349.5	1.835	161.1	1.645
28	ESTR	49	7	49	SDPB	-502.9	1.650	128.8	1.825
29	ESTR	49	8	49	SDMB	-160.9	1.825	459.1	1.650
30	ESTR	50	7	50	SDPB	-779.0	1.650	-56.70	1.825
31	ESTR	50	8	50	SDMB	28.03	1.825	734.9	1.650
32	ESTR	51	7	51	SDPB	-1035.	1.650	-243.9	1.820
33	ESTR	51	8	51	SDMB	218.6	1.820	990.8	1.650

Peak Roof Moments, 0.4g EQ

POST26 SUMMARY OF VARIABLE EXTREME VALUES

'E	IDENTIFIERS			NAME	MINIMUM	AT TIME	MAXIMUM	AT TIME
ℓ	36	3	36	MOMI	-0.4509E+06	1.635	0.3430E+07	1.150
ℓ	37	3	37	MOMI	-0.7824E+06	1.640	0.2770E+07	1.155
ℓ	38	3	38	MOMI	-0.1059E+07	1.645	0.2183E+07	1.160
ℓ	39	3	39	MOMI	-0.1309E+07	1.660	0.1672E+07	1.170
R	40	3	40	MOMI	-0.1518E+07	1.665	0.1232E+07	1.180
R	41	3	41	MOMI	-0.1684E+07	1.675	0.7793E+06	1.185
R	42	3	42	MOMI	-0.1779E+07	1.370	0.4253E+06	1.210
R	43	3	43	MOMI	-0.1857E+07	1.365	0.1815E+06	1.225
R	44	3	44	MOMI	-0.1793E+07	1.360	0.1561E+05	1.235
R	45	3	45	MOMI	-0.1573E+07	1.360	-0.9389E+05	1.240
R	46	3	46	MOMI	-0.1201E+07	1.355	-0.1566E+06	1.245
R	47	3	47	MOMI	-0.8392E+06	1.105	-0.4962E+05	1.635
R	48	3	48	MOMI	-0.7544E+06	1.115	0.4597E+06	1.655
R	49	3	49	MOMI	-0.6328E+06	1.120	0.9986E+06	1.660
R	50	3	50	MOMI	-0.4401E+06	1.120	0.1627E+07	1.670
R	51	3	51	MOMI	-0.1789E+06	1.140	0.2352E+07	1.675