Attachment 1

UCID-20480

TECHNICAL EVALUATION REPORT FOR THE LICENSEE'S PROPOSED SOIL-STRUCTURE INTERACTION ANALYSIS TECHNIQUES FOR LONG TERM SERVICE SEISMIC REEVALUATION: SAN ONOFRE NUCLEAR GENERATING STATION UNIT 1

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Lawrence Livermore National Laboratory

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TECHNICAL EVALUATION REPORT FOR THE LICENSEE'S PROPOSED SOIL-STRUCTURE INTERACTION ANALYSIS TECHNIQUES FOR LONG TERM SERVICE SEISMIC REEVALUATION

SAN ONOFRE NUCLEAR GENERATING STATION UNIT 1

By

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Prepared for

The U. S. Nuclear Regulatory Commission

1.0 INTRODUCTION

1.1 Background

In mid 1982, the San Onofre Nuclear Generating Station Unit 1 (SONGS 1) was shut down for upgrading of safety-related structures, systems and components to resist postulated seismic loadings developed for the SONGS 1 seismic reevaluation. In 1984, the plant was allowed to return to service for the refueling cycle, during which further upgrading was to be planned and prepared for by the licensee. In a meeting with the U.S. Nuclear Regulatory Commission (NRC) staff on February 12, 1985 (Ref. 1), and through a letter dated March 12, 1985 (Ref. 2), the licensee (Southern California Edison Company) proposed their criteria and analysis methodology for the Long Term Service (LTS) upgrading to ensure adequate seismic design margins for those safety-related structures, systems and components in the plant. A technical evaluation of the licensee's proposed plans is needed in order for the NRC to reach a decision regarding approval of the Full Term Operating License for the plant.

Assessment of the technical adequacy of the licensee's proposed LTS criteria and analysis methodologies are given in the following three areas:

1. Soil-structure interaction analysis.

2. Direct generation of floor response spectra accounting for the interaction effect between the supporting structure and piping systems considered in the spectrum generation, and the application of the generated floor spectra to the response analysis of a secondary system within the supporting structure with the response spectrum method of analysis.

3. Modal and directional response combinations for the response analysis of the secondary system with the response spectrum method of analysis.

1.2 Criteria of Review

SONGS 1 is one of the NRC designated Systematic Evaluation Program (SEP) plants which was not designed to current codes, standards and NRC requirements. It is therefore necessary to perform "more realistic" or "best estimate" assessments of the seismic capacity of the facility and to consider any conservatism associated with the existing design. For the purpose of the SEP plant seismic review, the NRC developed a set of review criteria and guidelines, as follows:

a. NUREG/CR-0098, "Development of Criteria for Seismic Review of Selected Nuclear Power Plants," by N. M. Newmark and W. J. Hall, May, 1978.

b. "SEP Guidelines for Soil-Structure Interaction Review," by SEP Senior Seismic Review Team, December 8, 1980.

c. Letter from W. Paulson, NRC, to R. Dietch, SCE, "Systematic Evaluation Program Position Re: Consideration of Inelastic Response Using NRC NUREG/CR-0098 Ductility Factor Approach," June 23, 1982.

d. Letter from W. Paulson, NRC, to R. Dietch, SCE, "SEP Topic III-6. Seismic Design Considerations, Staff Guidelines for Seismic Evaluation Criteria for the SEP Group II Plants," July 26, 1982.

e. (Revision of Criteria (d) above, to be issued.) For cases that are not specifically covered by the above criteria, the following SRP sections and Regulatory Guides are used as the basis for our review:

   1. Standard Review Plan, Sections 2.5, 3.7 and 3.8, 3.9 and 3.10.

   2. Regulatory Guides 1.26, 1.29, 1.60, 1.92, 1.100, and 1.122.

In the event that the licensee's proposed methodology and criteria deviate from the aforementioned review criteria and guidelines, we have reviewed, based on our experience and best engineering judgment, the justifications presented by the licensee. We recognize that plant specific deviations on a case-by-case basis may be necessary and may be found acceptable so long as they reasonably meet the intents of the SEP review guidelines.

This technical evaluation report (TER) presents our conclusions on the technical adequacy of the methodology proposed by the licensee soil-structure interaction analysis. Our assessment is accomplished by reviewing the pertinent theory, methodologies, computer codes, and licensee's planned applications to SONGS 1 LTS seismic reevaluation. To help substantiate our assessment, we also designed a test problem that compares the solution from the licensee's proposed methodology with the solution from the acceptable methodology.

Section 2.0 discusses the licensee proposed methodology and associated computer codes. Section 3.0 describes the test problem and results of the comparison between the proposed and the independent methodologies. Section 4.0 presents our conclusions. Details of the test problem and analysis results are provided in Appendix A. Additional analysis results from Impell Corporation are included in Appendix B.

2.0 DISCUSSION OF LICENSEE'S PROPOSED METHODOLOGY

The proposed soil-structure interaction (SSI) analysis methodology is a substructure approach. This approach divides the problem into three analyses--the determination of the foundation impedances, the determination of the fixed-base structure modal properties, and the response analysis of the coupled soil-structure system for the ground motion specified at the foundation level. The SASSI computer code (Ref. 3) is used to determine the foundation impedances. The EDSGAP code is used to determine the modal properties of the fixed-base structure. The CLASSI code (Ref. 3) then analyzes the coupled soil-structure system in which the soil foundation is represented by the foundation impedances and the structure properties by the fixed-base structural modes. In the following, a brief discussion is provided for the SASSI and CLASSI methodology.

The SASSI program models the massless structure foundation and, if necessary, a finite volume of soil by the finite element technique so that the details of the foundation geometry and variation of foundation soil properties such as that due to the backfill can be properly modeled. The remaining soil foundation is modeled by soil layering around the finite soil volume to simulate the effect of an infinite half space. The soil layering is condensed to equivalent energy absorbing transmitting boundary elements at the foundation and soil finite element boundary nodes. The transmitting boundary elements are, in general, frequency dependent. To determine the foundation impedances, the SASSI code analyzes the finite element model of the massless structure foundation and the soil in the frequency domain. The foundation impedances are represented by a frequency dependent impedance matrix associated wtih the degrees of freedom of the structure foundation. The CLASSI program calculates the seismic response of the SSI system. The SSI system includes the foundation impedances generated from the SASSI code, the structure foundation that is assumed rigid, and the structure that is represented by the structure masses and modal properties (structure frequencies, mode shapes, modal damping, etc.). The input ground motion is the free-field motion specified at the structure foundation level. The response analysis is then performed in the frequency domain which permits modeling the characteristics of the soil by frequency-dependent impedance. Fourier transform techniques are applied to obtain the time history of response.

3.0 TEST PROBLEM

The purpose of the test problem is to check the licensee proposed soil-structure interaction analysis methodology and its computer code implementation. We used the soil-spring and the CLASSI analysis method to calculate the floor response spectra. The results were compared among the three methods. The constant soil-spring method is acceptable to the NRC. The CLASSI was used in the calculation of foundation impedance of the Byron nuclear generating station.

CLASSI uses a three-step substructure approach--determination of foundation input motion, determination of foundation impedance and analysis of coupled soil-structure system. The free-field motion and foundation input motion differ primarily for two reasons. First, waves are scattered from the soil-foundation interface. Second, points on the foundation are constrained to move according to its geometry and stiffness. This leads to determine the foundation input motion. However, if the control motion is specified directly at the foundation, then this determination of foundation input motion is not needed. The foundation frequency dependent impedances are calculated in CLASSI by a continuum method. The description of the analysis of a coupled soil-structure system is the same as that provided in Section 2.0.

For the constant soil-spring SSI analysis method, the soil foundation is represented by frequency-independent impedances (springs and dampers). The structure is represented by the structural masses and modal properties. The response analysis is performed using the time history method with a direct integration scheme as implemented in the RESPONSE code of NCT Engineering.

Figure 1 shows the soil-structure system used to test the licensee's SSI methodology. The structure consists of an eleven-mass structure with a rigid circular base with a 65 foot radius. The base is on a uniform soil medium. A detailed description of the test problem and its material properties is given in Appendix A. The soil-structure system of the test problem is subject to a 10-second horizontal ground motion having a peak acceleration of 0.5g as shown in Figure A-1.

The licensee was required to generate floor spectra at four different elevations using the technique described in Section 2.0. We calculated the floor response spectra at the same locations with CLASSI and the constant soil-spring method to compare with the licensee's spectra for the examination of the licensee's soil-structure interaction methodology.

3.2 RESULTS

The impedance springs and damping, K_{HH}, C_{HH}, K_{MM} and C_{MM}, as generated from the SASSI code (licensee) (Ref. 4), CLASSI code (LLNL), and constant soil-springs (NCT), are compared to each other in Figs. 2 and 3. The subscripts HH and MM stand for the horizontal translation and rocking modes, respectively, of the structural base. The SASSI and CLASSI impedance springs and damping are in close agreement to each other for frequency up to about 7 Hz and 15 Hz, respectively. Beyond these frequencies, the SASSI and CLASSI impedances deviate from each other with increasing frequency. The 2% damping in-structure response spectra at structure nodes 11 (Top), 7, 4, and the base are shown in Figs. 4 to 7, respectively. Twenty-five frequency points were specified for the spectrum generation from all three analyses. The fundamental frequency of the soil structure system is, by inspection, around 2 Hz where the dominant spectrum peak occurs. The licensee solution (Appendix B) is essentially identical to the CLASSI and constant soil-spring solutions at all four locations. The minor discrepancies between the three solutions are anticipated due to the difference in methodology.

In general, we believe the licensee solution is acceptable. The discrepancy in impedances between the SASSI and CLASSI approach does not produce significant deviation in the in-structure response spectrum so long as the finite element mesh used in the SASSI approach is fine enough to produce a sufficient solution for frequencies up to at least the dominant modes of the soil-structure system. The results also suggest that the three methods of analysis, using the same soil and structure properties, can easily produce a different spectrum peak frequencies. Such variation due to analysis methodology should be sufficiently accounted for in the applications to the SONGS 1 LTS program with an appropriate amount of spectrum peak broadening.

4.0 CONCLUSIONS

Based on our review of the theory and the results of the test problem, we conclude that the methodology proposed by the licensee for the soil-structure interaction analysis, i.e., using SASSI for impedance generation and CLASSI for response analysis, is appropriate for the SONGS 1 LTS.

In actual applications to the SONGS 1 analysis, the licensee is required to: (1) require that the SASSI finite element foundation and soil mesh be fine enough to ensure the accuracy of impedance calculations up to at least the dominant modes; (2) use a sufficient number of frequency points to calculate the impedances; and (3) require sufficient frequency points in the spectrum computations around the spectrum peak locations so as to minimize missing the spectrum peaks. We also recommend that the seismic response calculation of the reactor building be reviewed independently and thoroughly.

5.0 ACKNOWLEDGEMENTS

The authors wish to thank Dr. M. S. Yang and Mr. W. L. Wong, both of NCT Engineering, for their contributions to this TER. They participated in generating the NCT portion of the test problem results and in preparing the draft report. In addition, Dr. Yang assisted in reviewing the licensee's proposed methodology.

6.0 REFERENCES

1. Memorandum from E. McKenna to C. I. Grimes, dated February 12, 1985.

2. Letter from Mark Medford, SCE, to J. A. Zwolinski, NRC, dated March 12, 1985.

3. Letter from M. Medford, SCE, to J. A. Zwolinski, NRC, dated March 29, 1985.

4. Letter from M. Medford, SCE, to J. A. Zwolinski, NRC dated Junel 4, 1985.

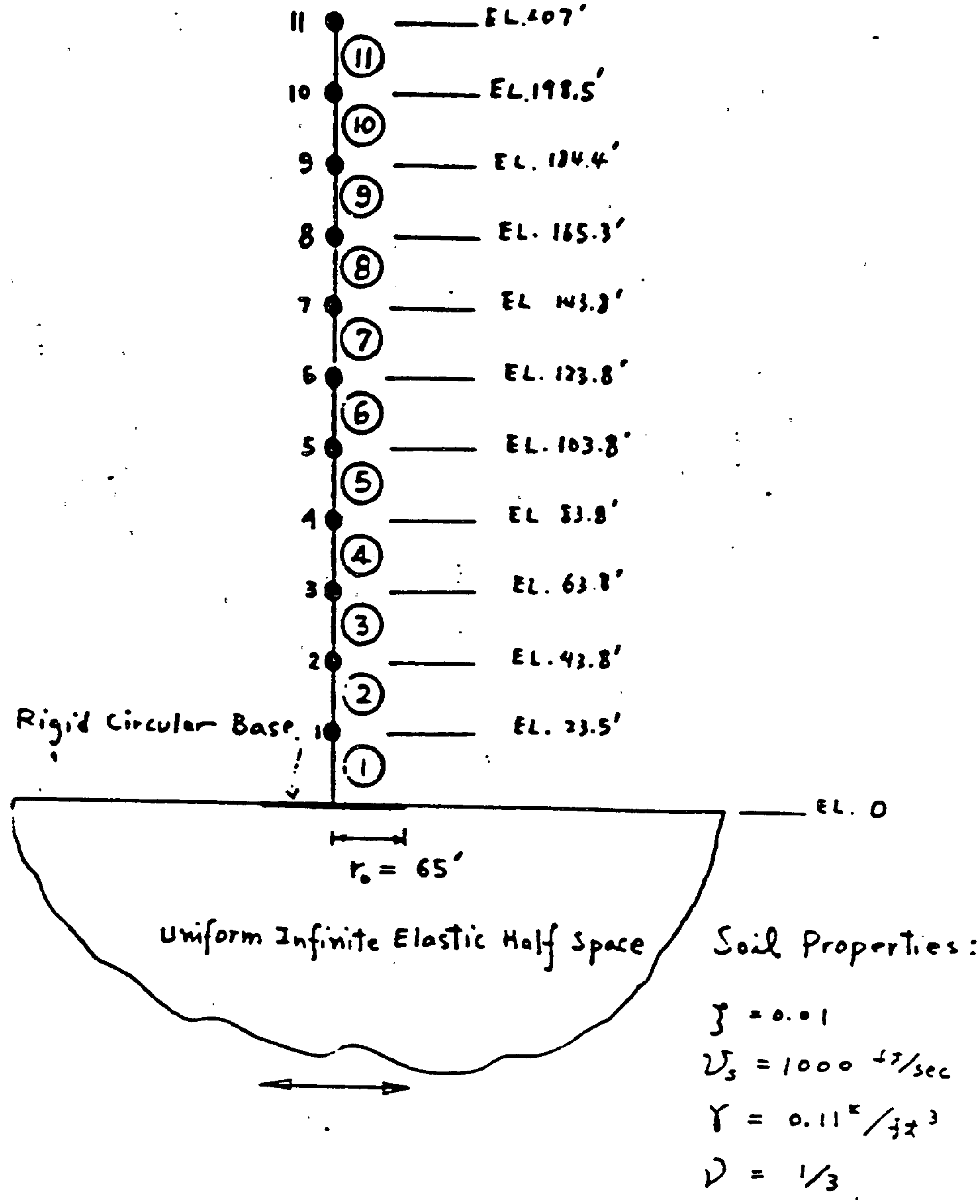

FIGURE 1. SOIL STRUCTURE SYSTEM

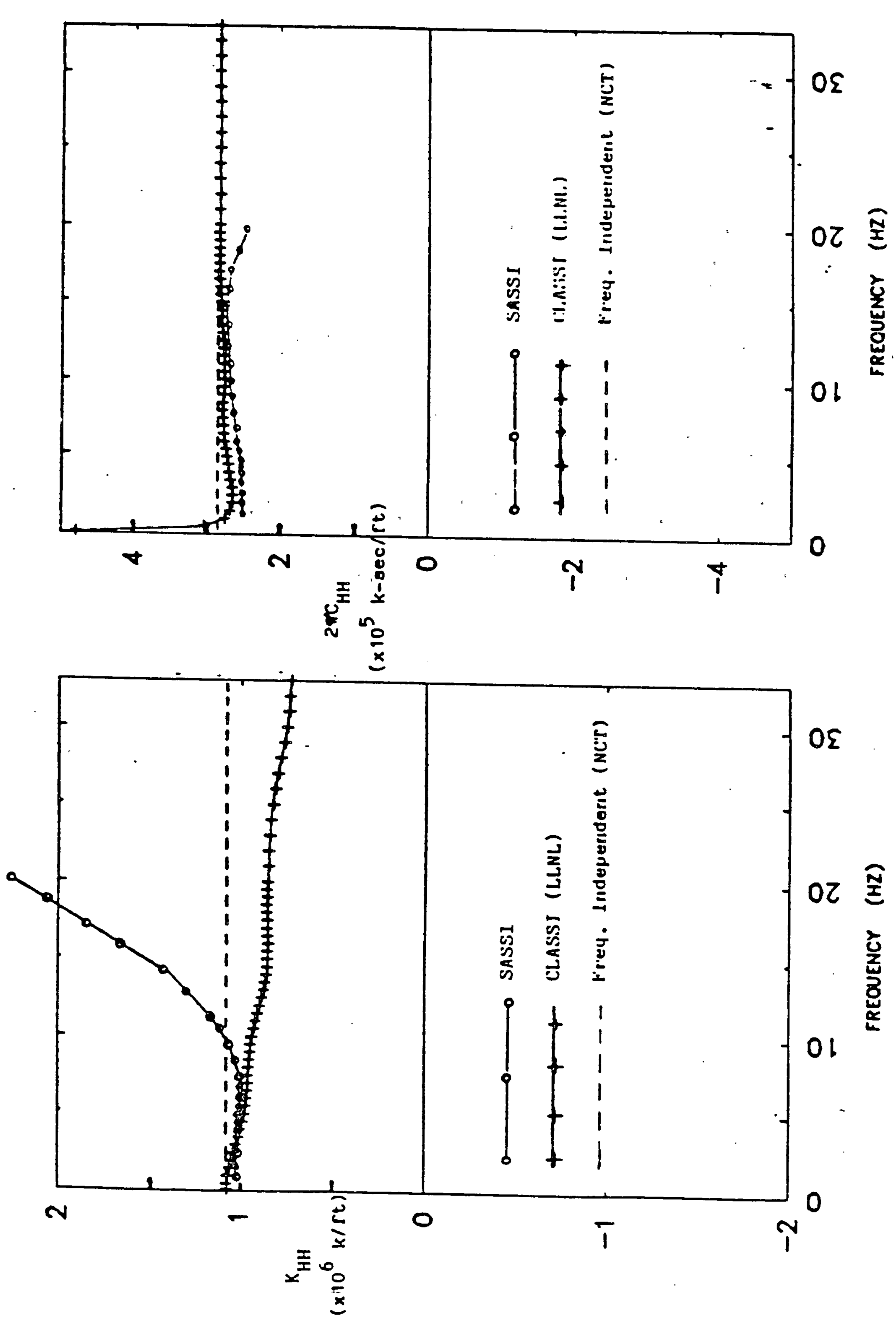

FIGURE 2. Horizontal Translation Mode Impedance Spring K_{HH}, and Damping, C

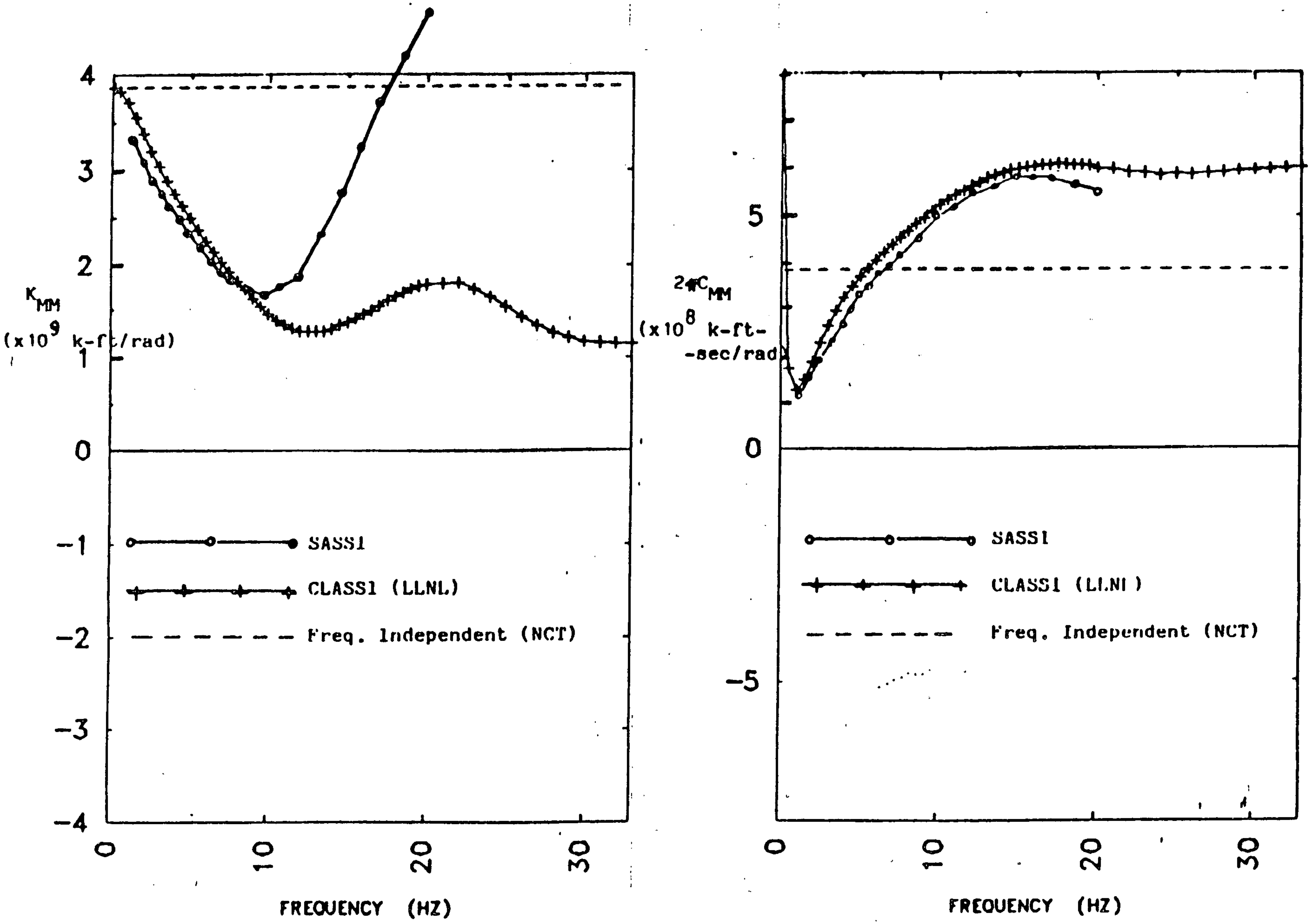

FIGURE 3. Rocking Mode Impedance Springs K_{MM}, and Damping, C_{MM}.

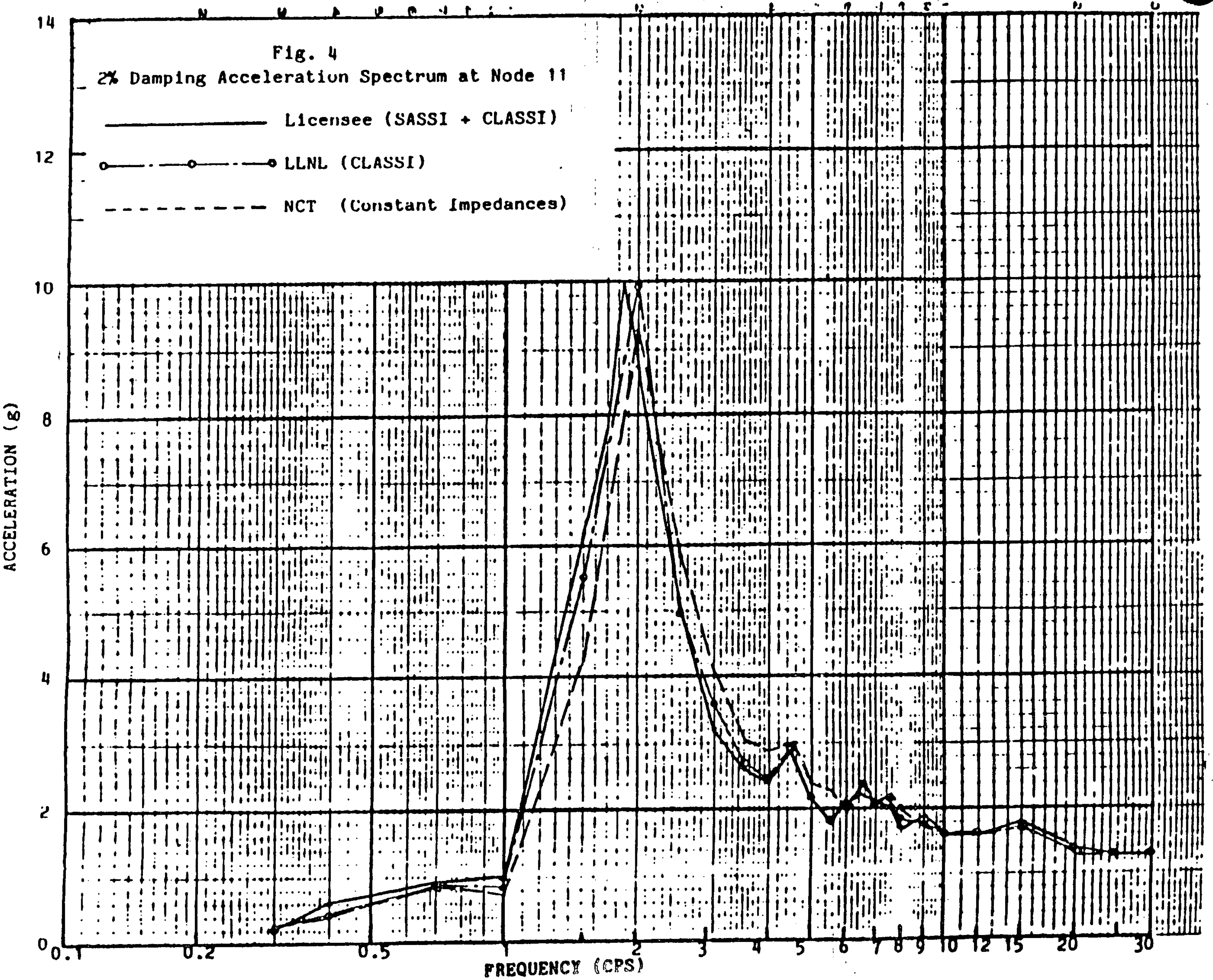

Fig. 4
2% Damping Acceleration Spectrum at Node 11
Licensee (SASSI + CLASSI)
LLNL (CLASSI)
NCT (Constant Impedances)
ACCELERATION (g)
14
12
10
8
6
4
2
0
0.1
0.2
0.5
1
2
3
4
5
6
7
8
9
10
12
15
20
30
FREQUENCY (CPS)

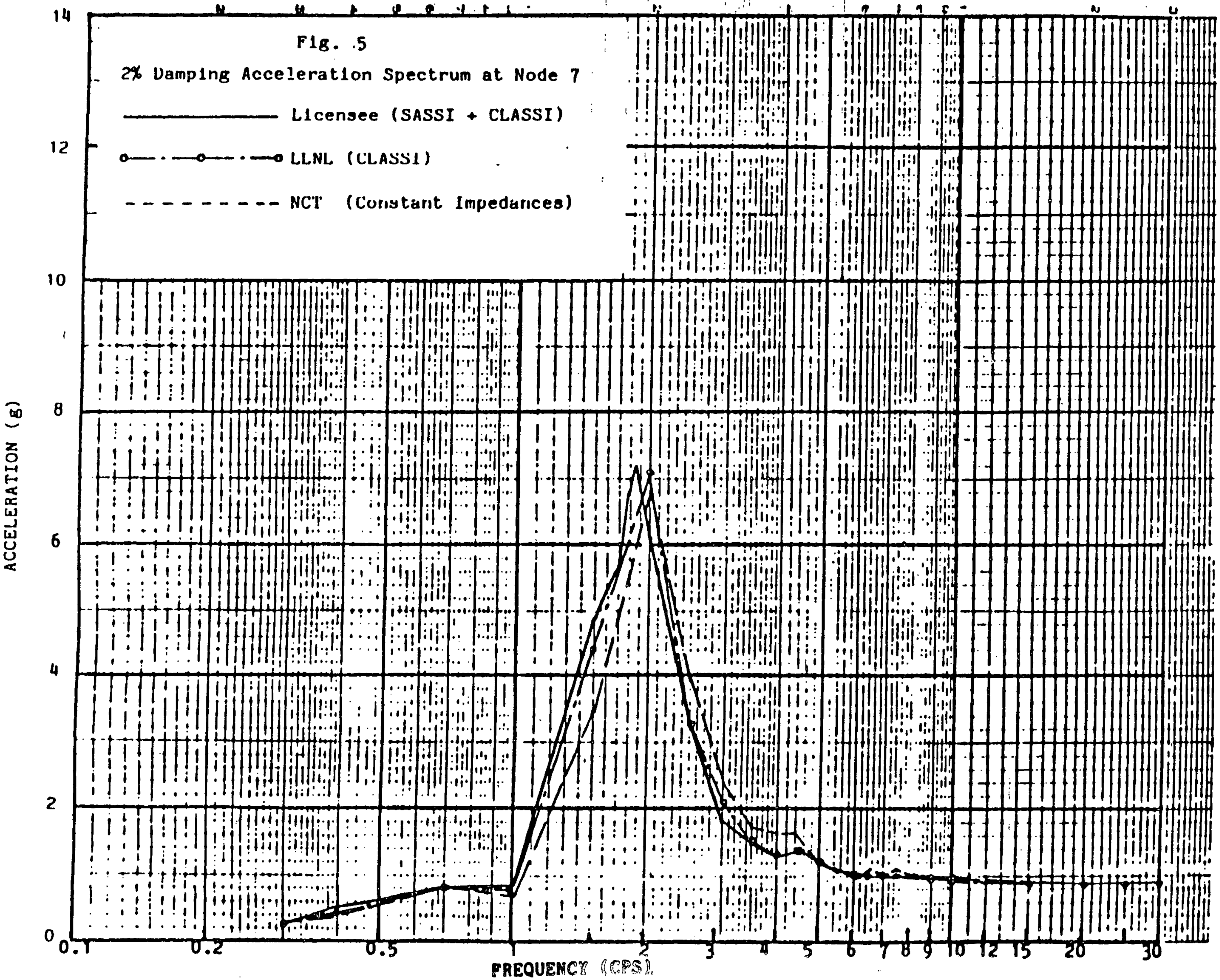

Fig. 5
2% Damping Acceleration Spectrum at Node 7
Licensee (SASSI + CLASSI)
LLNL (CLASSI)
NCT (Constant Impedances)
ACCELERATION (g)
14
12
10
8
6
4
2
0
0.1
0.2
0.5
1
2
3
4
5
6
7
8
9
10
12
15
20
30
FREQUENCY (CPS)

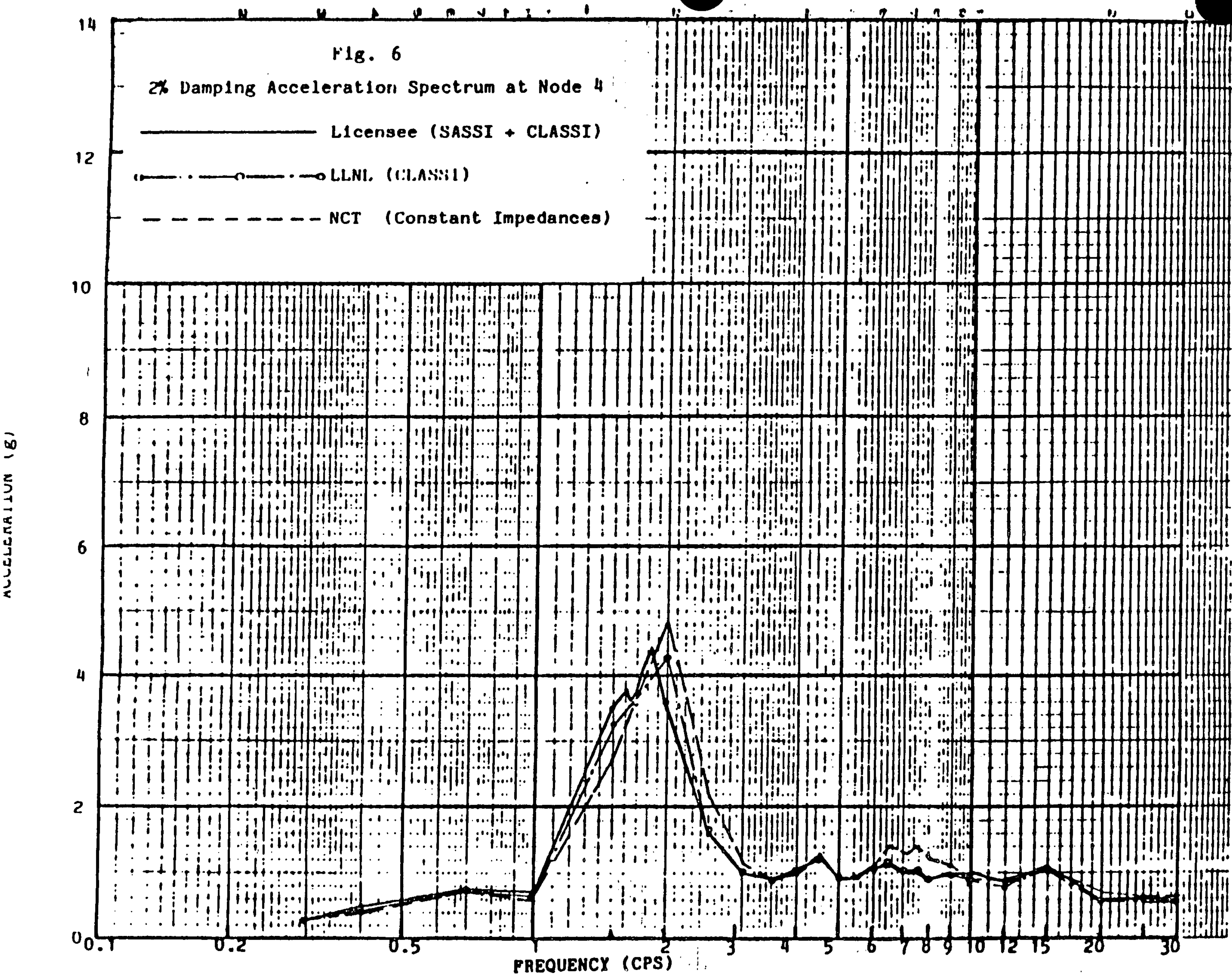
Fig. 6
2% Damping Acceleration Spectrum at Node 4
Licensee (SASSI + CLASSI)
LLNL (CLASSI)
NCT (Constant Impedances)
ACCELERATION (g)
FREQUENCY (CPS)
0
2
4
6
8
10
12
14
0.1
0.2
0.5
1
2
3
4
5
6
7
8
9
10
12
15
20
30

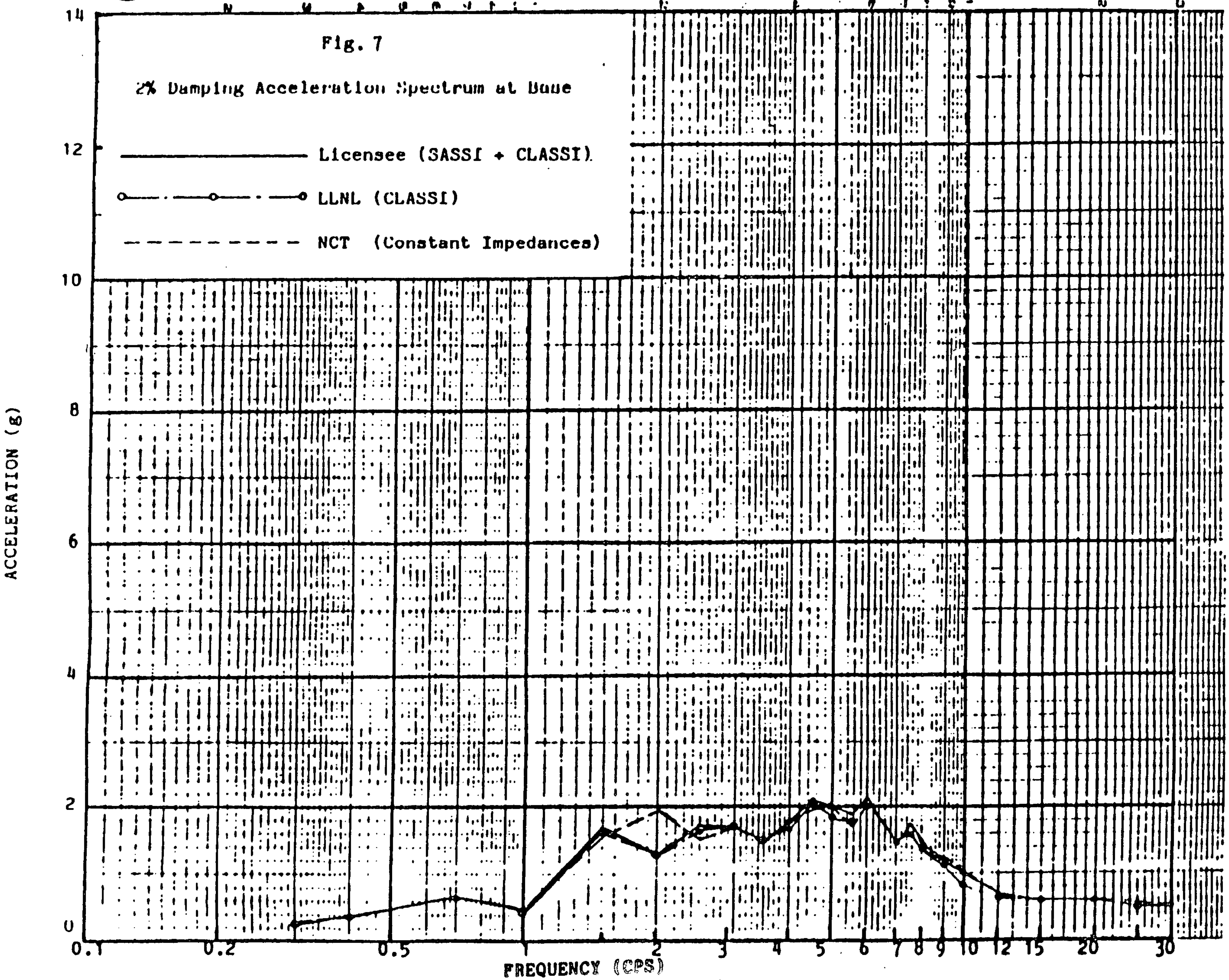
Fig. 7
2% Damping Acceleration Spectrum at Base
Licensee (SASSI + CLASSI)
LLNL (CLASSI)
NCT (Constant Impedances)
ACCELERATION (g)
14
12
10
8
6
4
2
0
0.1
0.2
0.5
1
2
3
4
5
6
7
8
9
10
12
15
20
30
FREQUENCY (CPS)

APPENDIX A

DETAILS OF TEST PROBLEM ANALYSES

A.1 Problem Description

The soil-structure system is illustrated in Figure 1. Properties of the structure and base are given in Tables A-1 and A-2. The free-field horizontal surface motion has a duration of 10 seconds and a maximum acceleration of 0.5 g. It is digitized at a time interval of 0.005 seconds. The plot of the acceleration time history, with the maximum amplitude normalized to 1.0 g, is shown in Figure A-1.

In both the licensee's and our analyses, the uniform half-space soil foundation are represented by the impedances: K_{HH}, K_{MM}, and K_{HM}, representing the lateral translational, rocking, and translation-rocking coupling springs, respectively; and the associated impedance damping, C_{HH}, C_{MM}, and C_{HM}. See Figure A-2 for illustration.

A.2 Licensee Analysis

The licensee determined the impedances which are all frequency-dependent, from both their SASSI and CLASSI codes. The SASSI results are shown as open circles in Figures 2 and 3. The coupling terms, K_{HM} and C_{HM} are relatively small compared with the remaining impedances, and hence are not shown here. The impedances from the licensee's CLASSI code are not shown here either. They are essentially the same as the SASSI impedances at the low frequency end, and are somewhat different at the higher frequency range (beyond about 10 Hz) due possibly to the fact that the CLASSI code is based on the continuum approach, and the SASSI code on the discretized finite element approach. Apparently, the agreement between the licensee's CLASSI and SASSI impedances would improve at the high frequency end when more refined meshes are used for the SASSI solution. For the current test problem, the discrepancy between the two impedance solutions beyond 10 Hz would not produce significant difference in the structural response because the soil-structure system dominant frequencies are expected in the 2 to 5 Hz range.

The licensee used the EDSGAP code to determine the modal properties of the fixed base structure. They then ran the CLASSI code, which coupled the soil impedances, the structural base and the fixed base structure modes, and performed the response calculations. The outputs are the 2% damping in-structure acceleration spectrum at structure nodes 11 (top), 7, 4, and the base. They are shown by the solid curves in Figures 3 to 6 in the text.

A.3 LLNL Analysis

LLNL performed the soil-structure interaction analysis using their CLASSI code for both the impedance and structural response calculations. The impedances, K_{HH}, K_{MM}, C_{HH}, and C_{MM} are shown compared with the licensee's SASSI results in Figures 2 and 3. These CLASSI solutions from LLNL are essentially identical to the Licensee's CLASSI solutions not shown here.

LLNL's in-structure response spectra at structural nodes 11, 7, 4 and at the base are shown as solid circles in Figures 3 to 6 in the text.

A.4 NCT Analyses

In the analysis by NCT Engineering, the coupling terms, K_{HM} and C_{HM}, were neglected because our past experience indicated that they can usually be ignored without introducing noticeable errors in the structural response. Additional simplifications were introduced by using frequency-dependent values for K_{HH}, ___, C_{MM}, as follows:

$$K_{HH} = \frac{8GR}{2-\nu} = 1.07 \times 10^6 \text{ kip/ft;}$$

$$K_{MM} = \frac{8GR^3}{3(1-\nu)} = 3.75 = 3.75 \times 10^9 \text{ kip-ft/rad;}$$

$$C_{HH} = 0.65RK_{HH}/ V_s = 4.50 \times 10^4 \text{ kip-sec/ft;}$$

$$C_{MM} = 0.25RK_{MM}/ V_s = 6.10 \times 10^7 \text{ kip-ft-sec/rad}$$

Both K_{HH} and K_{MM} are simply the static case (zero frequency) impedances from the CLASSI solutions. C_{HH} was taken to be the essentially constant portion of the corresponding CLASSI solution. C_{MM} was taken to be the CLASSI solution at 3 Hz, which we estimated as the approximate first mode frequency of the soil-structure system. The frequency-independent impedances are shown as dashed lines in Figures 2 and 3 in the text, to compare with the SASSI and CLASSI solutions for impedances.

The LLNL version of SAP4 was used to determine the fixed base structure modal properties. The NCT code RESPONSE then coupled the impedances with the structural modes and structural base and performed the response calculations with a direct integration time history analysis scheme. The 2% damping in-structure response spectra at the four structure locations are shown as dashed curves in Figures 4 to 7 in the text.

TABLE A-1

BEAM ELEMENT PROPERTIES OF THE STRUCTURE

Element No.	Section Area (ft^2)	Shear Area (ft^2)	Moment of Inertia (ft^2)
1 - 7	1400	700	2.8×10^6
8	990	500	1.9×10^6
9	990	500	1.5×10^6
10	990	500	0.8×10^6
11	990	500	0.2×10^6

TABLE A.2

NODAL MASSES OF THE STRUCTURE

Node No.	Nodal Mass (Kips)
1	4,600
2	4,200
3	4,200
4	4,200
5	4,200
6	4,200
7	4,610
8	3,020
9	2,470
10	2,120
11	190
Base	20,000

$I_{base} = 4.5 \times 10^6$ kip-ft^2

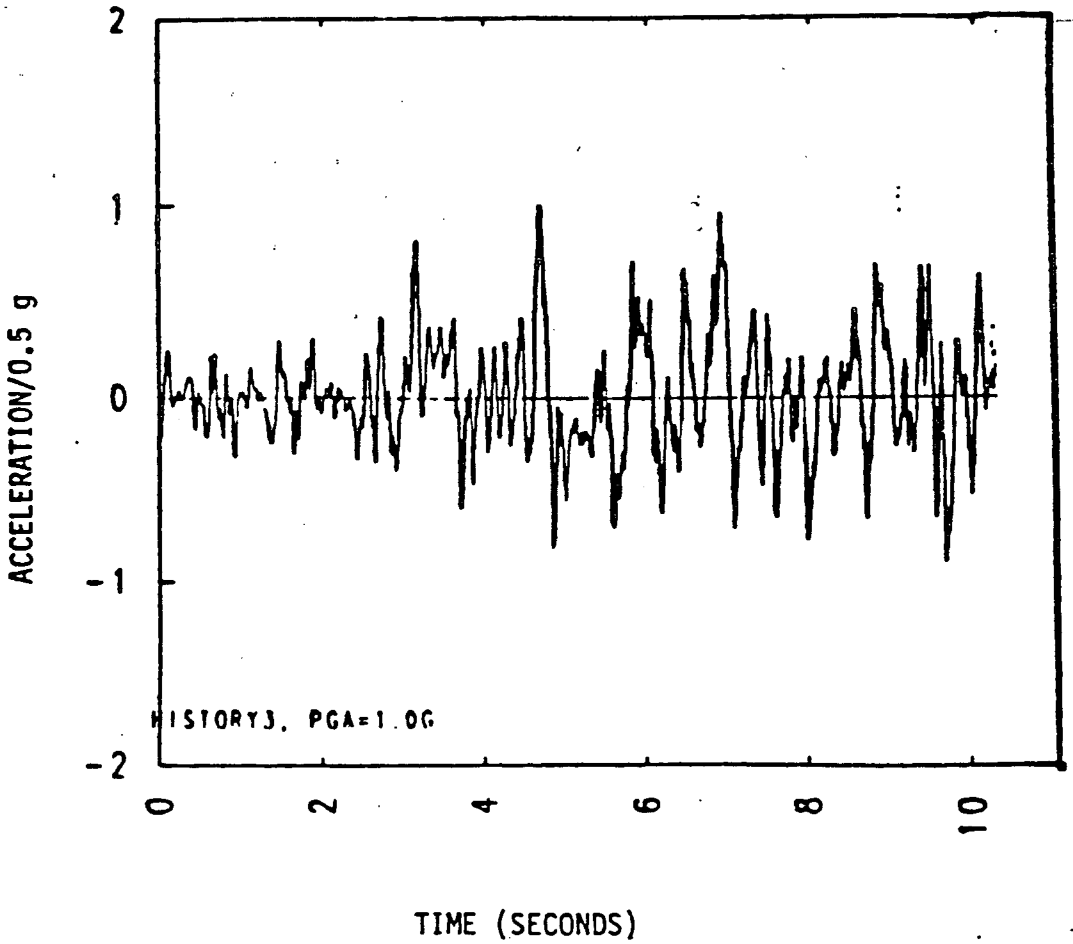

FIGURE A-1. Horizontal Free Field Time History

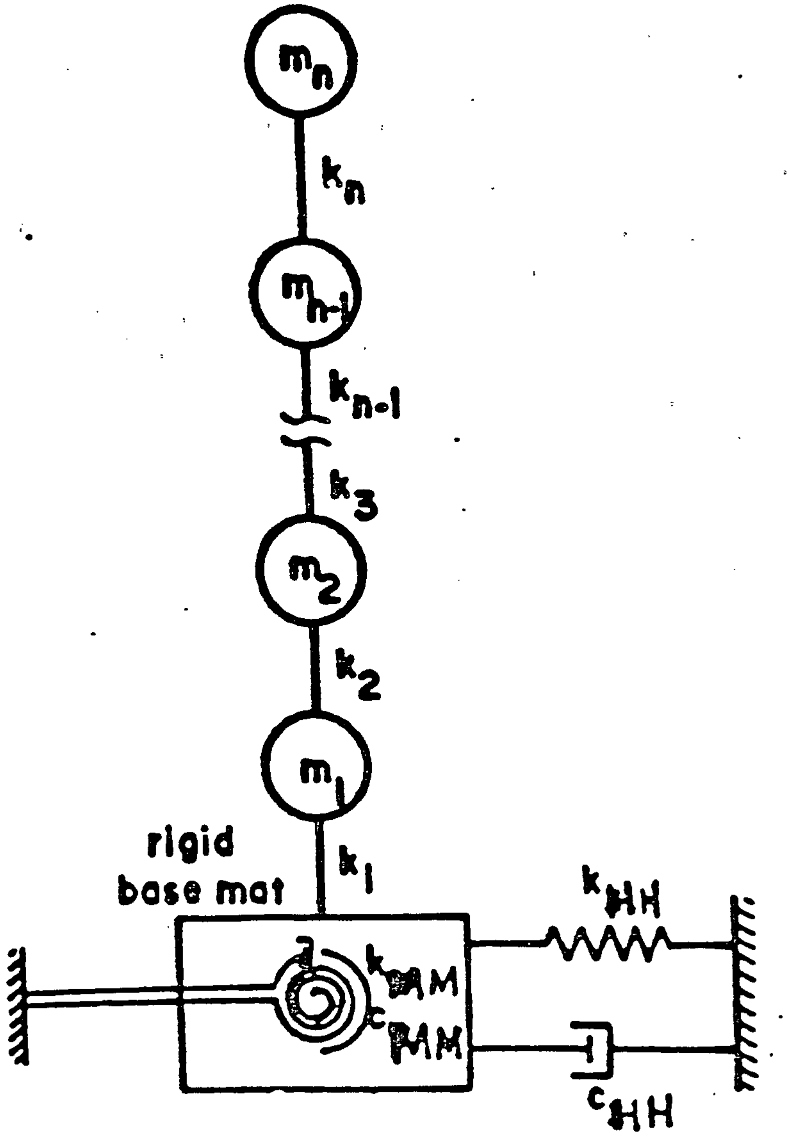

FIGURE A-2. A Lumped Model of Structure-Foundation System.

APPENDIX B

IMPELL ANALYSIS RESULTS

Tables B.1 through B.4 are the digitized values of the floor response spectrum corresponding to Nodes 4, 7, 11 and the base of the structural model generated by the Impell Corporation of Walnut Creek.

RESPONSE SPECTRUM AT DAMPING = .0200 * * * * OUTPUT , TAPE 3

FREQUENCY (CPS)	PERIOD (SECS)	ABSOLUTE ACCELERATION	PSEUDO VELOCITY	TIME AT MAXIMUM
.300	3.333	.2744E+00	.1562E+00	.9375E+01
.400	2.500	.5343E+00	.1615E+00	.1077E+02
.700	1.429	.9062E+00	.2197E+00	.6320E+01
1.000	1.000	.7745E+00	.1233E+00	.5305E+01
1.500	.667	.6339E+01	.6725E+00	.6435E+01
1.550	.645	.7077E+01	.7195E+00	.6300E+01
1.600	.625	.7044E+01	.7007E+00	.7065E+01
1.650	.606	.7135E+01	.6882E+00	.7040E+01
1.700	.588	.7760E+01	.7247E+00	.7295E+01
1.750	.571	.8655E+01	.7871E+00	.7545E+01
1.800	.556	.9422E+01	.8331E+00	.7780E+01
1.850	.541	.1092E+02	.8618E+00	.8015E+01
1.900	.526	.9589E+01	.8032E+00	.7975E+01
1.950	.513	.9443E+01	.7707E+00	.9995E+01
2.000	.500	.8501E+01	.6765E+00	.9960E+01
2.500	.400	.4881E+01	.3107E+00	.6590E+01
3.000	.333	.3049E+01	.1634E+00	.9115E+01
3.500	.286	.2579E+01	.1173E+00	.5070E+01
4.000	.250	.2459E+01	.9763E-01	.7295E+01
4.500	.222	.2894E+01	.1023E+00	.7105E+01
5.000	.200	.2072E+01	.6596E-01	.6525E+01
5.500	.182	.1712E+01	.4953E-01	.6605E+01
6.000	.167	.2005E+01	.5317E-01	.9370E+01
6.500	.154	.2320E+01	.5681E-01	.9350E+01
7.000	.143	.2055E+01	.4673E-01	.9340E+01
7.500	.133	.1930E+01	.4202E-01	.9320E+01
8.000	.125	.1643E+01	.3279E-01	.9605E+01
9.000	.111	.1932E+01	.3240E-01	.6300E+01
10.000	.100	.1711E+01	.2724E-01	.6280E+01
12.000	.083	.1594E+01	.2113E-01	.6260E+01
15.000	.067	.1755E+01	.1872E-01	.6025E+01
20.000	.050	.1241E+01	.1027E-01	.7080E+01
25.000	.040	.1295E+01	.8243E-02	.7090E+01
30.000	.033	.123[illegible]E+01	.[illegible]833E-02	.7085E+01

MAXIMUM ABSOLUTE SPECTRAL ACCELERATION .1092E+02
AT FREQUENCY (CPS) .1850E+01

TABLE B.1 Digitized Floor Response Spectra at Top of the Structure.

RESPONSE SPECTRUM AT DAMPING = .0200 * * * * OUTPUT TO TAPE

FREQUENCY (CPS)	PERIOD (SECS)	ABSOLUTE ACCELERATION	PSEUDO VELOCITY	TIME AT MAXIMUM
.300	3.333	.2874E+00	.1525E+00	.9975E+01
.400	2.500	.4883E+00	.1554E+00	.1079E+02
.700	1.429	.8735E+00	.1986E+00	.6325E+01
1.000	1.000	.6715E+00	.1069E+00	.5295E+01
1.500	.667	.4944E+01	.5246E+00	.6130E+01
1.550	.645	.5431E+01	.5576E+00	.6795E+01
1.600	.625	.5359E+01	.5330E+00	.6765E+01
1.650	.606	.5312E+01	.5124E+00	.7035E+01
1.700	.588	.5703E+01	.5339E+00	.7295E+01
1.750	.571	.6347E+01	.5773E+00	.7540E+01
1.800	.556	.6846E+01	.6053E+00	.8050E+01
1.850	.541	.7187E+01	.6183E+00	.8010E+01
1.900	.526	.6902E+01	.5699E+00	.7770E+01
1.950	.513	.6551E+01	.5347E+00	.9990E+01
2.000	.500	.5884E+01	.4683E+00	.9955E+01
2.500	.400	.3174E+01	.2021E+00	.6585E+01
3.000	.333	.1745E+01	.9260E-01	.9905E+01
3.500	.286	.1455E+01	.6618E-01	.5070E+01
4.000	.250	.1262E+01	.5022E-01	.6295E+01
4.500	.222	.1408E+01	.4984E-01	.7090E+01
5.000	.200	.1144E+01	.3642E-01	.6515E+01
5.500	.182	.1032E+01	.2986E-01	.6500E+01
6.000	.167	.1017E+01	.2699E-01	.6595E+01
6.500	.154	.9953E+00	.2437E-01	.9835E+01
7.000	.143	.9593E+00	.2181E-01	.5285E+01
7.500	.133	.9272E+00	.1968E-01	.6295E+01
8.000	.125	.9246E+00	.1849E-01	.6295E+01
9.000	.111	.9507E+00	.1681E-01	.6285E+01
10.000	.100	.9174E+00	.1460E-01	.5510E+01
12.000	.083	.8836E+00	.1172E-01	.6505E+01
15.000	.067	.8614E+00	.9140E-02	.6305E+01
20.000	.050	.8642E+00	.6877E-02	.6600E+01
25.000	.040	.8531E+00	.5431E-02	.6500E+01
30.000	.033	.8512E+00	.4516E-02	.6700E+01

MAXIMUM ABSOLUTE SPECTRAL ACCELERATION .7187E+01
AT FREQUENCY (CPS) .1850E+01

TABLE B.2 Digitized Floor Response Spectra at Node 7.

[illegible] SPECTRUM AT DAMPING = .0200 * * * * OUTPUT TO TAPE [illegible]

FREQUENCY (CPS)	PERIOD (SECS)	ABSOLUTE ACCELERATION	PSEUDO VELOCITY	TIME AT MAXIMUM
.300	3.333	.2405E+00	.1489E+00	.9080E+01
.400	2.500	.4444E+00	.1509E+00	.1081E+02
.700	1.429	.7441E+00	.1783E+00	.6330E+01
1.000	1.000	.5745E+00	.9175E-01	.5280E+01
1.500	.667	.4590E+01	.3804E+00	.6330E+01
1.550	.645	.3906E+01	.4010E+00	.6790E+01
1.600	.625	.3825E+01	.3804E+00	.6760E+01
1.650	.606	.3529E+01	.3501E+00	.6740E+01
1.700	.588	.3723E+01	.3491E+00	.7290E+01
1.750	.571	.4120E+01	.3747E+00	.7535E+01
1.800	.556	.4371E+01	.3464E+00	.8050E+01
1.850	.541	.4446E+01	.3825E+00	.8005E+01
1.900	.526	.4119E+01	.3451E+00	.7965E+01
1.950	.513	.3731E+01	.3086E+00	.9980E+01
2.000	.500	.3396E+01	.2702E+00	.9940E+01
2.500	.400	.1522E+01	.9669E-01	.6580E+01
3.000	.333	.9425E+00	.5000E-01	.9540E+01
3.500	.286	.6333E+00	.3815E-01	.6305E+01
4.000	.250	.1010E+01	.4019E-01	.6575E+01
4.500	.222	.1240E+01	.4385E-01	.6560E+01
5.000	.200	.9362E+00	.2980E-01	.6550E+01
5.500	.182	.9774E+00	.2828E-01	.7850E+01
6.000	.167	.1072E+01	.2844E-01	.5100E+01
6.500	.154	.1129E+01	.2765E-01	.9780E+01
7.000	.143	.9855E+00	.2241E-01	.9770E+01
7.500	.133	.1025E+01	.2176E-01	.9755E+01
8.000	.125	.8735E+00	.1738E-01	.9745E+01
9.000	.111	.1010E+01	.1785E-01	.6355E+01
10.000	.100	.9317E+00	.1494E-01	.6335E+01
12.000	.083	.8277E+00	.1098E-01	.6305E+01
15.000	.067	.1085E+01	.1152E-01	.6060E+01
20.000	.050	.6003E+00	.4781E-02	.6325E+01
25.000	.040	.5771E+00	.3674E-02	.6330E+01
30.000	.033	.5747E+00	.3049E-02	.6325E+01

MAXIMUM ABSOLUTE SPECTRAL ACCELERATION .4446E+01
AT FREQUENCY (CPS) .1850E+01

TABLE B.3 Digitized Floor Response Spectra at Node 4.

RESPONSE SPECTRUM AT DAMPING = .0200 * * * * OUTPUT TO TAPE [illegible]

FREQUENCY (CPS)	PERIOD (SECS)	ABSOLUTE ACCELERATION	PSEUDO VELOCITY	TIME AT MAXIMUM
.300	3.333	.2712E+00	.1439E+00	.9090E+01
.400	2.500	.3367E+00	.1474E+00	.1084E+02
.700	1.429	.6617E+00	.1504E+00	.6345E+01
1.000	1.000	.4705E+00	.7489E-01	.5225E+01
1.500	.667	.1726E+01	.1831E+00	.6315E+01
1.550	.645	.1851E+01	.1900E+00	.6765E+01
1.600	.625	.1821E+01	.1811E+00	.6725E+01
1.650	.606	.1725E+01	.1664E+00	.6695E+01
1.700	.588	.1682E+01	.1574E+00	.6575E+01
1.750	.571	.1657E+01	.1509E+00	.6555E+01
1.800	.556	.1566E+01	.1385E+00	.6530E+01
1.850	.541	.1332E+01	.1149E+00	.6510E+01
1.900	.526	.1238E+01	.1037E+00	.7090E+01
1.950	.513	.1274E+01	.1040E+00	.9450E+01
2.000	.500	.1249E+01	.9939E-01	.9120E+01
2.500	.400	.1761E+01	.1121E+00	.5990E+01
3.000	.333	.1728E+01	.9166E-01	.8455E+01
3.500	.286	.1537E+01	.6988E-01	.4940E+01
4.000	.250	.1859E+01	.7398E-01	.7930E+01
4.500	.222	.2097E+01	.7418E-01	.6550E+01
5.000	.200	.2054E+01	.6538E-01	.5070E+01
5.500	.182	.1874E+01	.5424E-01	.8035E+01
6.000	.167	.2071E+01	.5495E-01	.4590E+01
6.500	.154	.1845E+01	.4518E-01	.4470E+01
7.000	.143	.1495E+01	.3399E-01	.9765E+01
7.500	.133	.1649E+01	.3499E-01	.9750E+01
8.000	.125	.1426E+01	.2837E-01	.9740E+01
9.000	.111	.1187E+01	.2099E-01	.6515E+01
10.000	.100	.1034E+01	.1645E-01	.5490E+01
12.000	.083	.6832E+00	.9062E-02	.6215E+01
15.000	.067	.6086E+00	.6457E-02	.4720E+01
20.000	.050	.5863E+00	.4665E-02	.4710E+01
25.000	.040	.5502E+00	.3503E-02	.4700E+01
30.000	.033	.5422E+00	.2876E-02	.4700E+01

MAXIMUM ABSOLUTE SPECTRAL ACCELERATION .2097E+01
AT FREQUENCY (CPS) .4500E+01

TABLE B.4 Digitized Floor Response Spectra at Base.