TRANSNUCLEAR WEST

ATTACHMENT 4

LS DYNA V & V

Software Verification and Validation Report

Program: LS-DYNA950(c)

NON-PROPRIETARY
FOR INFORMATION ONLY

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4/11/00

Date

Revision 1 Changes

Revision 1 corrects problem statement for Test Problem 3-4 in page 9.
Affected pages by Revision 1: 1, 2, 9

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LS-DYNA VALIDATION AND VERIFICATION

1 INTRODUCTION

This report provides the quality assurance documentation for validation and verification of the LS-DYNA explicit finite element program in accordance with TNW Quality Assurance Procedures Manual (Ref. 1). The LS-DYNA version that is being V&V is Version 950c (07/12/99), procured from Livermore Software Technology Corporation (LSTC). The hardware platform on which it is installed at TNW consists of an Intel PIII-600 PC, and Windows NT 4.0, Build 1381, service pack 5 operating system. LS-DYNA was installed in this platform on 12/20/99. The applicable User's Manual is LS-DYNA Keyword User's Manual, Version 950 (Ref. 2).

2 V&V TEST PLAN AND ACCEPTANCE CRITERIA

The LS-DYNA V&V plan implemented in this report consists of three parts as follows:

1. Part 1 Test Problems: These test problems serve to verify that the installation of LS-DYNA on the TNW platform has been performed correctly and produces essentially identical results as those run in LSTC system. For this purpose, ten sample problems, provided by LSTC, are executed and results verified against the results provided by LSTC.

   Acceptance Criteria: LS-DYNA results on the TNW platform shall be within 1% of the results provided by LSTC.

2. Part 2 Test Problems: These test problems are intended to verify LS-DYNA against a public domain finite element code such as ANSYS. A set of five sample problems used for the V&V of the ANSYS program are selected. These sample problems are based on close form solutions available in standard engineering textbooks. The ANSYS results are compared with results produced by LS-DYNA.

   Acceptance Criteria: LS-DYNA results shall be within 10% of the ANSYS/close form solution results. The basis for this criterion is the differences in modeling and numerical solution algorithms between LS-DYNA (explicit) and ANSYS (implicit).

3. Part 3 Test Problems: These test problems consist of a set of sample problems executed to specifically demonstrate proper execution of the sliding and contact solution algorithms in LS-DYNA. The LS-DYNA responses are verified against first principles of rigid body dynamics, solutions available in the open literature,

and/or solutions obtained by comparison with another finite element code (SAP2000).

Acceptance Criteria: The same acceptance criterion is used as for Part 2 Test Problems.

3 V&V Plan Implementation

4 CONCLUSIONS

It is concluded that LS-DYNA has been properly installed at TNW computer and that it has been validated and verified for use.

5 REFERENCES

1. TNW Quality Procedures Manual, QP 3-10, Rev. 0 "Use of Software in Design.

2. LS-DYNA Keyword User's Manual, Version 950, May 1999, Livermore Software Technology Corporation.

3. ANSYS Verification Manual, Fisrt Edition.

4. Yim, C. S., Chopra, A. K., Penzien, J., "Rocking Response of Rigid Blocks to Earthquakes", Earthquake Engineering and Structural Dynamics Journal, Vol. 8 565-587 (1980).

5. TNW Calculation SCE-01.0213, Rev. A, "Seismic Stability Analysis of a Single AHSM AS a Rigid Body – A Verification of Parametric Study in Calculation No. SCE-01.0211, Rev A., 12/10/99.

6. TNW Calculation SCE-01.0211, Rev. A, "Seismic Stability Analysis of a Single AHSM – SAP2000 Parametric Analysis", 12/6/99.

Note: Results documented in References 5 and 6 (both Rev. A since design data is preliminary) were used for comparison with LS-DYNA results for purposes of LS-DYNA V&V. Dynamic properties of the AHSM (e.g. mass, cg location, mass moment of inertia, etc.) consistent with those in References 5 and 6 were used in the LS-DYNA analyses. Any future revisions to these calculations as a result of final design of the AHSM do not relate to the purpose not affect the conclusions of this V&V report.

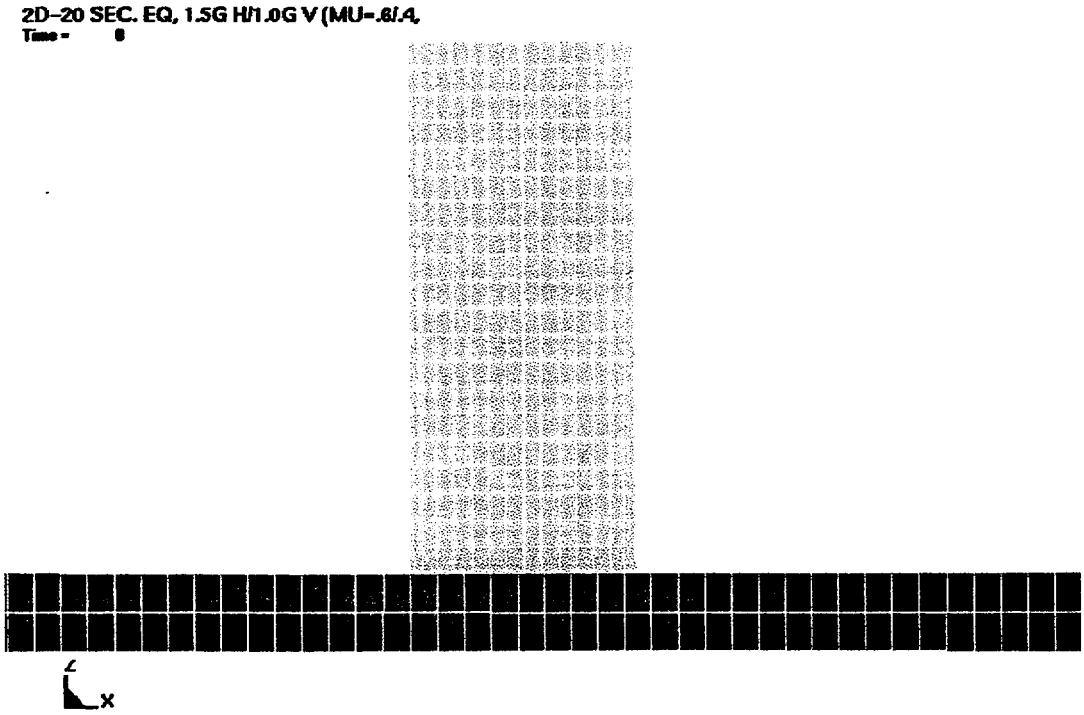

Figure 1
LS-DYNA Simplified AHSM Model

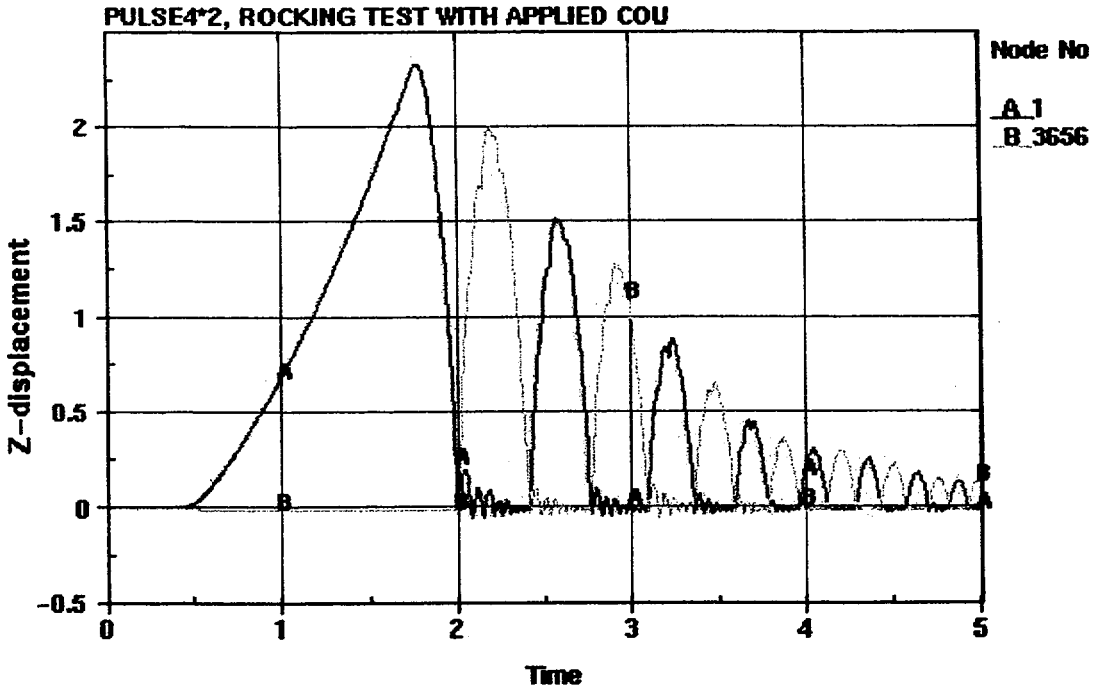

Figure 2
Free Vibration Rocking Response

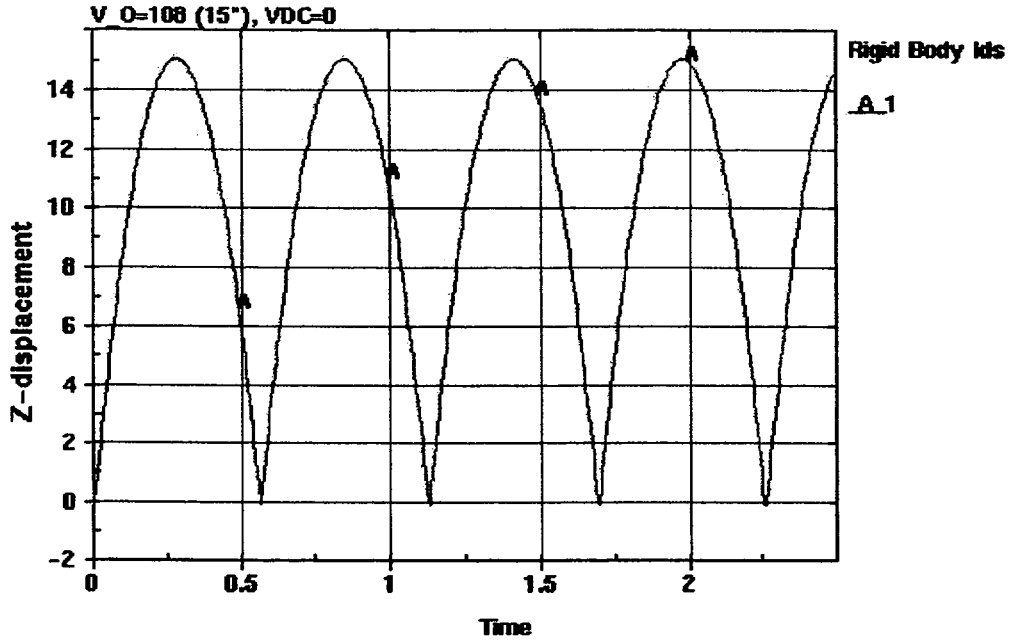

Figure 3
Vertical Drop Free Vibration Displacement Response – e = 1.0

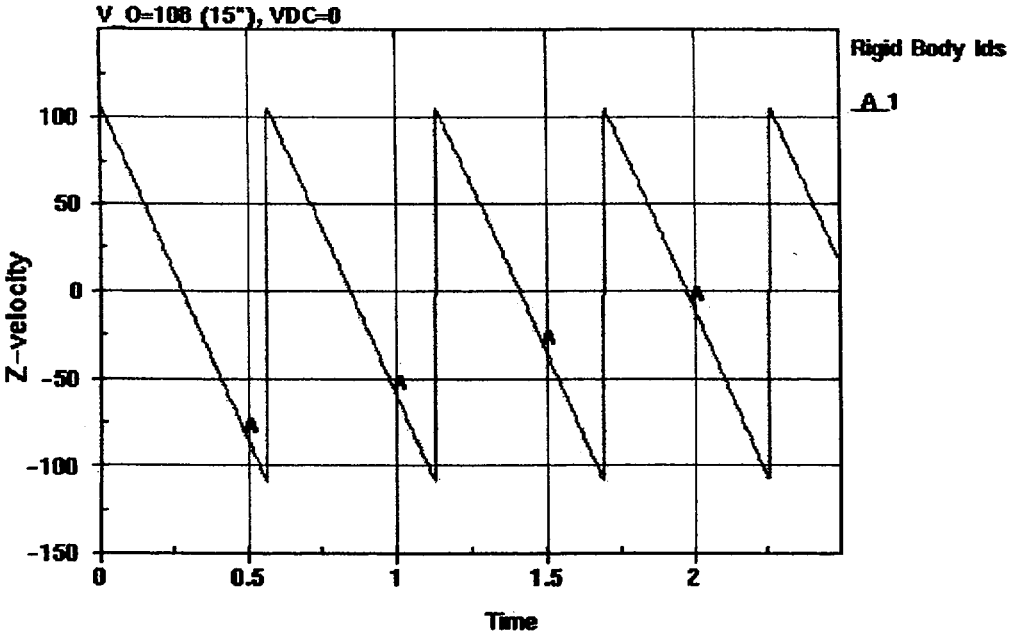

Figure 4
Vertical Drop Free Vibration Velocity Response – e =1. 0

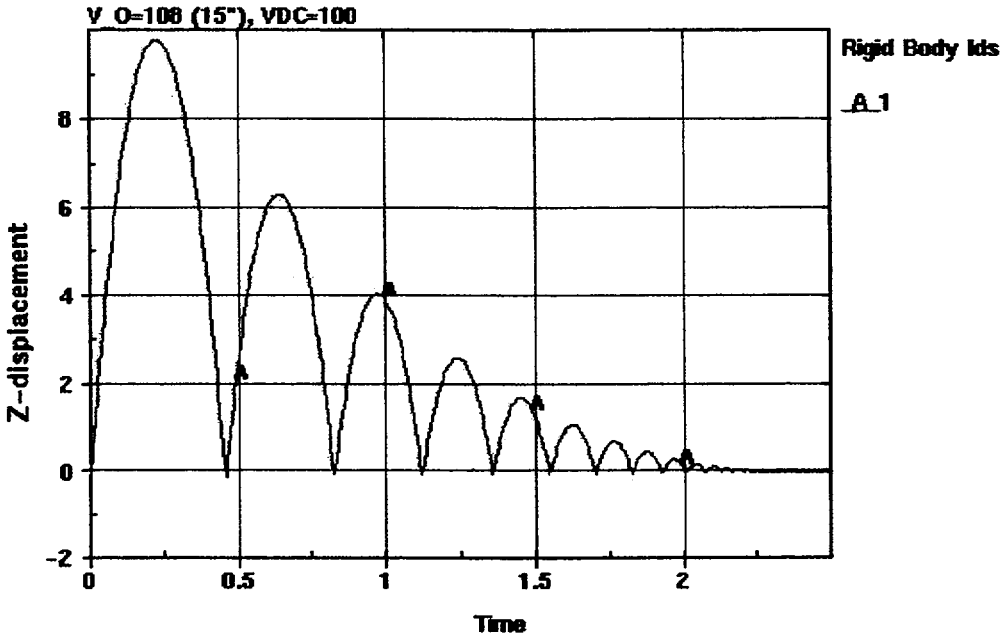

Figure 5
Vertical Drop Free Vibration Displacement Response – e = 0.80

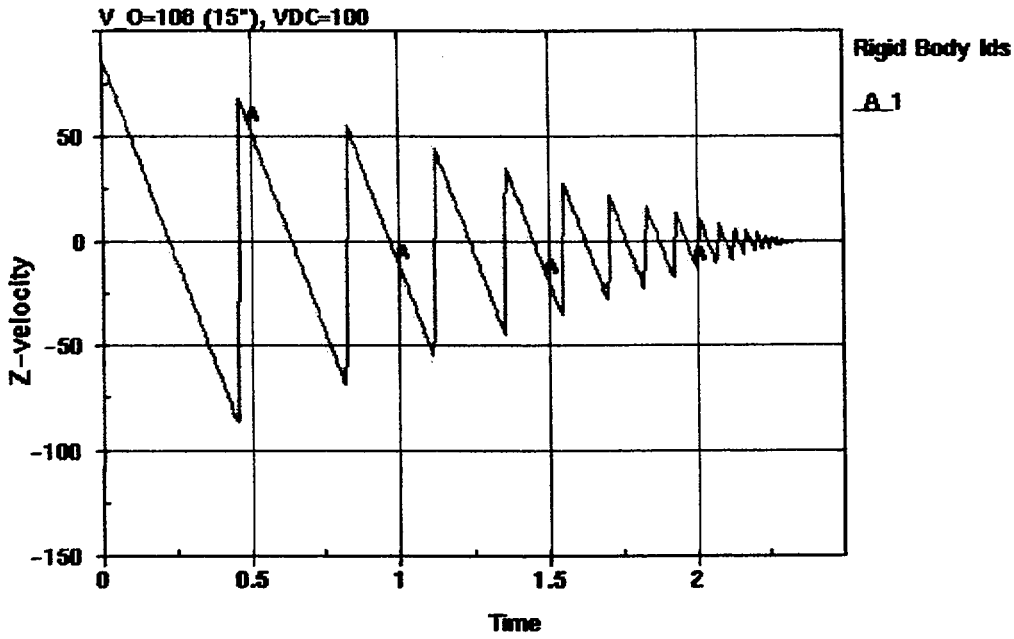

Figure 6
Vertical Drop Free Vibration Velocity Response – e = 0.80

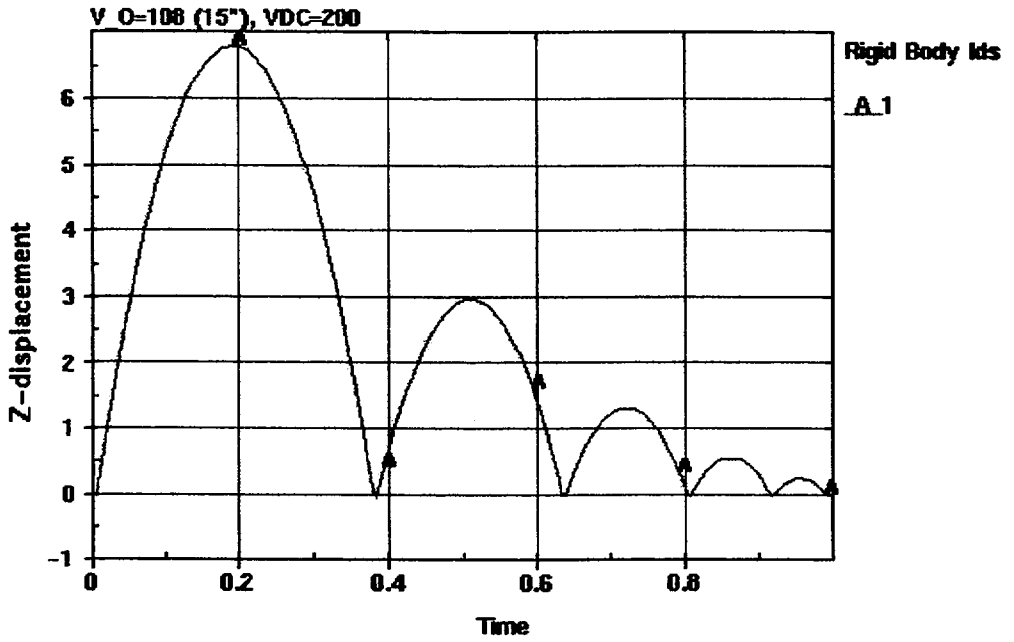

Figure 7
Vertical Drop Free Vibration Displacement Response – e = 0.66

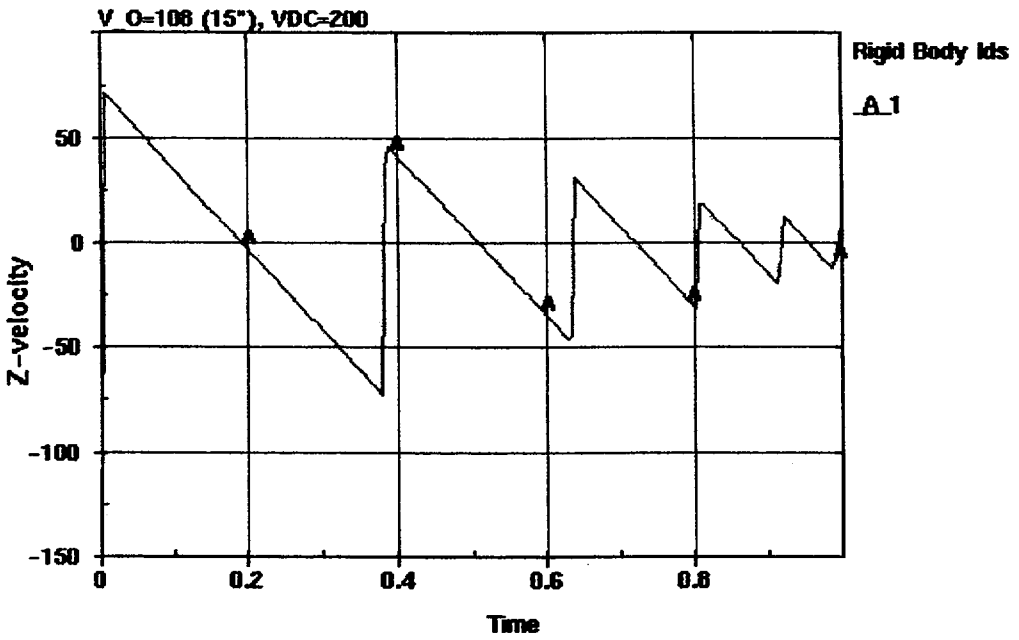

Figure 8
Vertical Drop Free Vibration Velocity Response – e = 0.66

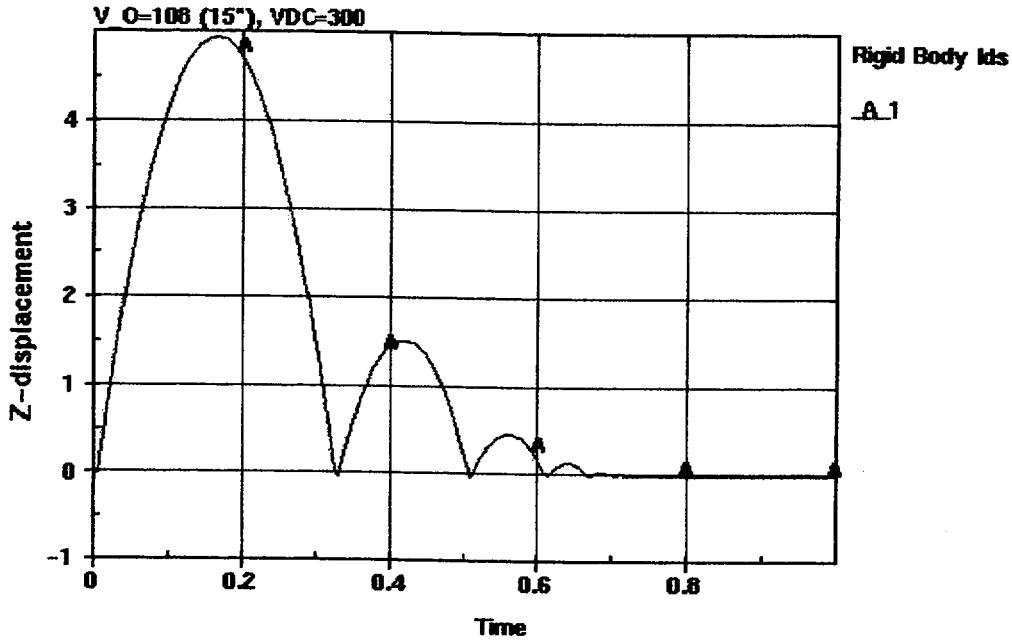

Figure 9
Vertical Drop Free Vibration Displacement Response – e = 0.55

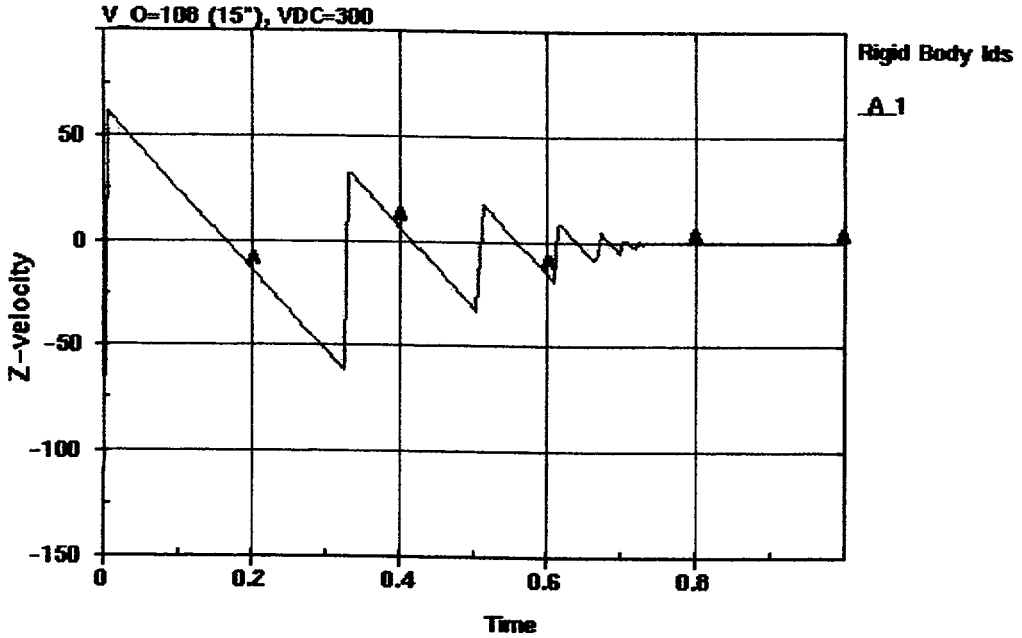

Figure 10
Vertical Drop Free Vibration Velocity Response – e = 0.55

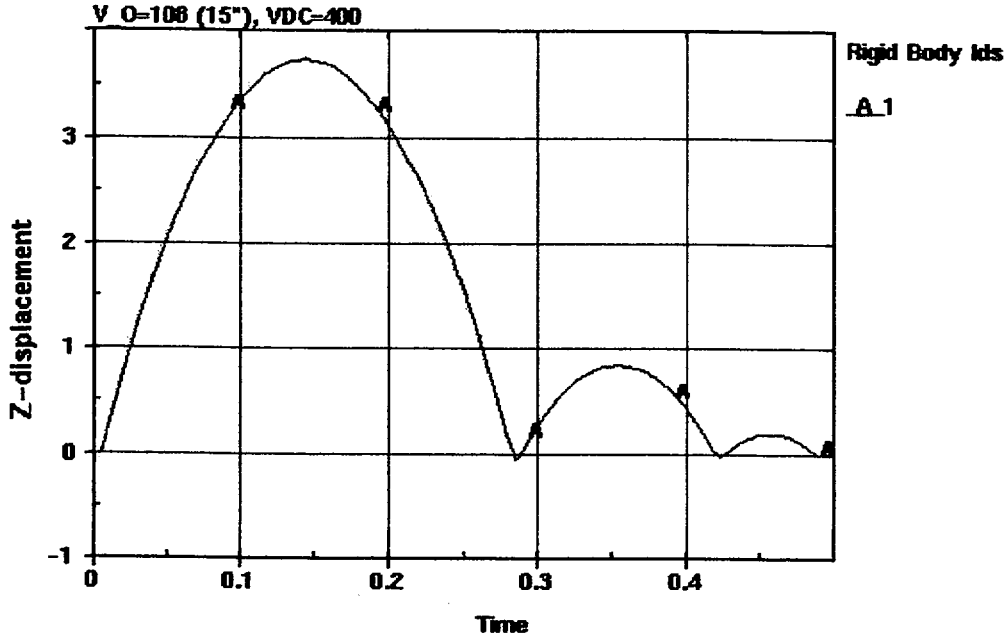

Figure 11
Vertical Drop Free Vibration Displacement Response – e = 0.49

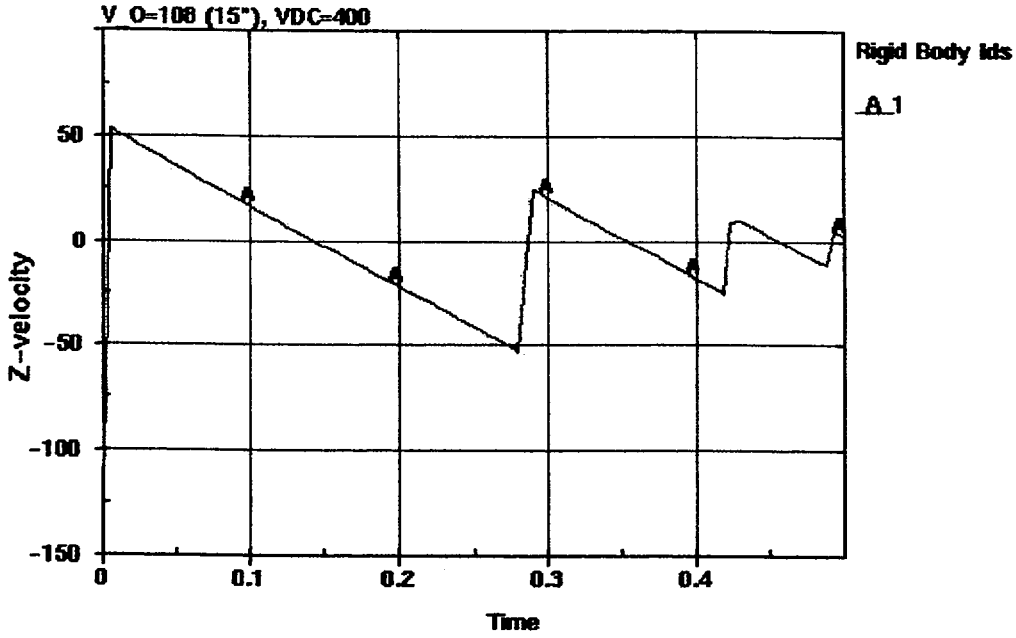

Figure 12
Vertical Drop Free Vibration Velocity Response – e = 0.49

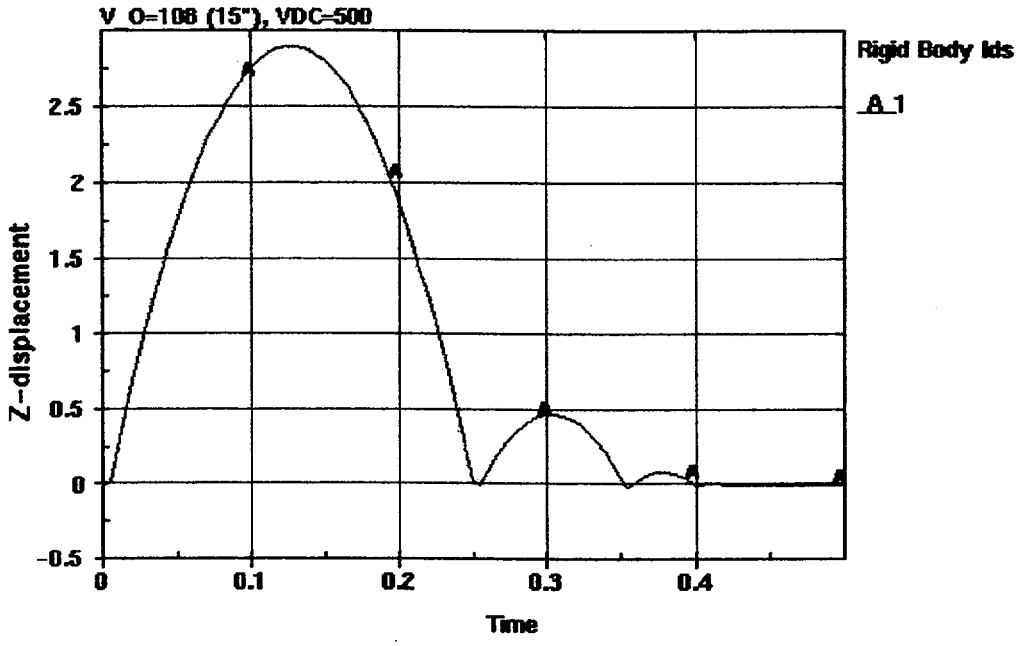

Figure 13
Vertical Drop Free Vibration Displacement Response – e = 0.42

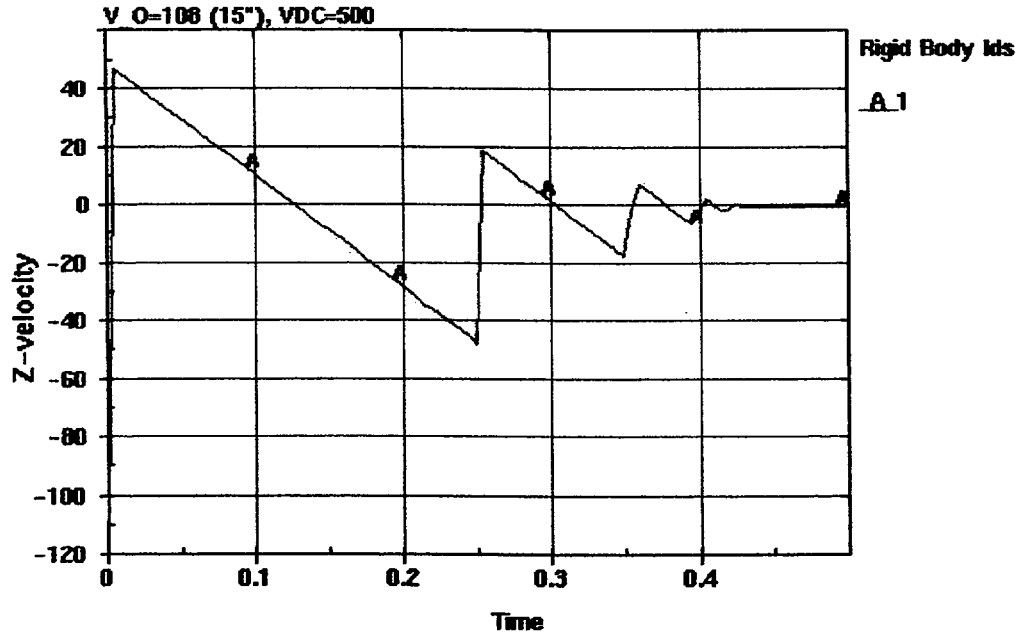

Figure 14
Vertical Drop Free Vibration Velocity Response – e = 0.42

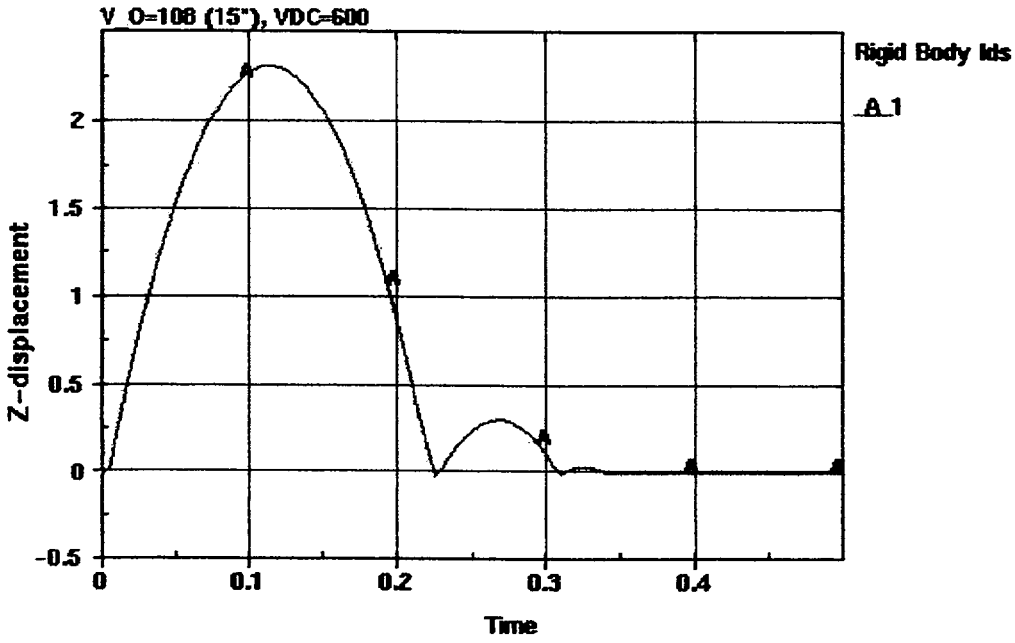

Figure 15
Vertical Drop Free Vibration Displacement Response – e = 0.38

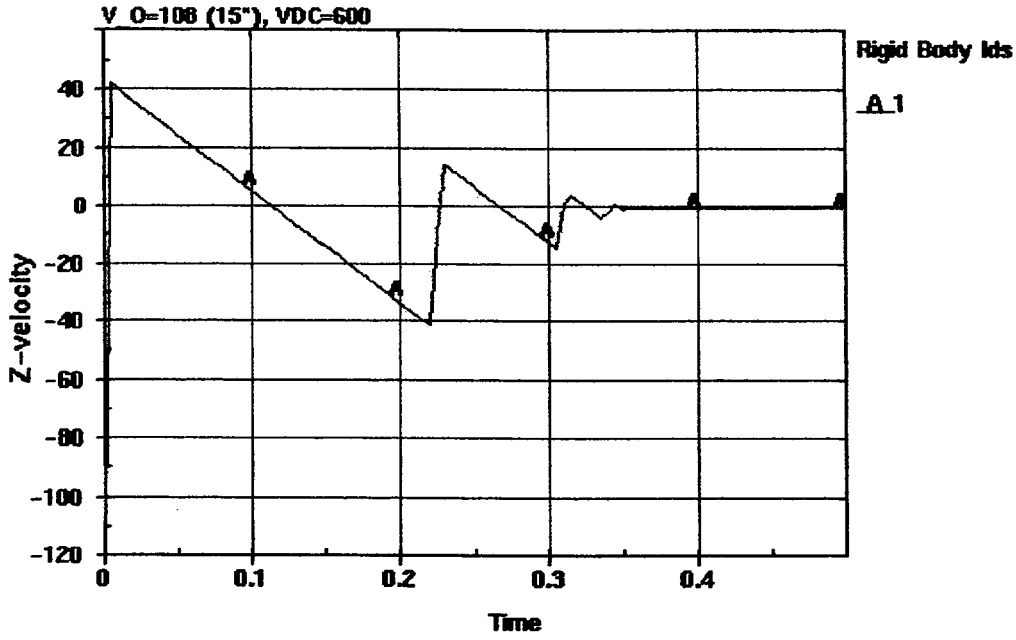

Figure 16
Vertical Drop Free Vibration Velocity Response – e = 0.38

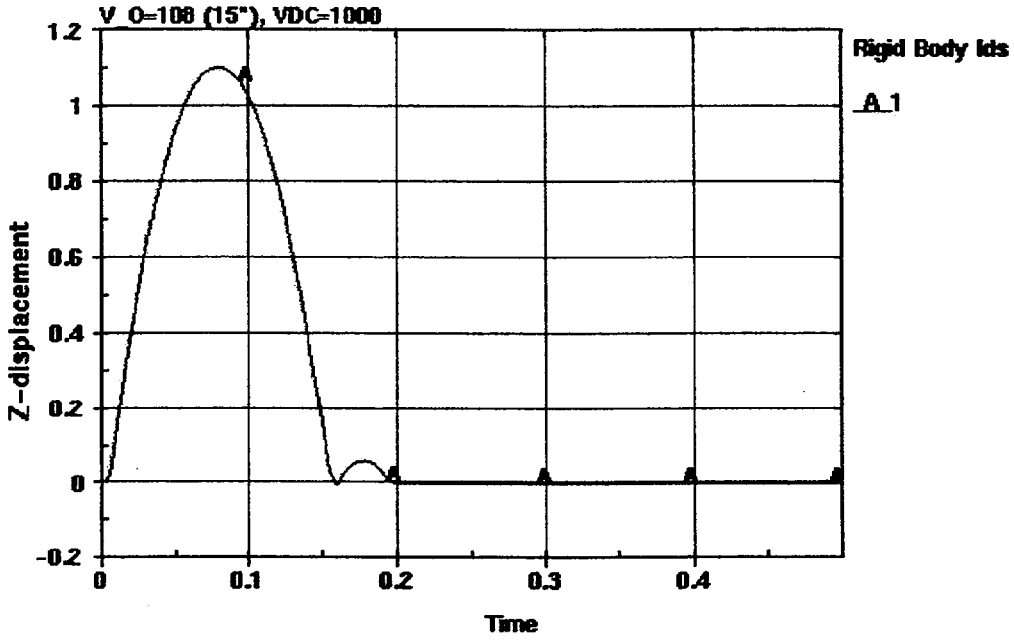

Figure 17
Vertical Drop Free Vibration Displacement Response – e = 0.25

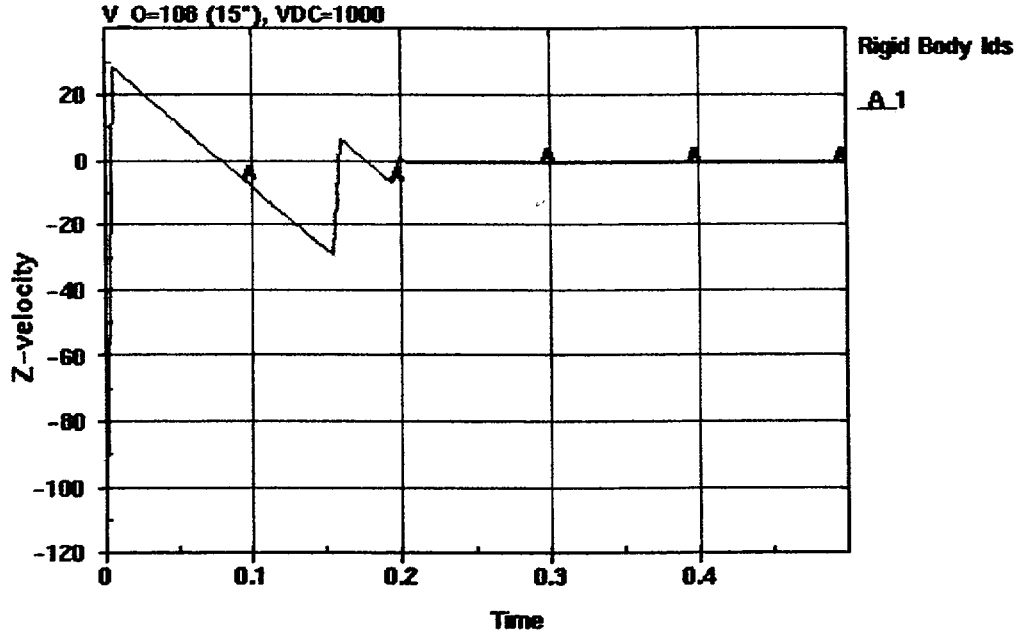

Figure 18
Vertical Drop Free Vibration Velocity Response – e = 0.25

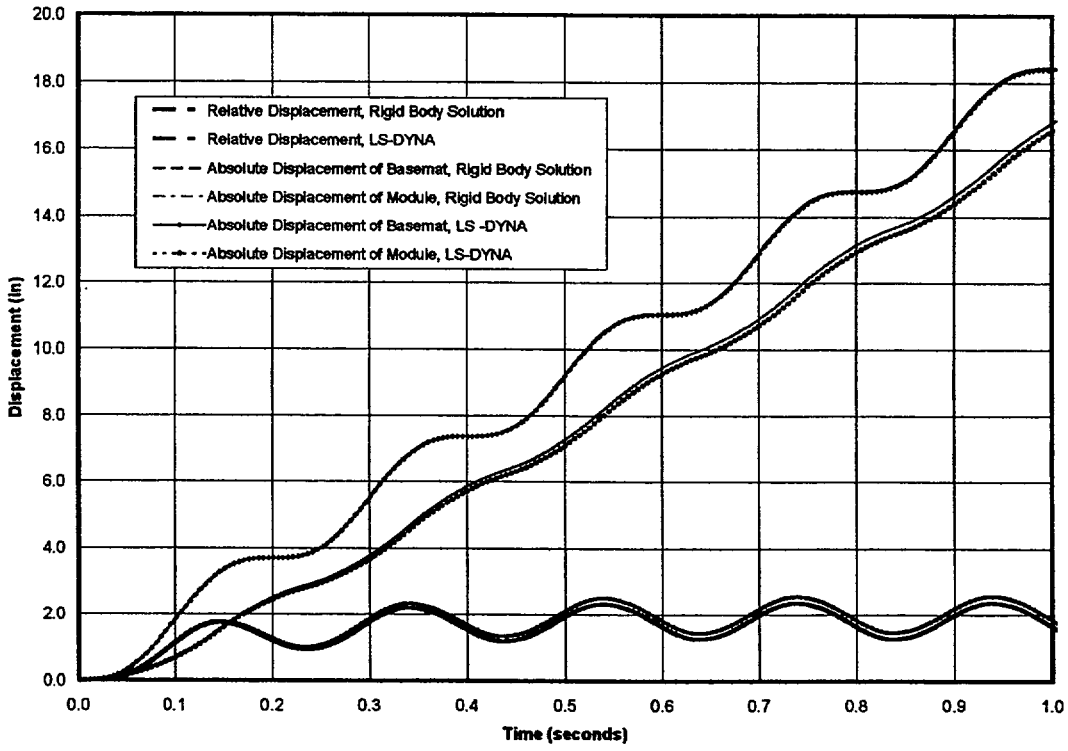

Figure 19
Sliding Response Under Sinusoidal Loads

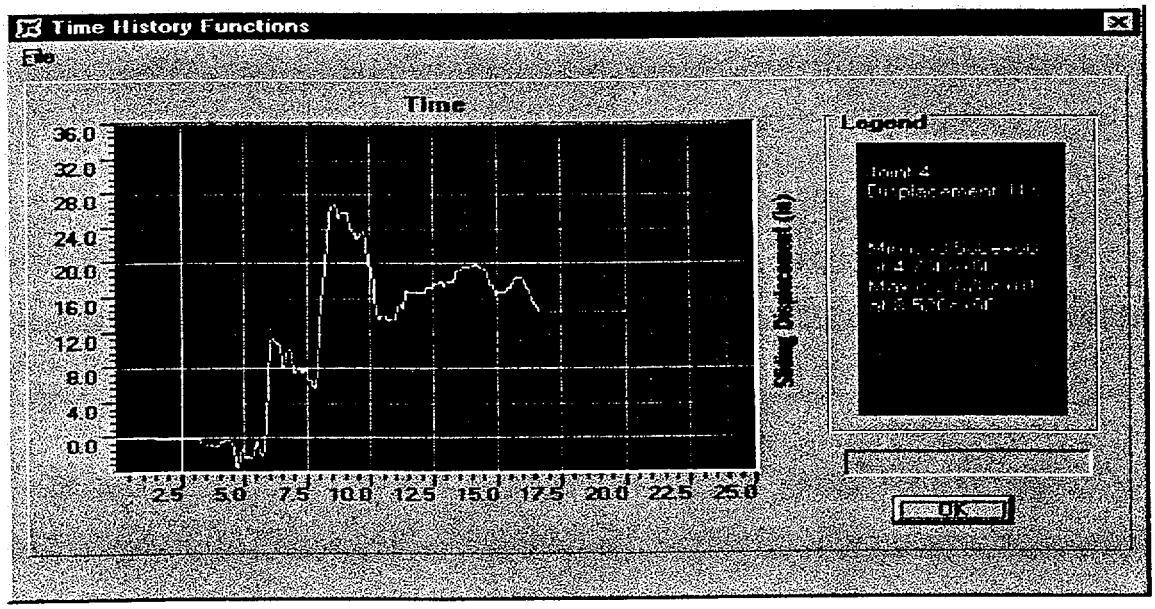

Figure 20
SAP2000 Sliding Response - Earthquake Loads

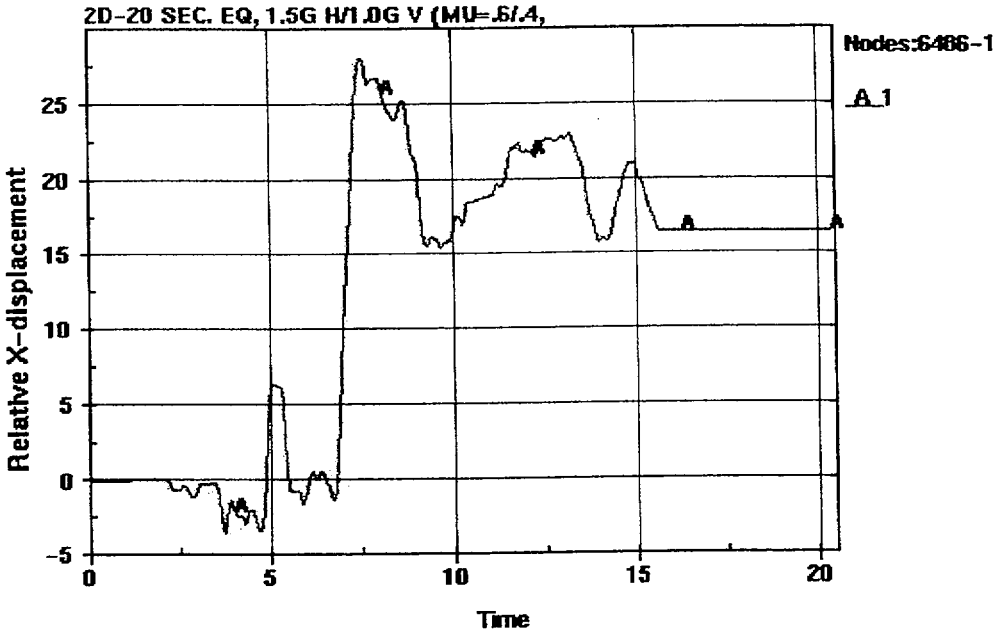

Figure 21
LS-DYNA Sliding Response - Earthquake Loads

ATTACHMENT A

DESCRIPTION OF SAMPLE PROBLEMS

PART 1: INSTALLATION VERIFICATION

(28 pages + cover page)

Attachment Intentionally Removed

ATTACHMENT B

INSTALLATION VERIFICATION COMPARISON

(2 pages)

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ATTACHMENT C

ANSYS SAMPLE PROBLEMS DESCRIPTIONS

(18 pages)

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ATTACHMENT D

LS-DYNA/ANSYS RESULTS SUMMARY COMPARISONS

(9 pages)

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ATTACHMENT E

Paper by Chopra et al

"Rocking Response of Rigid Blocks to Earthquakes"

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