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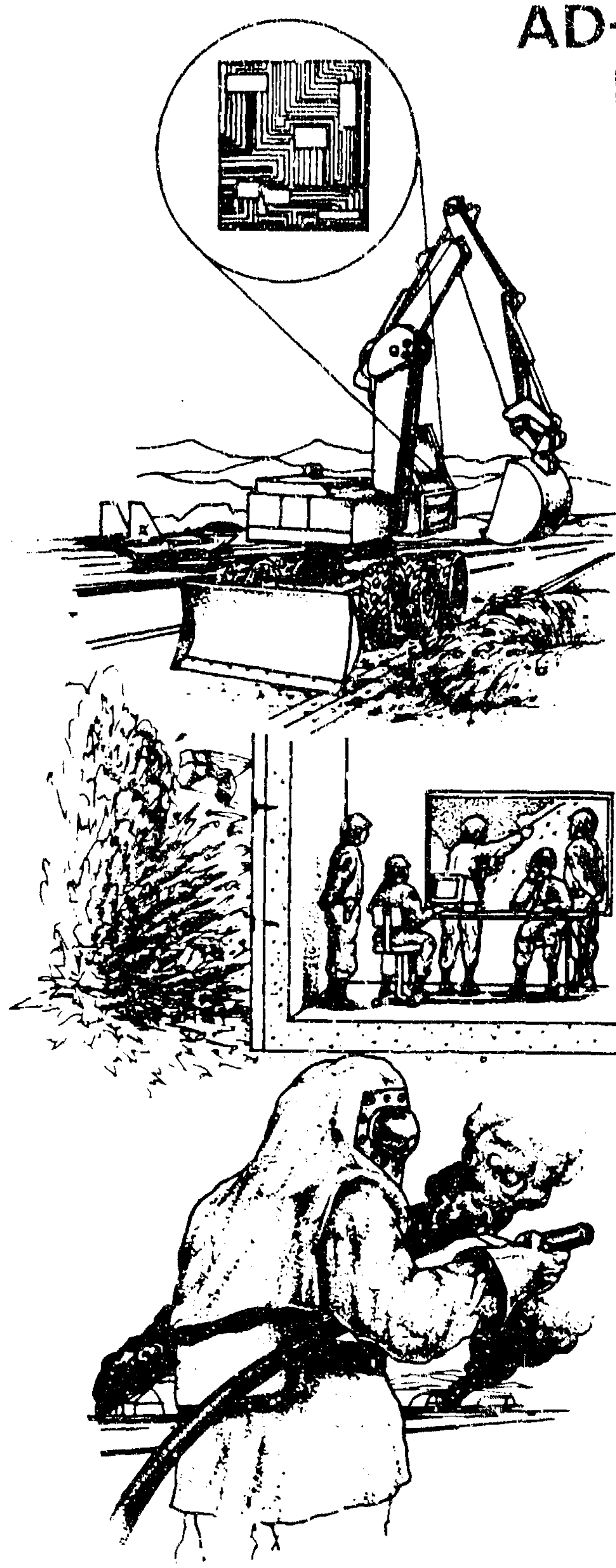

DYNAMIC RESPONSE OF REINFORCED SOIL SYSTEMS VOLUME II: APPENDICES

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Civil Engineering Laboratory
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Blast resistant structures; Blast loading; Reinforced soil; Geosynthetics; Centrifuge modeling; Finite Element analysis; Pullout test.

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

This report describes the results of a comprehensive laboratory, numerical and physical modeling investigation of the response of reinforced soil structures to blast loading. Dynamic laboratory pullout testing of geogrid and metal strip reinforcement embedded in coheshionless soil shows negligible rate effects with rise times to peak pullout load ranging from several minutes to less than 50 ms. Triaxial tests on fiber-reinforced soil show significant increases in peak strength, axial strain at peak strength and volume reduction with increasing fiber content.

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A numerical model was developed using the DYNA3D finite-element code. A numerical parametric study shows the importance of reinforcement stiffness, soil compaction and roof support on the response of a reinforced soil wall to blast loading.

Centrifuge model tests were conducted on 1:30 scale models of reinforced soil walls. Centrifuge results compare well to numerical predictions and full scale tests. Geogrid reinforced walls (modeled with nylon mesh) performed better than steel strip reinforced walls.

This technical report is divided into two volumes. Volume I contains the main body of the report and Volume II contains the Appendices.

EXECUTIVE SUMMARY

A. OBJECTIVE

The objective of this study was to investigate the response of reinforced soil systems subjected to blast loading and to assess the feasibility of using reinforced soil to provide blast resistance. To meet this objective, a testing program was developed and executed to accomplish the following: (i) to establish the properties of reinforced soil subjected to blast loading, (ii) to develop numerical and physical modeling techniques which are appropriate for evaluating the response of reinforced soil systems subjected to blast loading, and (iii) to establish preliminary analysis methods which can be used for the design of reinforced soil systems subjected to blast loading.

B. BACKGROUND

Blast-protective structures are commonly used by the United States Air Force (USAF) and other branches of the armed forces to protect equipment, explosives, and personnel from conventional weapons effects. These effects include high-pressure impulse loading, projectile/fragment impact and penetration, and cratering. Currently, these structures are constructed either as heavily-reinforced concrete structures or as buried structures protected by a burster slab. These protection measures are costly, time consuming to construct, and sensitive to multiple strikes.

Soil has been used to increase the survivability of these structures by providing a cover or barrier to reduce the shock, pressure, and impact on the structures. However, soil berms must be built at relatively flat slopes (about 2.5 horizontal:1 vertical (2.5H:1V)) for adequate stability. Because of this, the use of a soil cover or berm is restricted by the amount of land available for construction and the logistics of moving large quantities of soil to the site.

The USAF has recently expressed interest in using reinforced soil in the development of blast-protective structures. Reinforced soil is a composite material made up of soil and high-tensile-strength materials such as steel or geogrid. Soil alone has no tensile strength, and the reinforcement strengthens the soil by confining it and restricting movement parallel to the reinforcement. Incorporating reinforced soil structures in the development of blast-protective structures can accomplish the following: (1) eliminate the use of heavily reinforced concrete, (2) reduce volume of soil required for construction, (3) reduce the amount of land space required, (4) reduce the construction time, (5) simplify structural repair due to bomb damage as compared to reinforced concrete structures, and (6) reduce initial cost of construction compared to other types of structures.

To design blast-protective structures using reinforced soil, the dynamic response characteristics and analytical theory of reinforced soil subjected to blast loading must be established. Although a substantial amount of research has been performed in the past decade to determine the properties of reinforced soil under static loading condition, little work has been carried out to determine reinforced soil properties or theory under blast loading conditions. Research is therefore required to develop a better understanding of the response of reinforced soil to blast loading. This report represents the first comprehensive research effort conducted to understand the response of reinforced soil wall systems subjected to blast loading.

C. SCOPE

A scope of work was developed to achieve the objectives outlined in Section A. This scope of work includes the following:

- an extensive literature review for evaluation of soil and reinforced soil response to blast loading and availability of soil constitutive models and finite element numerical codes for analyzing reinforced soil systems;

- development of laboratory dynamic soil testing equipment and a laboratory testing program to evaluate dynamic response of a reinforced soil system subjected to blast (i.e.: impulse) loading;

- development and utilization of a numerical simulatio for analysis of reinforced soil wall systems subjected to blast loading; and

- physical modeling of reinforced soil systems subjected to blast loading using centrifuge modeling.

Using this technical approach makes it possible to compare the different analysis techniques and results, provide a quantitative assessment of the properties of reinforced soil and reinforced soil systems subjected to blast loading, and provide preliminary guidelines for selecting appropriate analysis techniques for the design of reinforced soil systems for blast protection.

D. TEST DESCRIPTION

Laboratory testing, numerical modeling and physical modeling was conducted to study the response of reinforced soil structures subjected to blast loading. A brief description of each test is presented below.

Laboratory Tests: Laboratory strength tests were conducted on three types of reinforcing systems: fiber-reinforced sands, geogrid-reinforced sands and steel-reinforced sands. Triaxial tests were conducted on fiber-reinforced sand to estimate the sand's strength properties. Static pullout tests were conducted with both steel and geogrid reinforcement and sands under various confining pressures to characterize the static load-deflection behavior of the reinforced soil. Dynamic pullout tests were then performed using the same parameters as the static tests. A standard static pullout test box was modified to a dynamic load system by installing an impact beam, hydraulic cylinders, springs, and a trigger system. The system was capable of loading the sample in just a few micro-seconds to simulate a blast load. Dynamic load-deflection behavior was characterized and compared to that obtained from static testing.

Numerical Modeling: A numerical model was developed based on the computer code DYNA3D, a non-linear, three-dimensional finite-element code developed by the Lawrence Livermore National Laboratory for use in the analysis of dynamic solid and structural mechanics problems. A parametric study was conducted to observe the influence of several critical factors on the behavior of the reinforced soil wall subjected to blast loading. These factors included reinforcement strength, reinforcement length, weapon size, and weapon location.

Physical Modeling: Nine 1/30th scale model reinforced soil walls were tested in the Air Force Civil Engineering Support Agency (AFCESA) centrifuge at Tyndall Air Force Base, Florida. A parametric study was conducted to observe the influence of several critical factors on the behavior of the model reinforced soil walls subjected to blast loading. These factors included reinforcement length, reinforcement type, reinforcement width, weapon location, and influence of a roof slab on the structure.

E. CONCLUSIONS

A brief summary of results obtained from the laboratory testing, numerical modeling, and physical modeling portions of the study are presented below.

Laboratory Testing Results: Results of triaxial testing on fiber-reinforced sand indicate that soil strength, strain at failure and compressibility increase and stiffness decreases as fiber content increases. Results of the pullout testing indicate that dynamic pullout behavior of geogrid in sand, when measured in terms of load vs. displacement, is very similar under constant normal stress to that observed with standard pullout rates used for static design. The dynamic pullout tests subjected the geogrid to a stress path similar to that caused by blast loading.

Numerical Modeling Results: Results of the numerical modeling program indicate that soil stiffness and friction angle significantly affect was performance, as does reinforcement stiffness. Reinforcement length and soil/reinforcement interface friction coefficient are relatively less important parameters, provided they are kept within normal ranges for static stability.

Physical Modeling: Results of the physical modeling tests indicate that reinforcement type and width play a significant role in wall behavior. The importance of a horizontal constraint along the top of the wall (i.e., a roof slab) has also been demonstrated. Reproducibility of test results and similarity to numerical predictions provide evidence of the appropriateness of the centrifuge modeling technique for this problem.

F. RECOMMENDATIONS

The results of limited laboratory, centrifuge modeling, and numerical modeling tests conducted in this study indicate that statically designed reinforced soil structures perform favorably as blast-protective structures. It is recommended that the Air Force pursue a more comprehensive study of the use of reinforced soil structures for blast protection with the ultimate goal of developing design procedures and design drawings for reinforced soil structures. This study should include full-scale testing, a comprehensive series of centrifuge tests, modifications to the numerical model, and comprehensive numerical modeling of the centrifuge tests. Ultimately, studies should be developed that investigate other weapons effects on reinforced soil structures such as airblasts and projectile penetrations.

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PREFACE

This report was prepared by GeoSyntec Consultants, 5775 Peachtree Dunwoody Road, Suite 200F, Atlanta, Georgia 30342 under Contractor Number F08635-90-C-0198 for the Air Force Civil Engineering Support Agency (AFCESA), Civil Engineering Laboratory, 139 Barnes Drive, Tyndall Air Force Base, Florida 32403-6001.

This report summarizes work accomplished between 8 June 1990 and 30 June 1992. Captain Richard A. Reid, USAF, was the AFCESA/RACS technical program manager.

This report has been reviewed by the Public Affairs Office and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nationals.

This technical report has been reviewed and is approved for publication.

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Felix T. Uhlik III

FELIX T. UHLIK III, Lt Col, USAF
Chief, Engineering Research Division

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APPENDIX A

LABORATORY TESTING

A. INTRODUCTION

This appendix contains plots of laboratory test results. The appendix is organized as follows:

- Part B presents results from direct shear tests on the SP and SW-SM sands.
- Part C presents the results of static pullout tests on geogrids and galvanized earth bars.
- Part D presents a verification of the numerical integration method used to determine dynamic displacement-time histories for pullout tests.
- Part E contains results of dynamic tensile tests.
- Part F contains results of dynamic pullout tests.

B. DIRECT-SHEAR TESTS

Figures 1 and 2 present the results of direct-shear tests conducted on the SP and SW-SM sands, respectively.

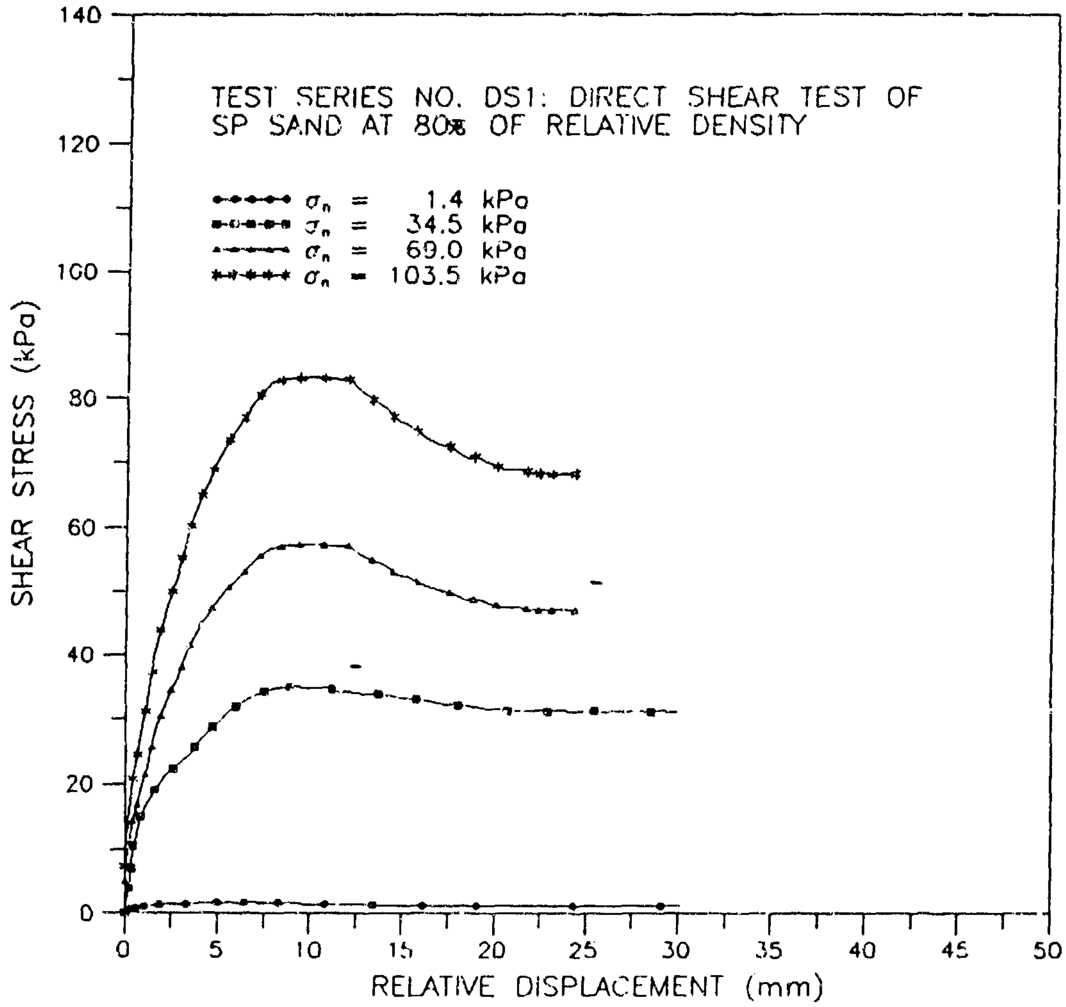

Figure 1. Direct-Shear Test Results on SP Sand.

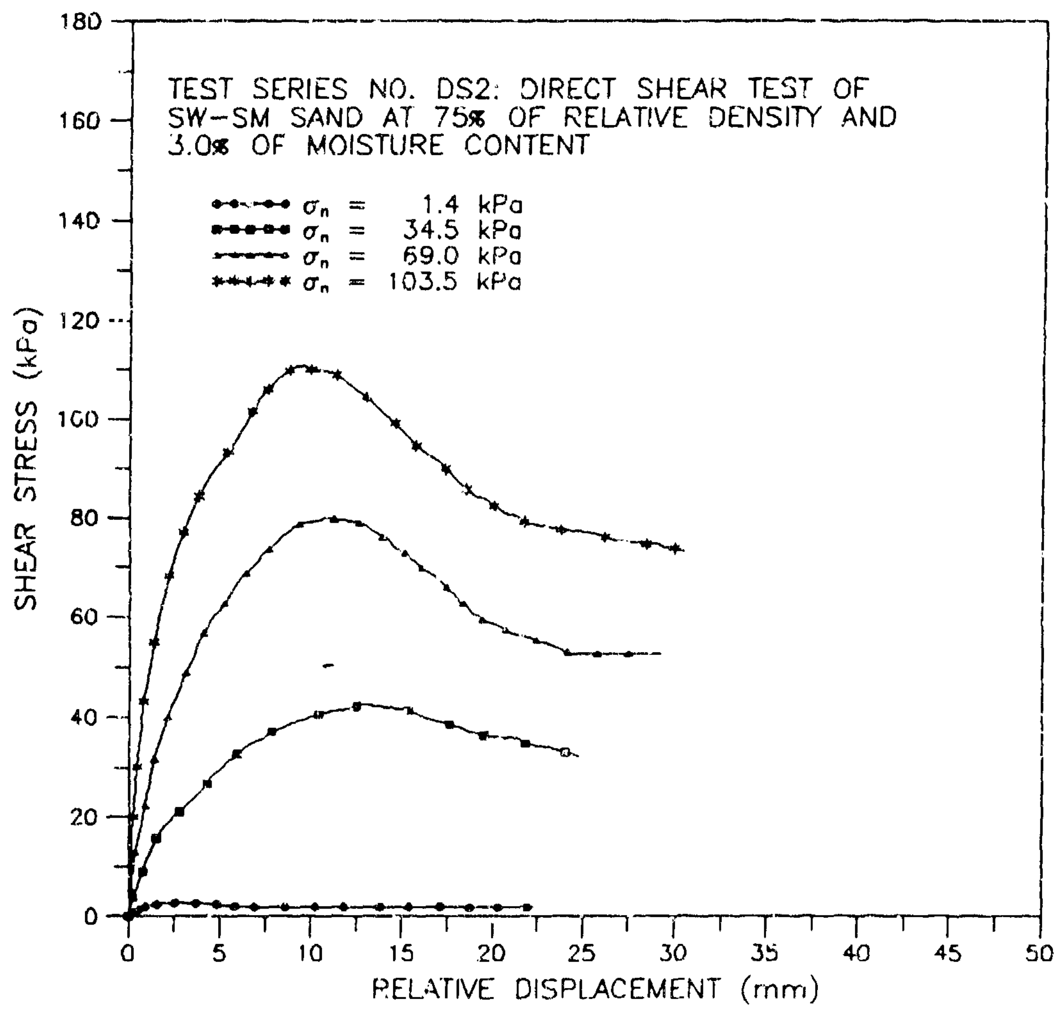

Figure 2. Direct-Shear Test Results on SW SM Sand.

C. STATIC PULLOUT TESTS

Figures 3 - 10 present the results of static pullout tests on Miragrid 10T, Matrex 120 and Tensar UX1500 geogrid, and galvanized earth bars in SP sand.

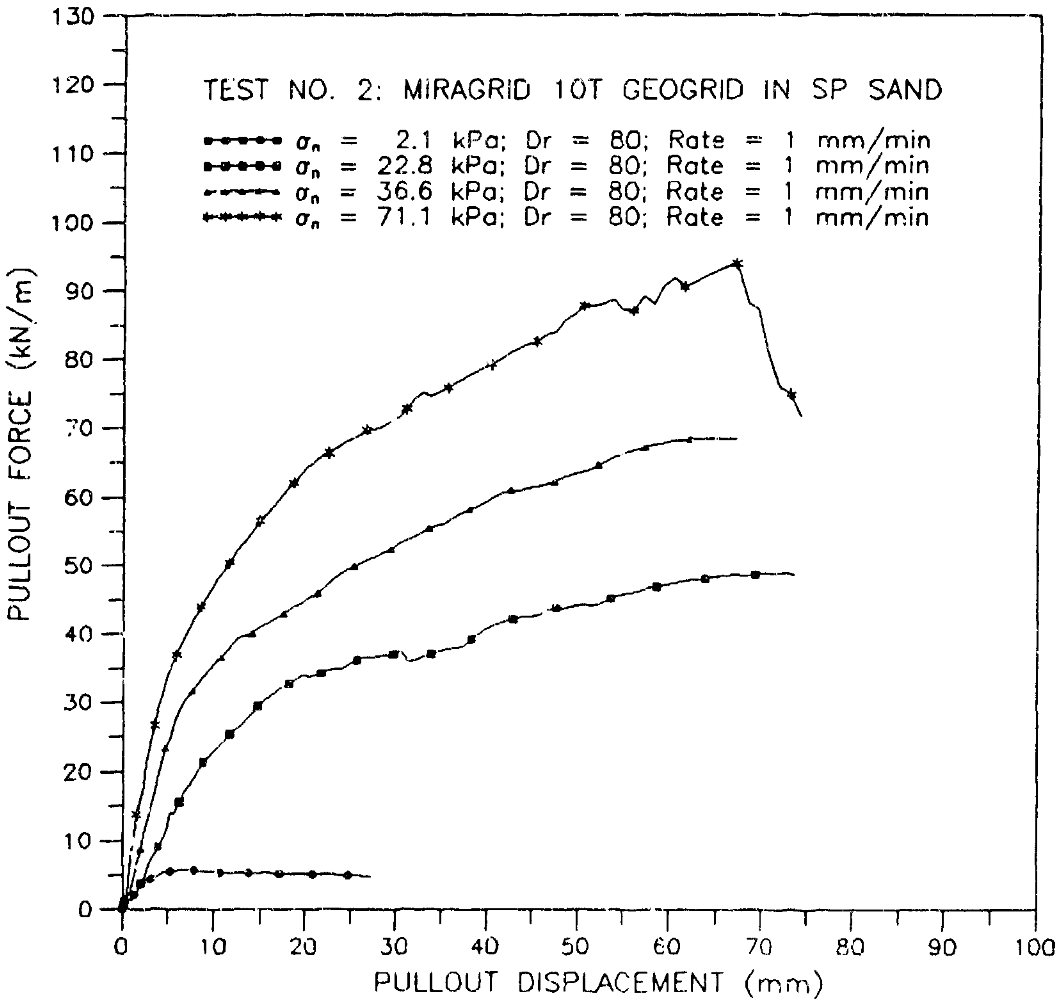

Figure 3. Pullout Responses of Miragrid 10T Geogrid in SP Sand.

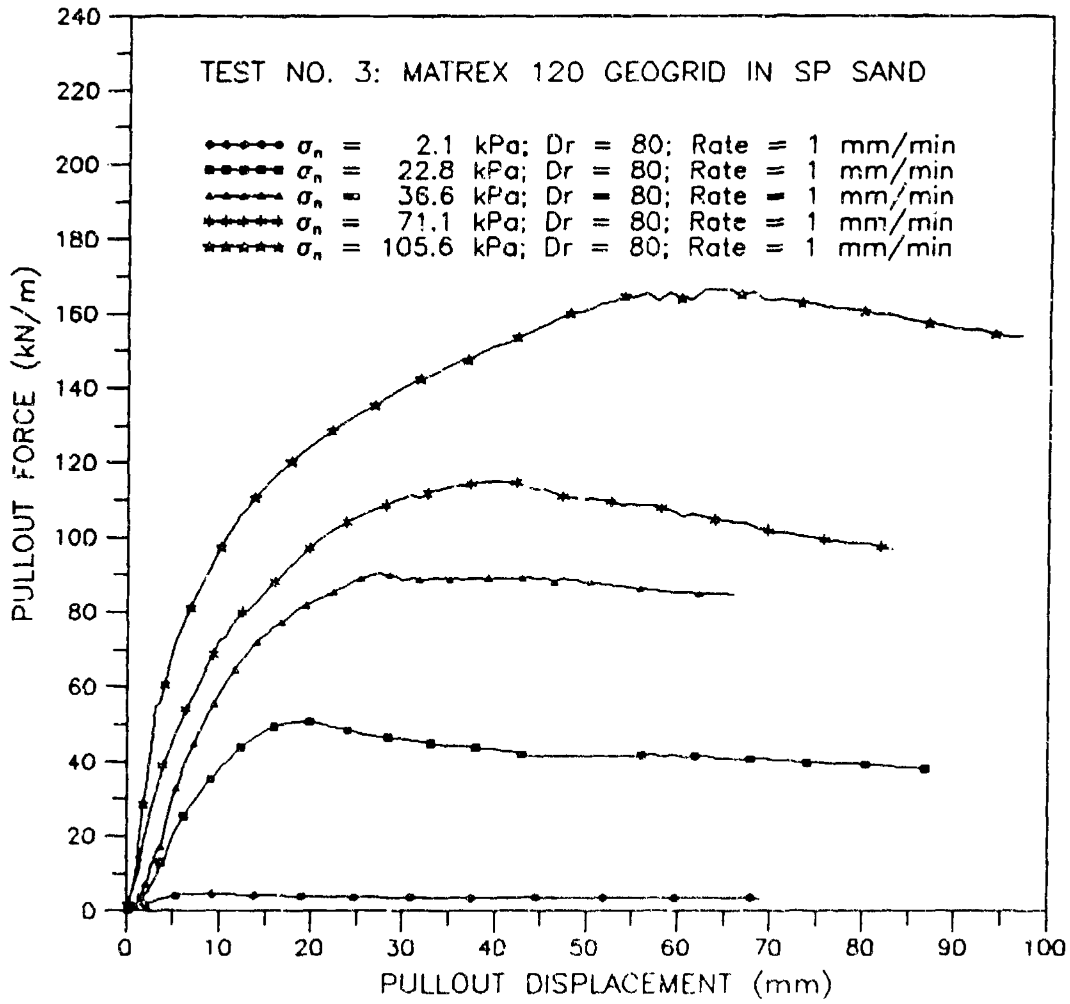

Figure 4. Pullout Responses of Matrex 120 Geogrid in SP Sand.

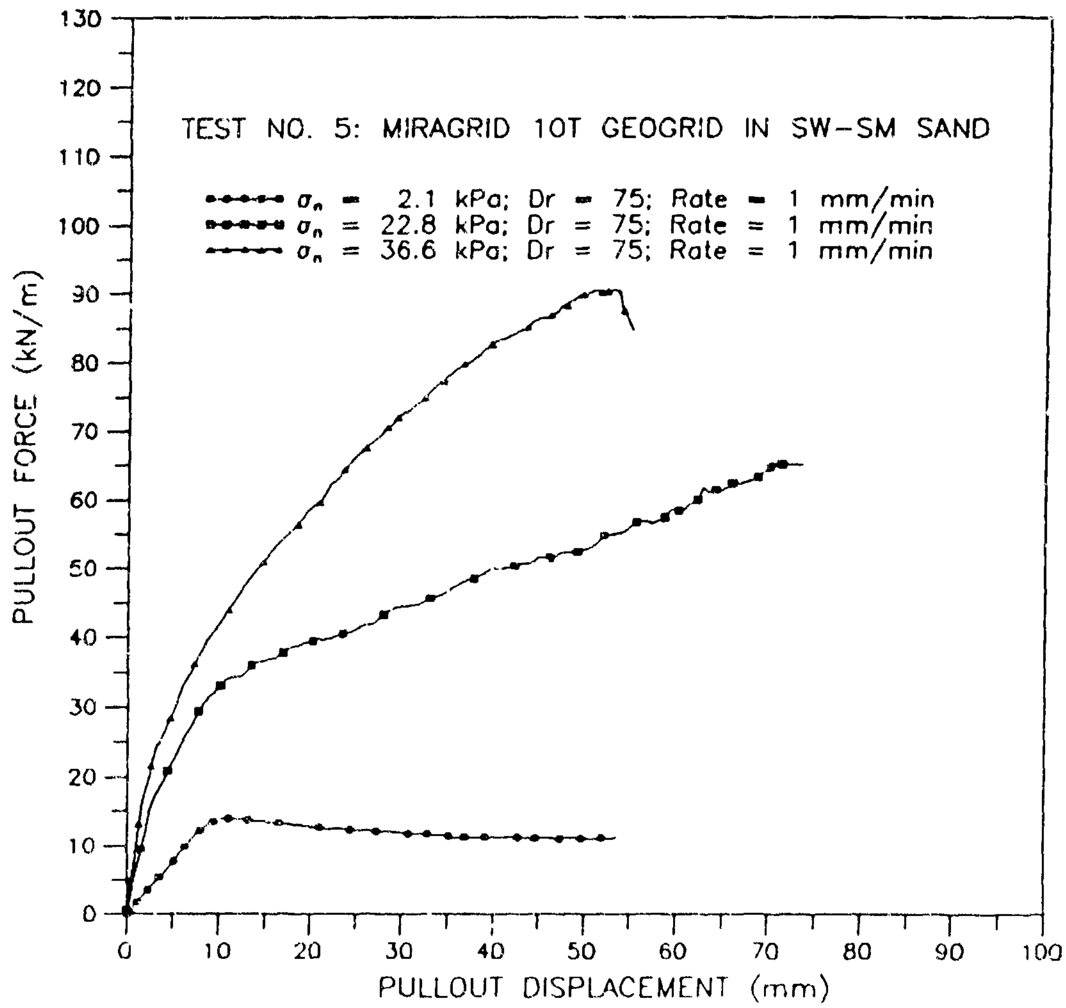

Figure 5. Pullout Responses of Miragrid 10T Geogrid in SW-SM Sand.

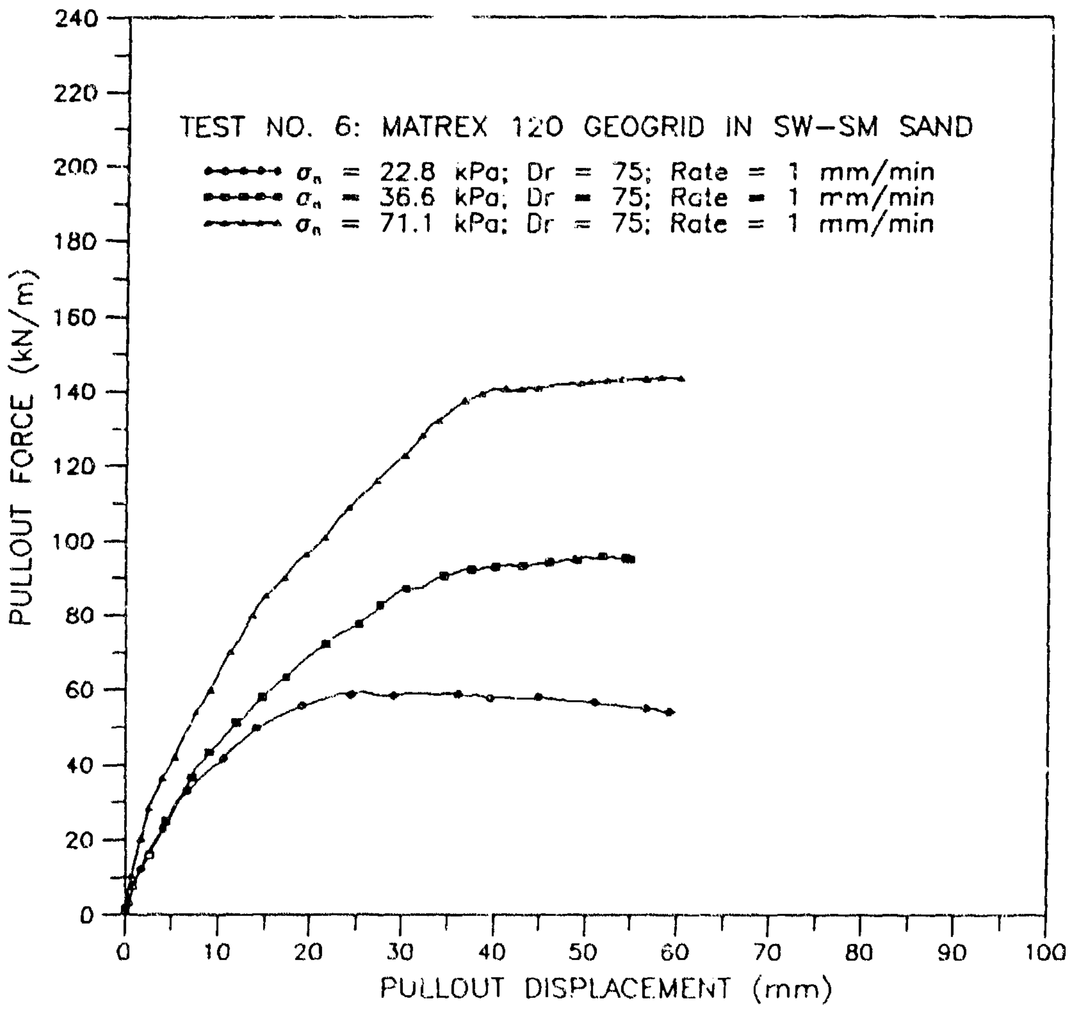

Figure 6. Pullout Responses of Matrex 120 Geogrid in SW-SM Sand.

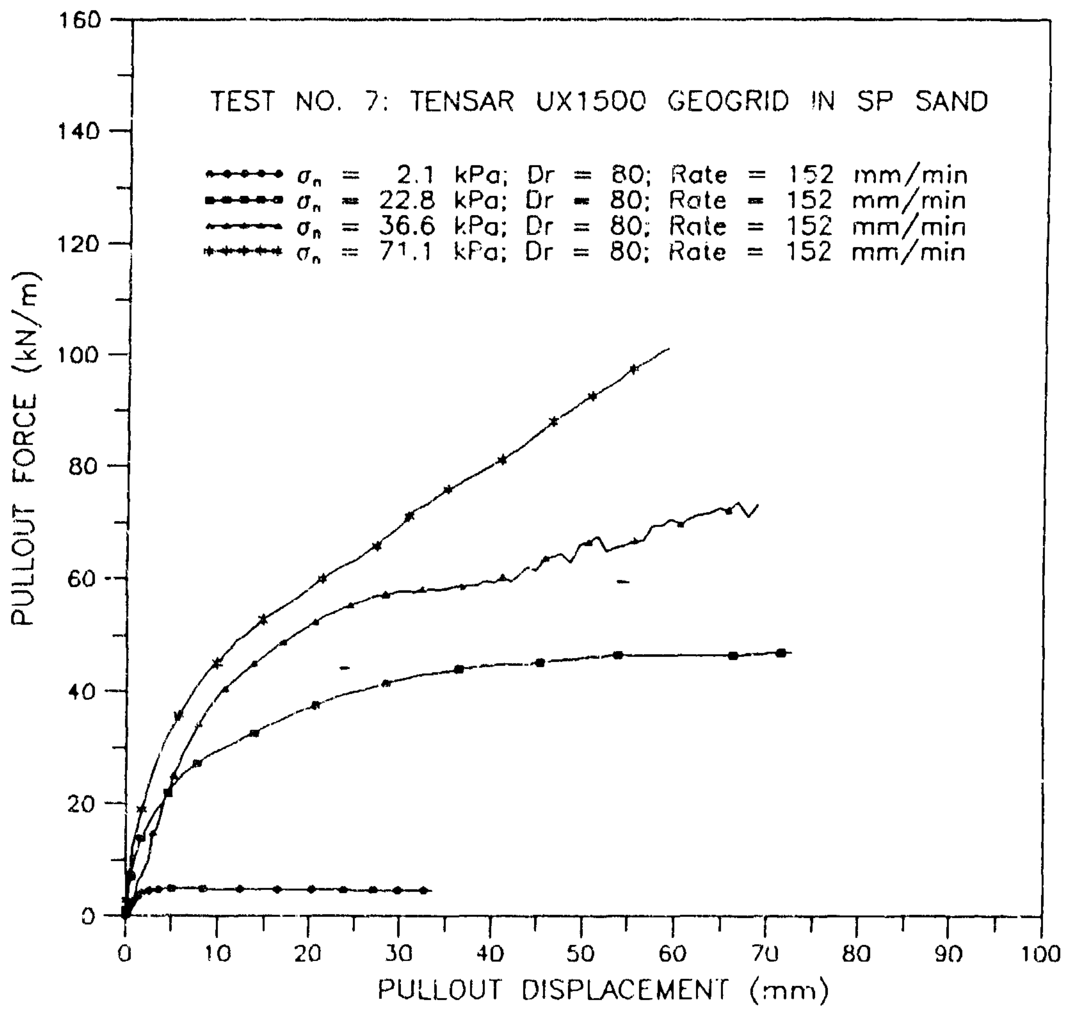

Figure 7. Pullout Responses of Tensar UX1500 Geogrid in SP Sand.

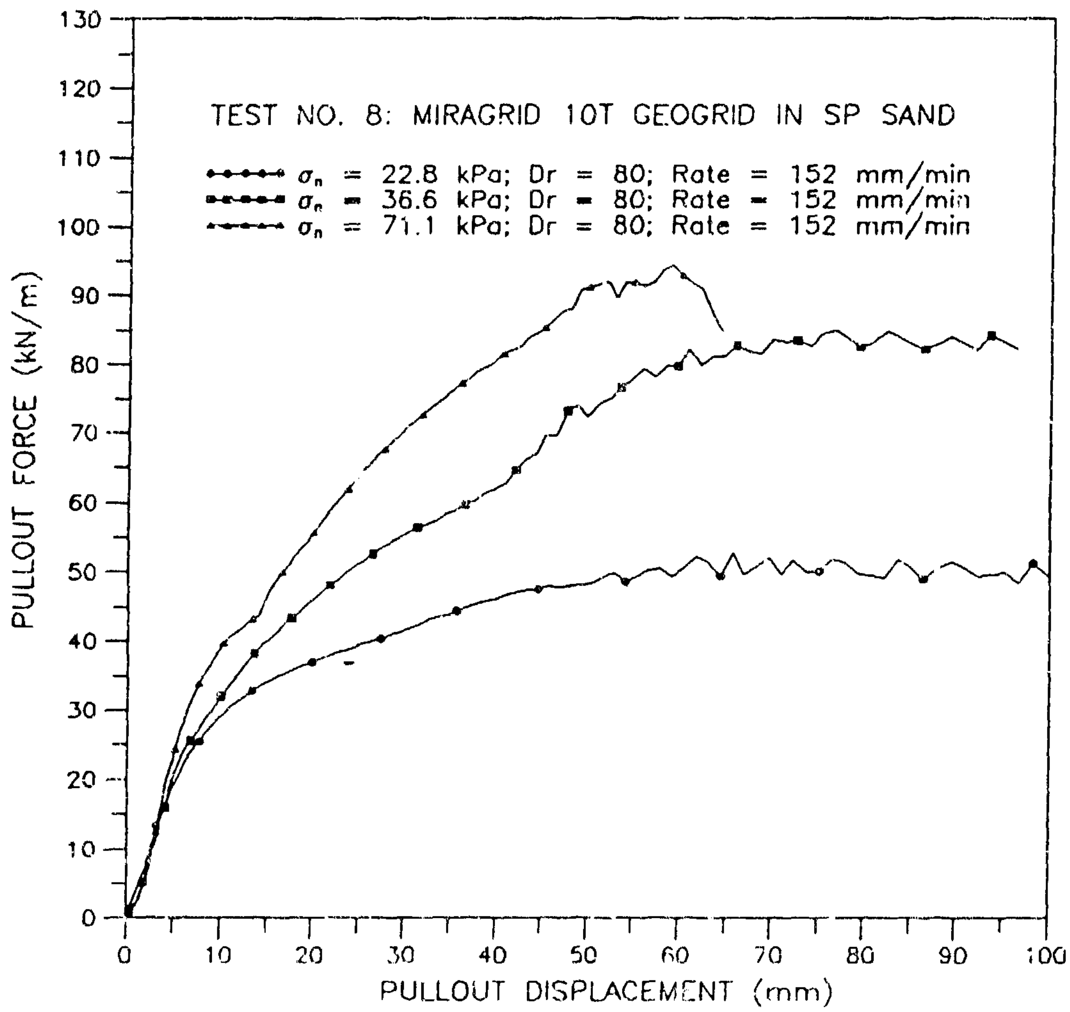

Figure 8. Pullout Responses of Miragrid 10T Geogrid in SP Sand.

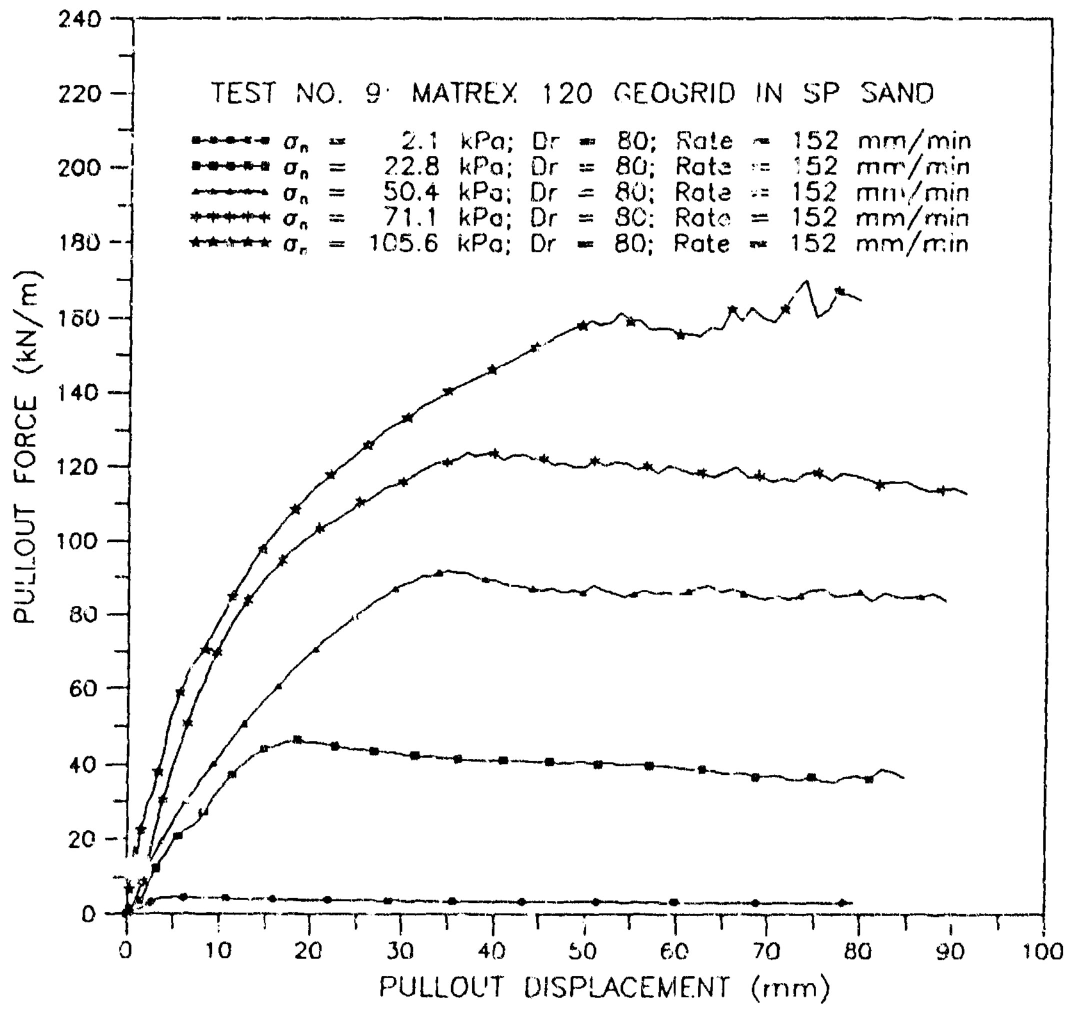

Figure 9. Pullout Responses of Matrex 120 Geogrid in SP Sand.

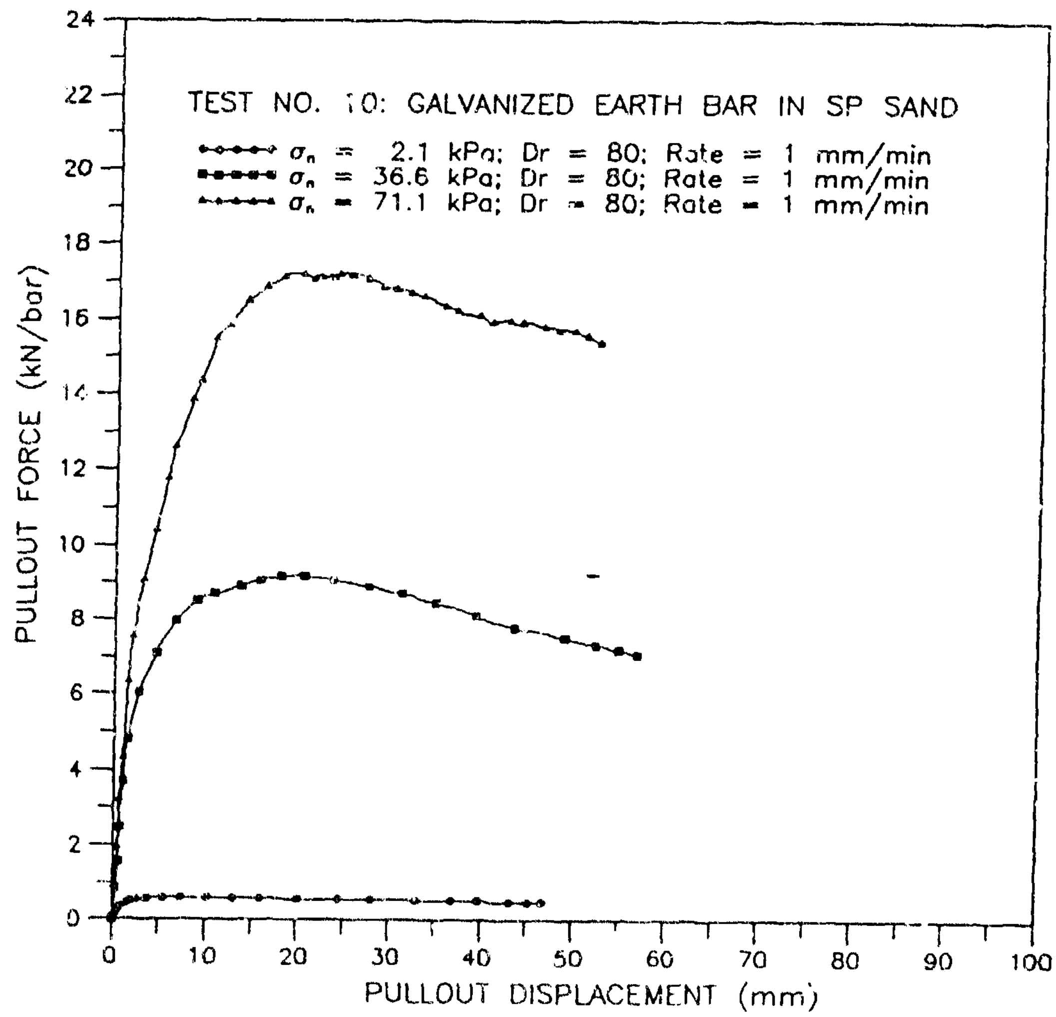

Figure 10. Pullout Responses of Galvanized Earth in SP Sand.

D. VERIFICATION OF THE NUMERICAL INTEGRATION METHOD

Figure 11 presents the assumed velocity-time history used to validate the numerical integration method utilized for calculation of dynamic displacement-time histories. Figure 12 presents a comparison of numerical and closed-form integration of this velocity-time history.

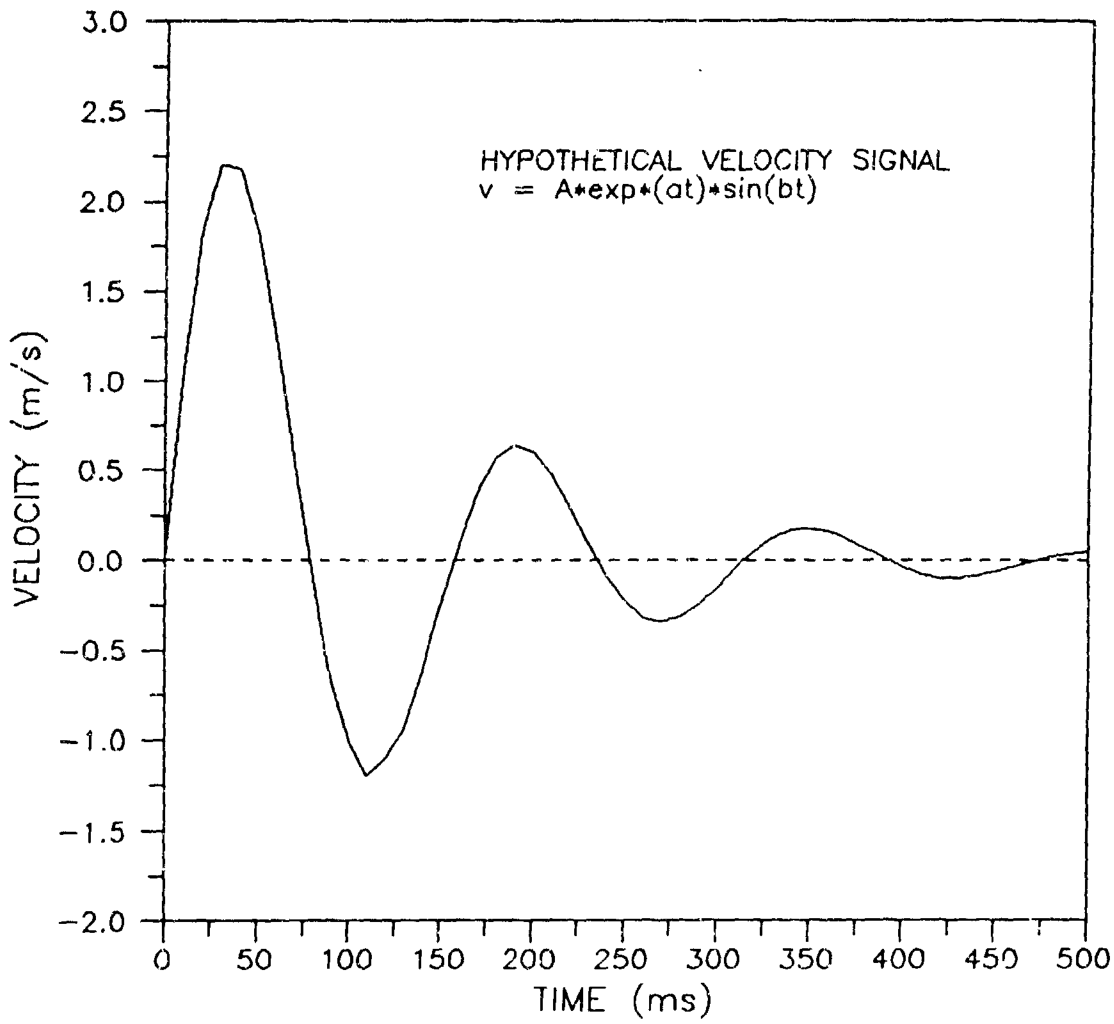

Figure 11. A Hypothetical Velocity Time History.

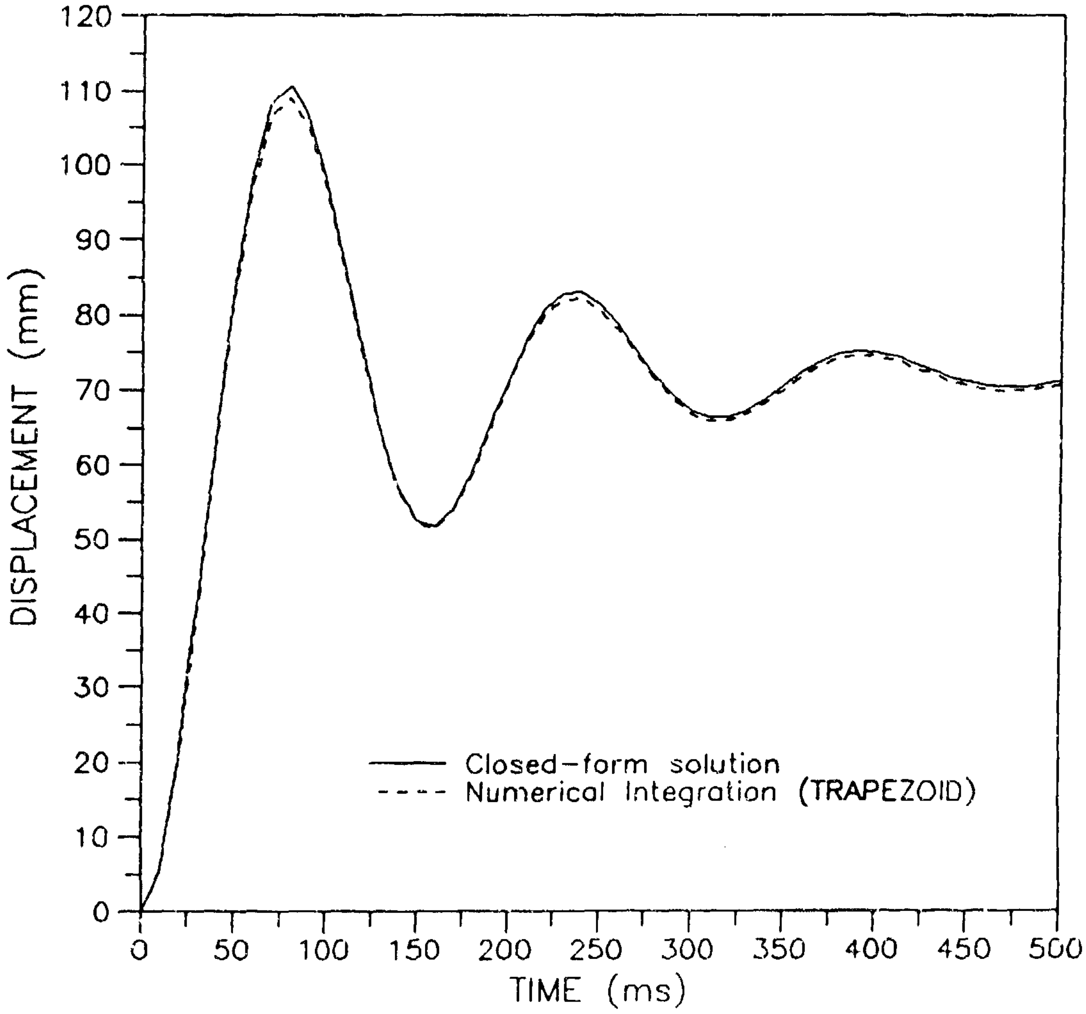

Figure 12. Comparison of Numerical Integration and Closed-Form Solution.

E. DYNAMIC TENSILE TESTS

Figures 13 - 24 present the results of dynamic tensile tests on Miragrid 10T, Matrex 120 and Tensar UX1500 geogrid.

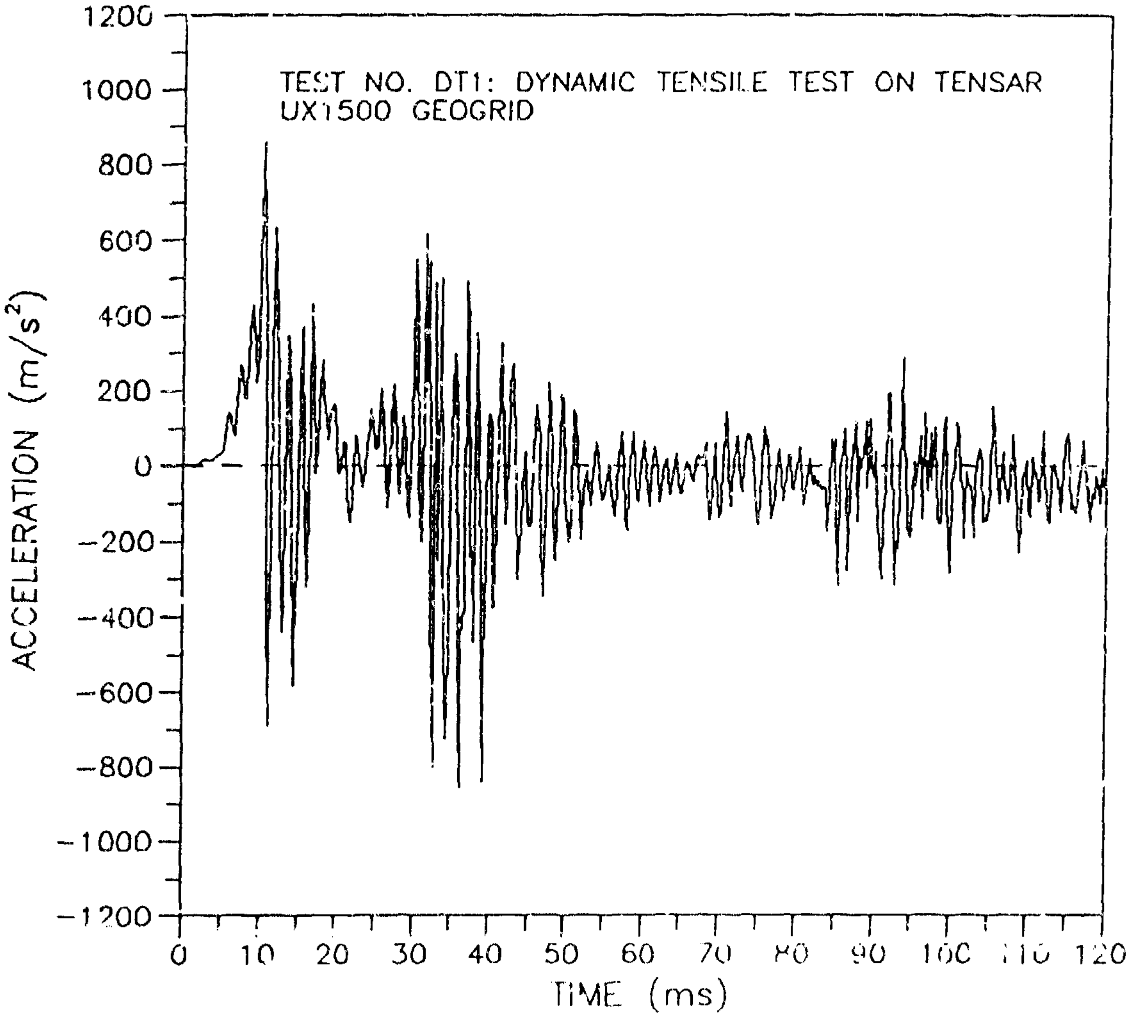

Figure 13. Measured Acceleration at Pulling End of Tensar UX1500 Geogrid for Test DT1.

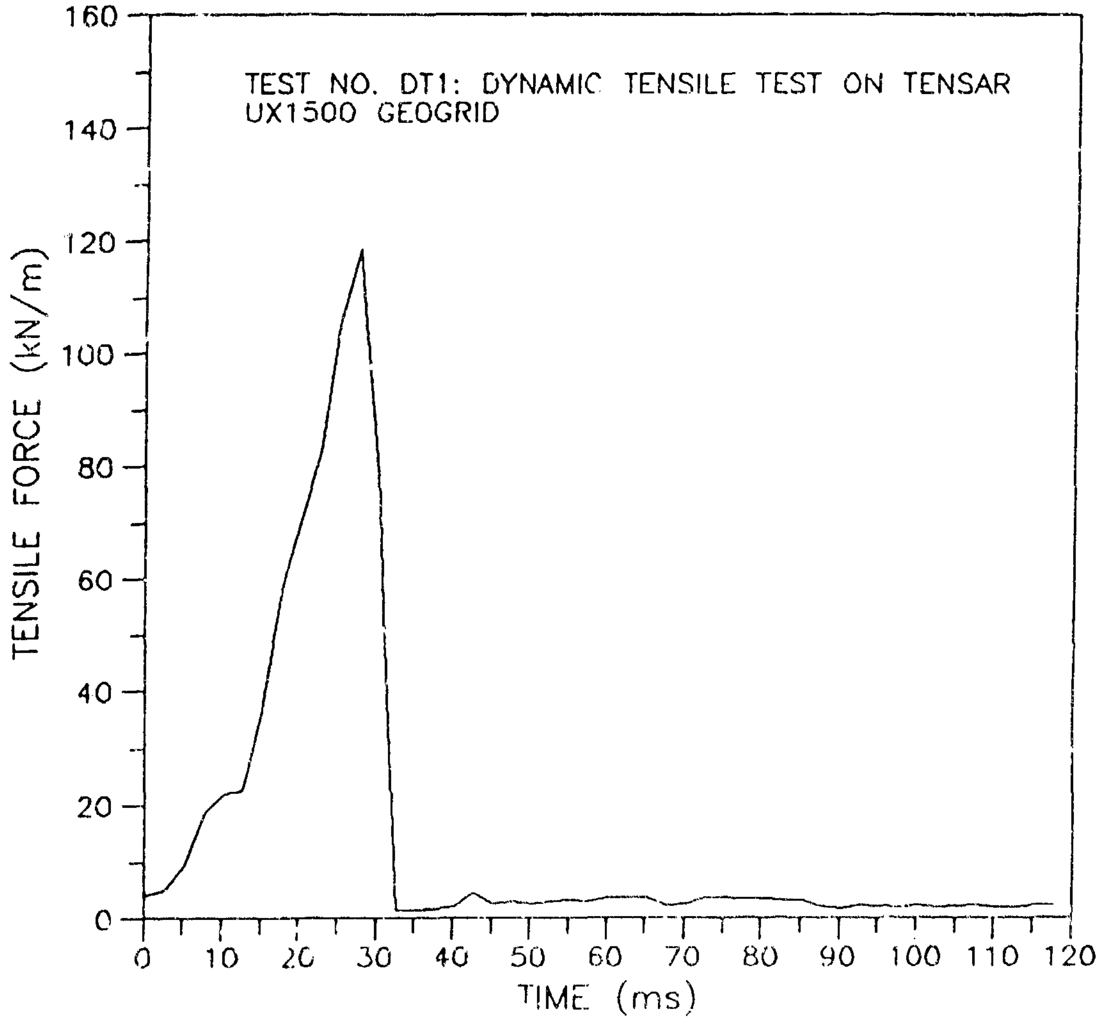

Figure 14. Measured Force at Pulling End of Tensar UX1500 Geogrid for Test DT1.

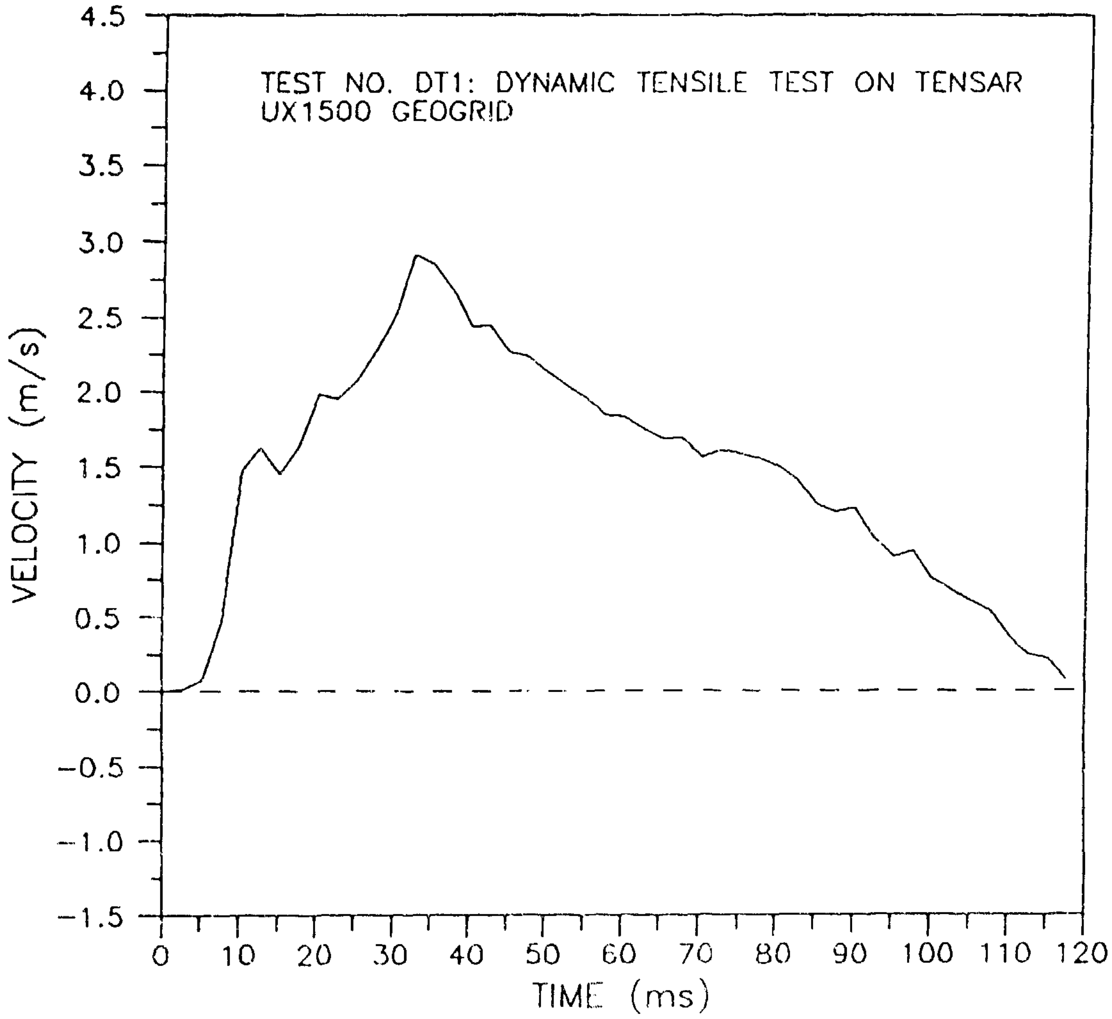

Figure 15. Velocity Time History at Pulling End of Tensar UX1500 Geogrid for Test DT1.

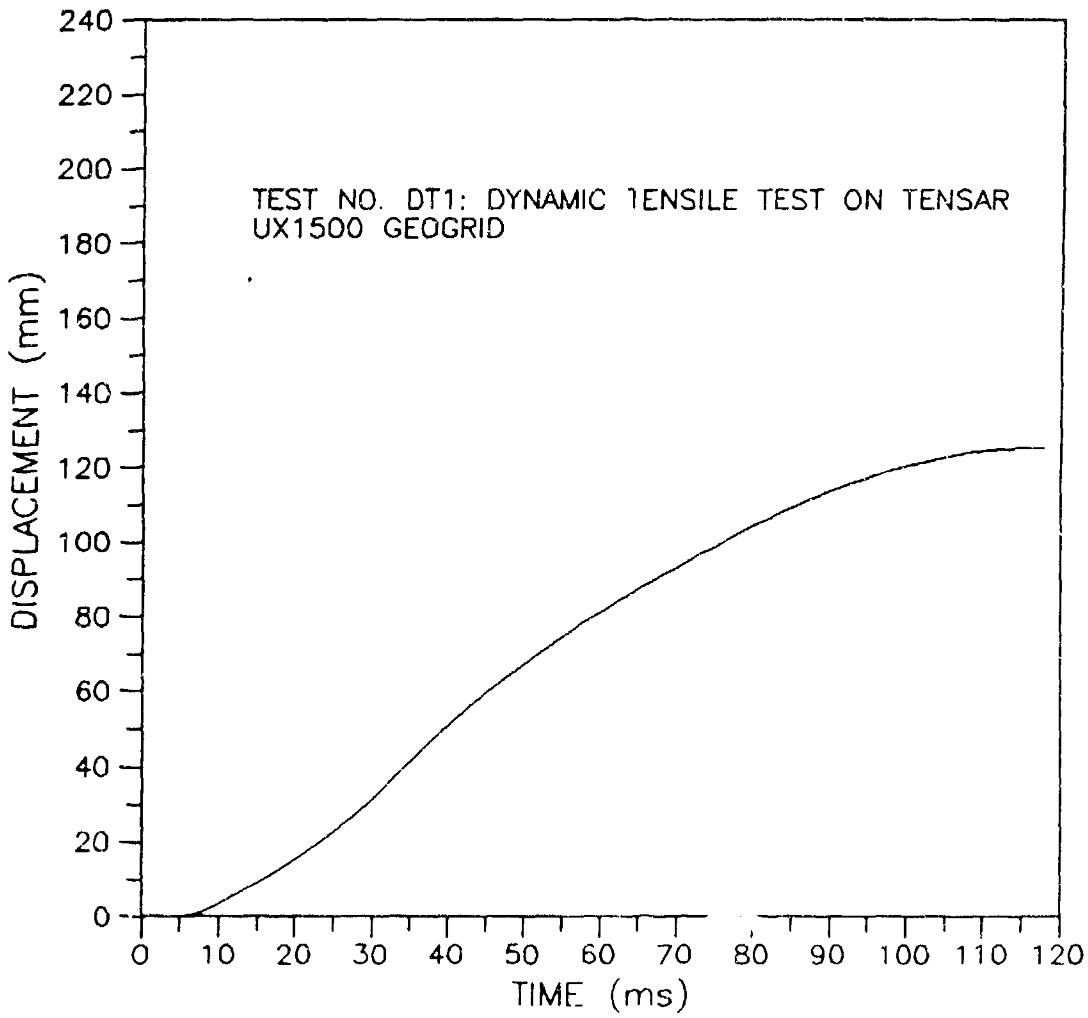

Figure 16. Displacement Time History at Pulling End of Tensar UX1500 Geogrid for Test DT1.

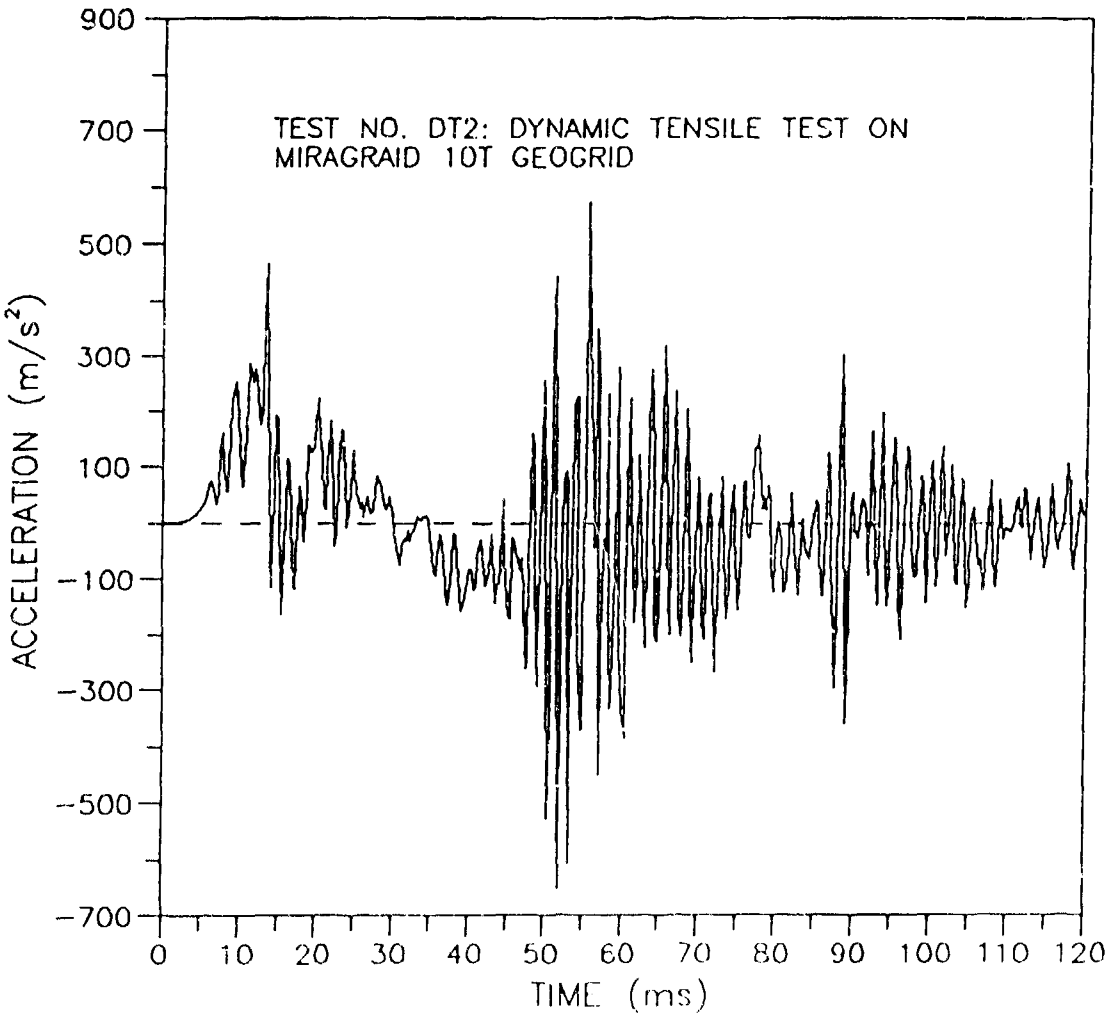

Figure 17. Measured Acceleration at Pulling End of Miragrid 10T Geogrid for Test DT2.

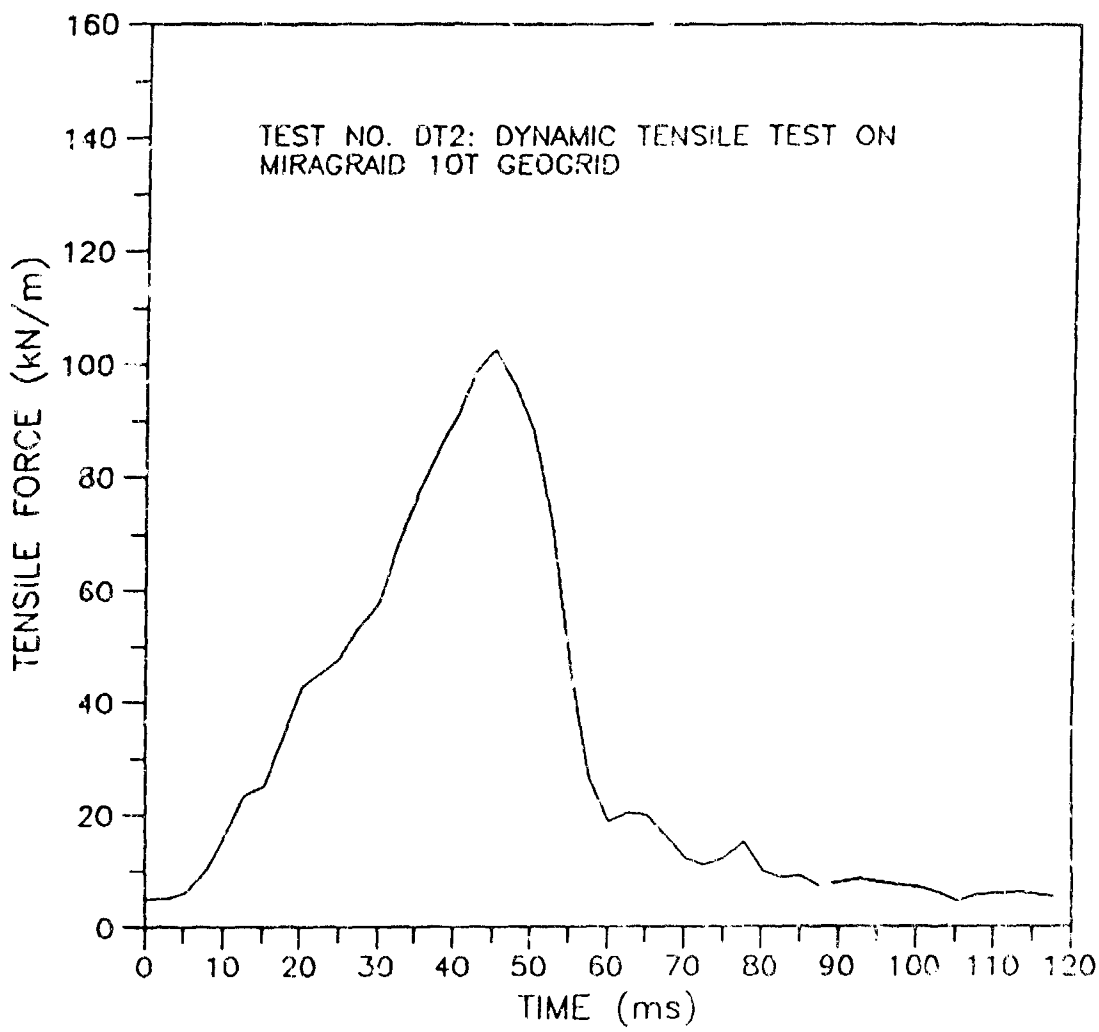

Figure 18. Measured Force at Pulling End of Miragrid 10T Geogrid for Test DT2.

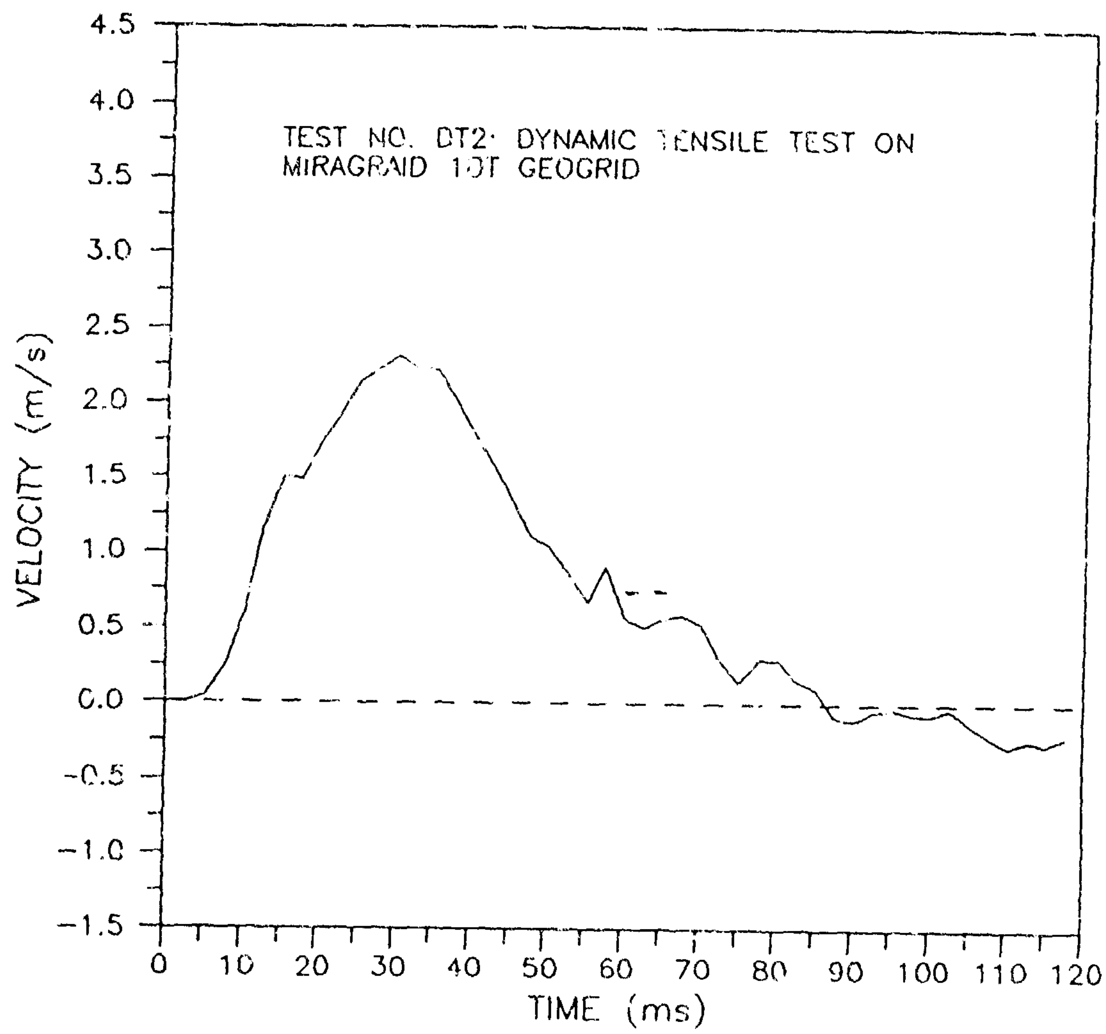

Figure 19. Velocity Time History at Pulling End of Miragrid 10T Geogrid for Test DT2.

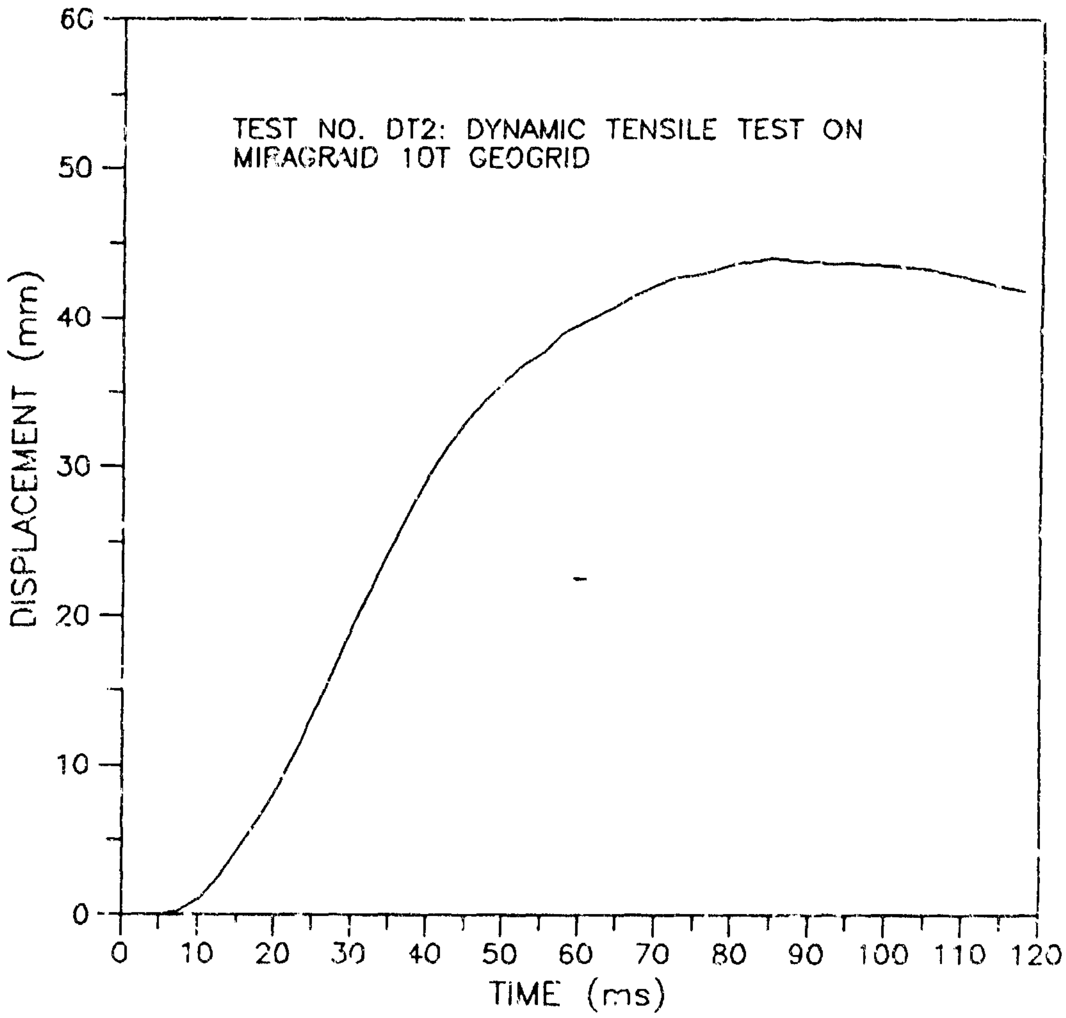

Figure 20. Displacement Time History at Pulling End of Miragrid 10T Geogrid for Test DT2.

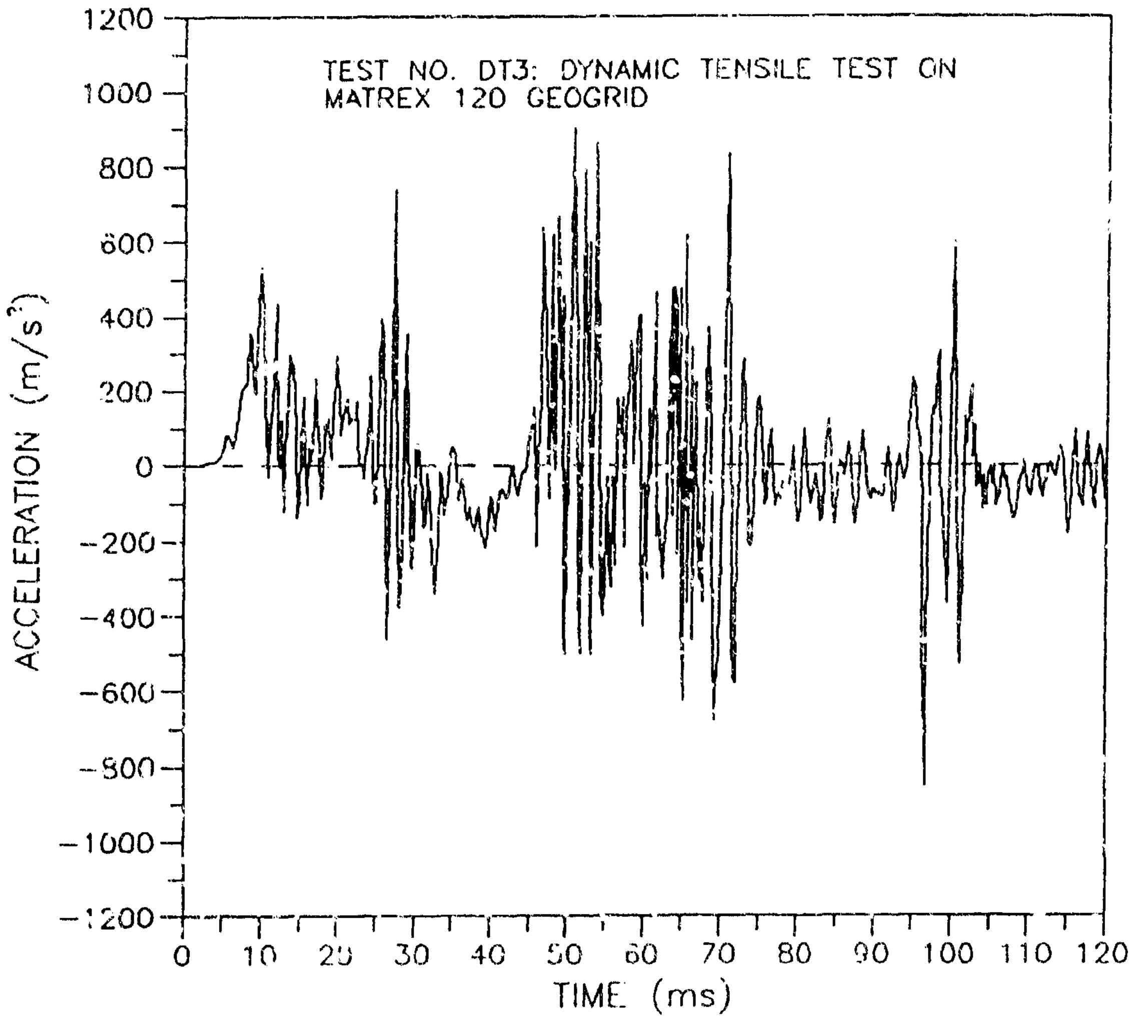

Figure 21. Measured Acceleration at Pulling End of Matrex 120 Geogrid for Test DT3.

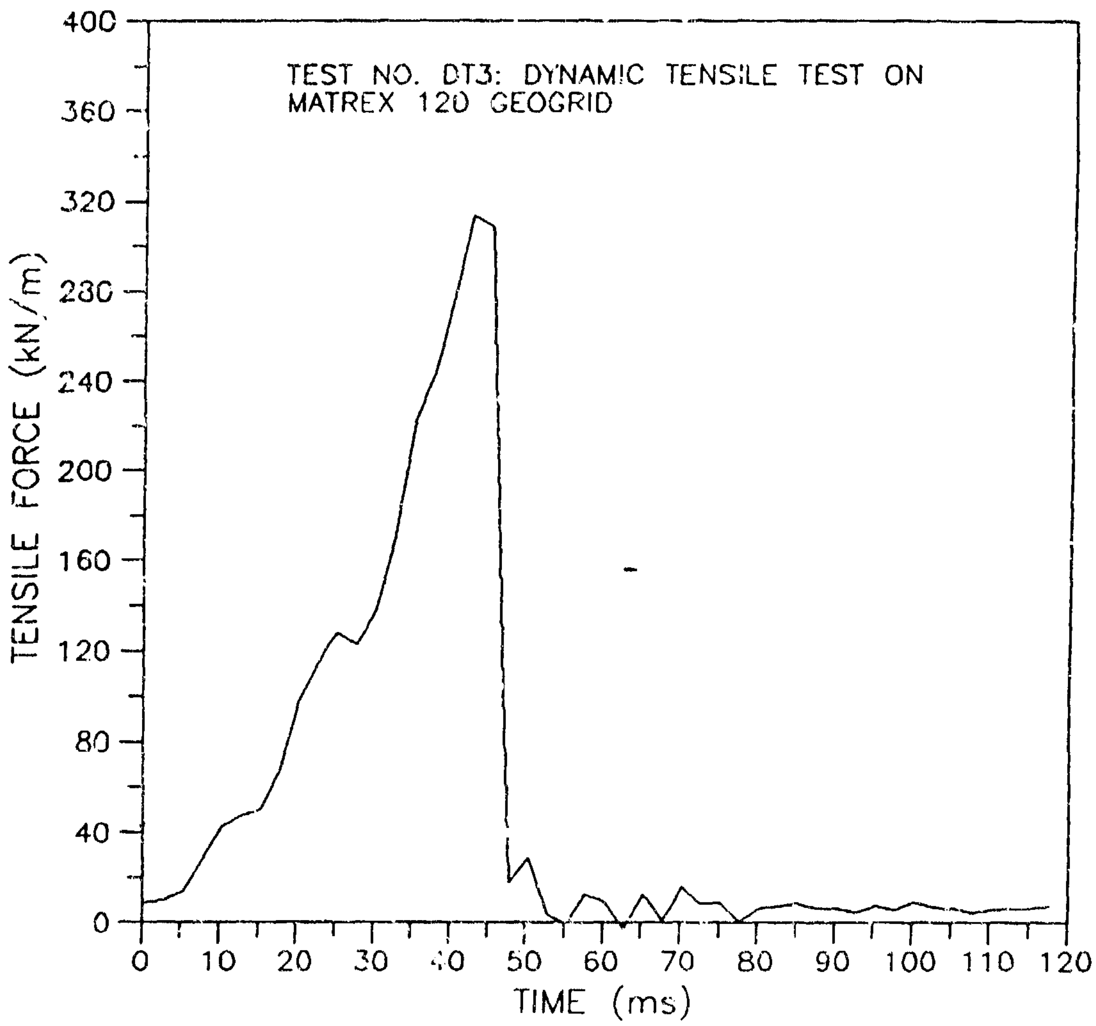

Figure 22. Measured Force at Pulling End of Tensar Matrex 120 Geogrid for Test DT3.

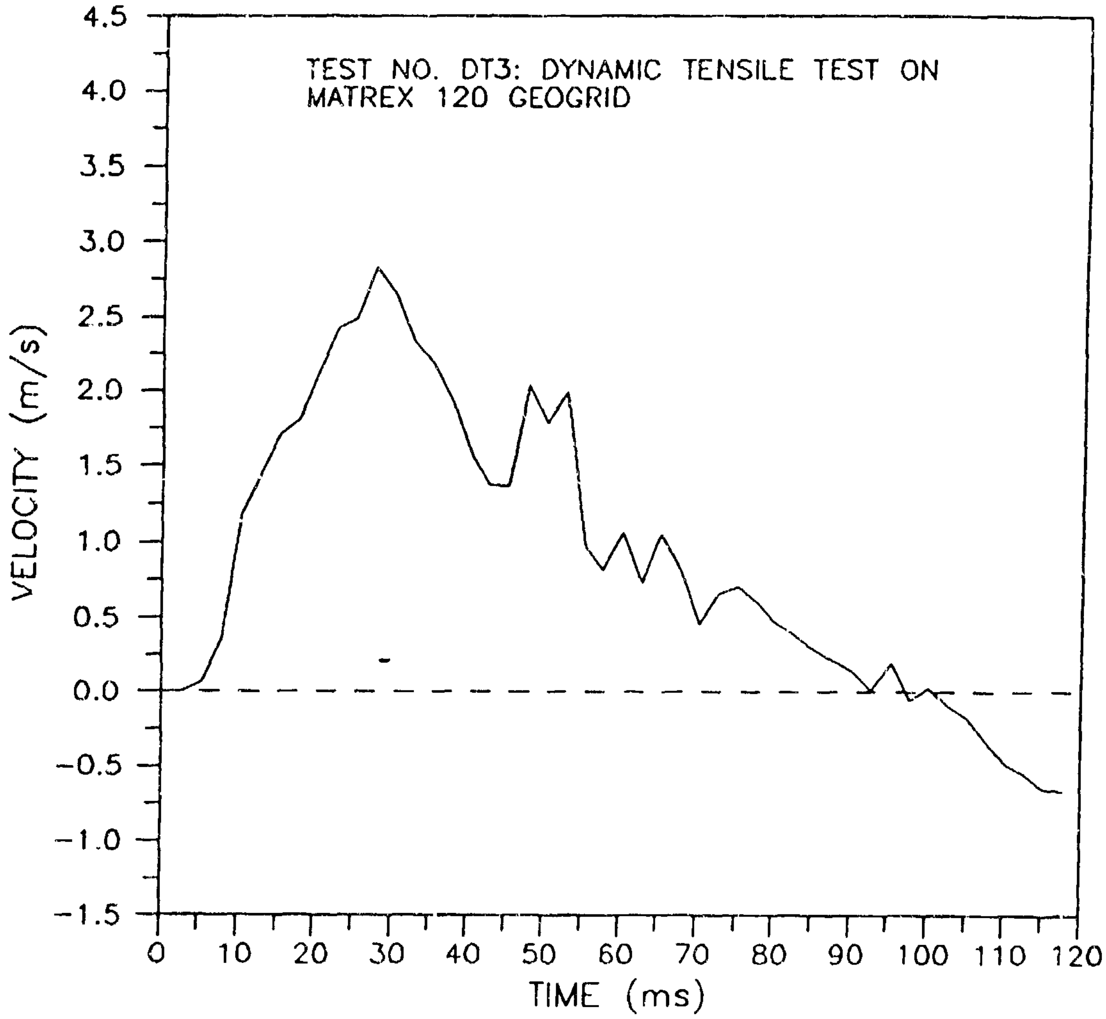

Figure 23. Velocity Time History at Pulling End of Matrex 120 Geogrid for Test DT3.

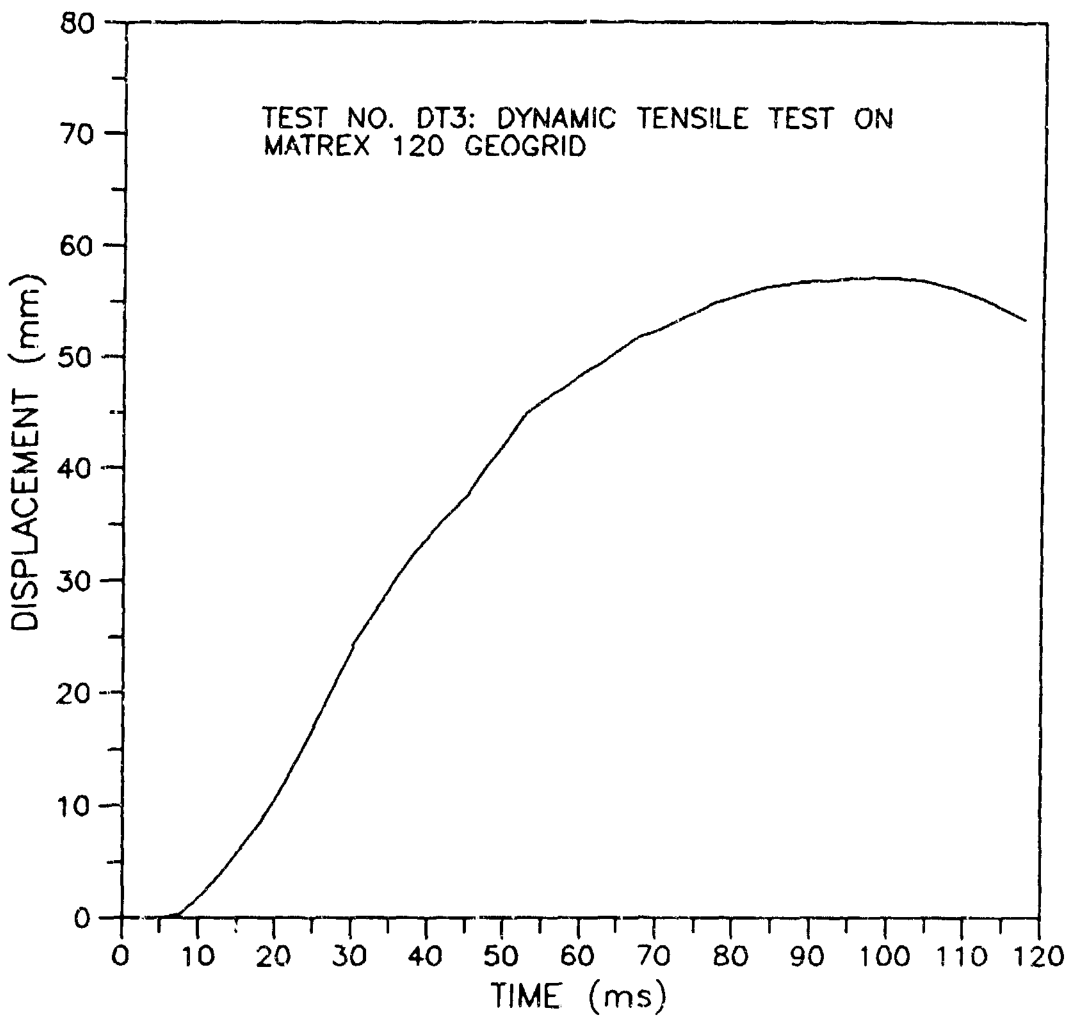

Figure 24. Displacement Time History at Pulling End of Matrex 120 Geogrid for Test DT3.

F. DYNAMIC PULLOUT TESTS

Figures 25 - 92 present the results of all dynamic pullout tests conducted on Miragrid 10T, Matrix 120 and Tensar UX1500 geogrid.

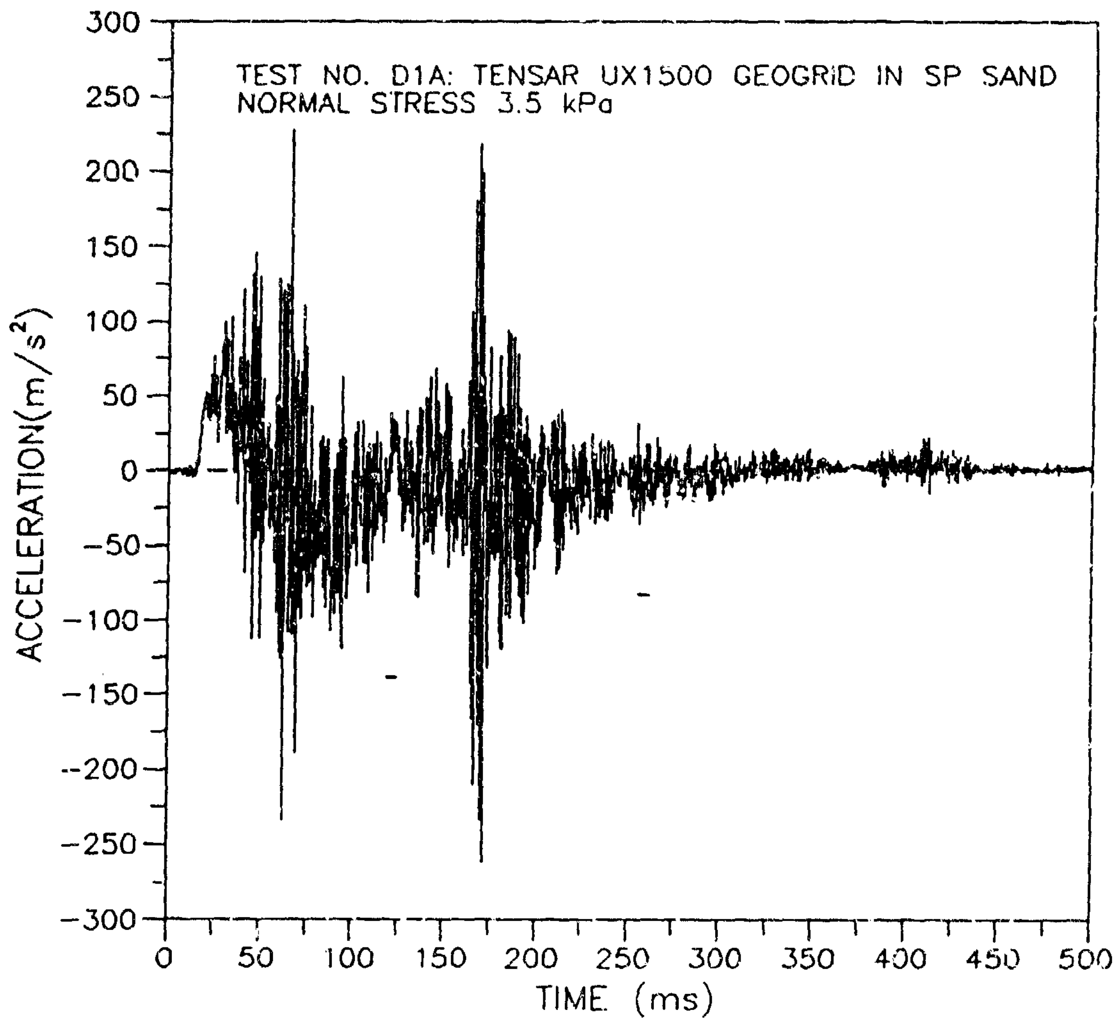

Figure 25. Measured Acceleration at Pulling End of Tensar UX1500 Geogrid for Test D1A.

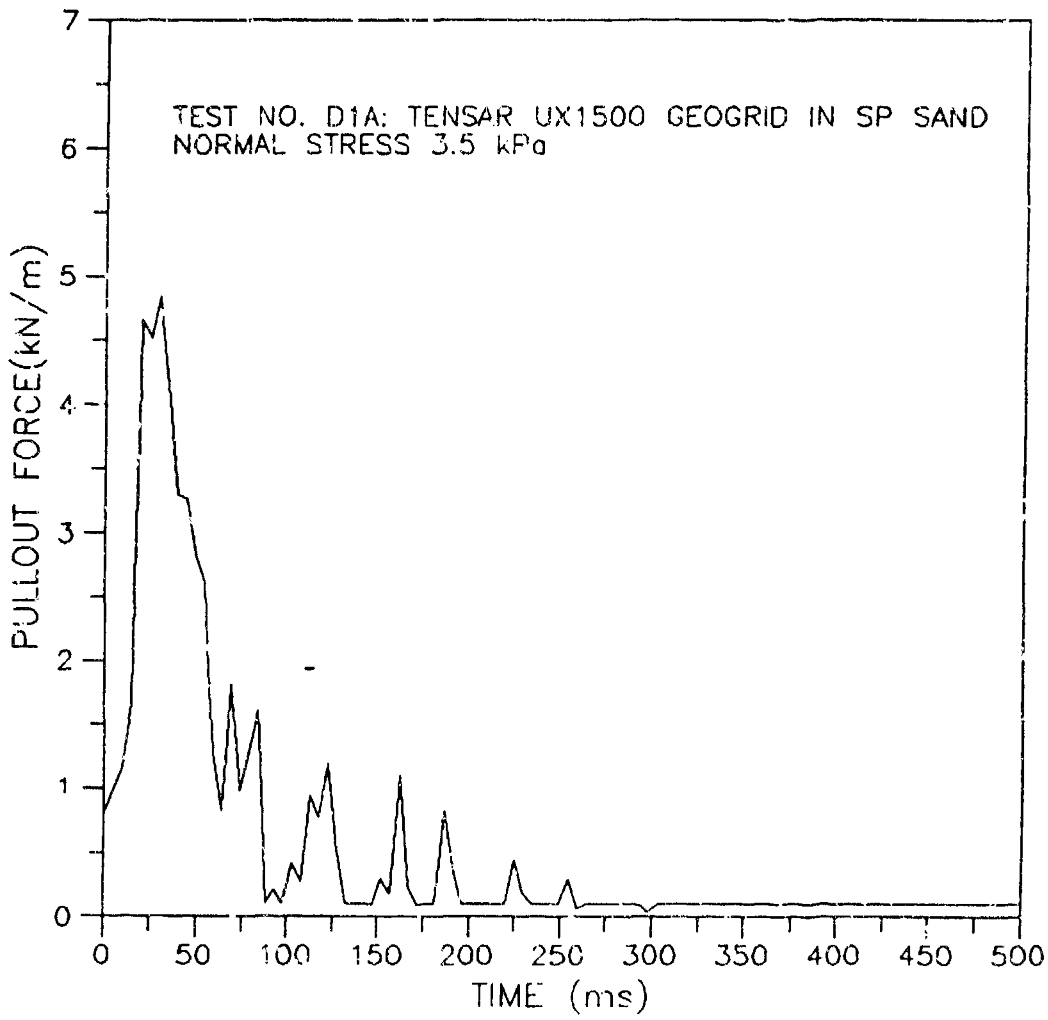

Figure 26. Measured Force at Pulling End of Tensar UX1500 Geogrid for Test D1A.

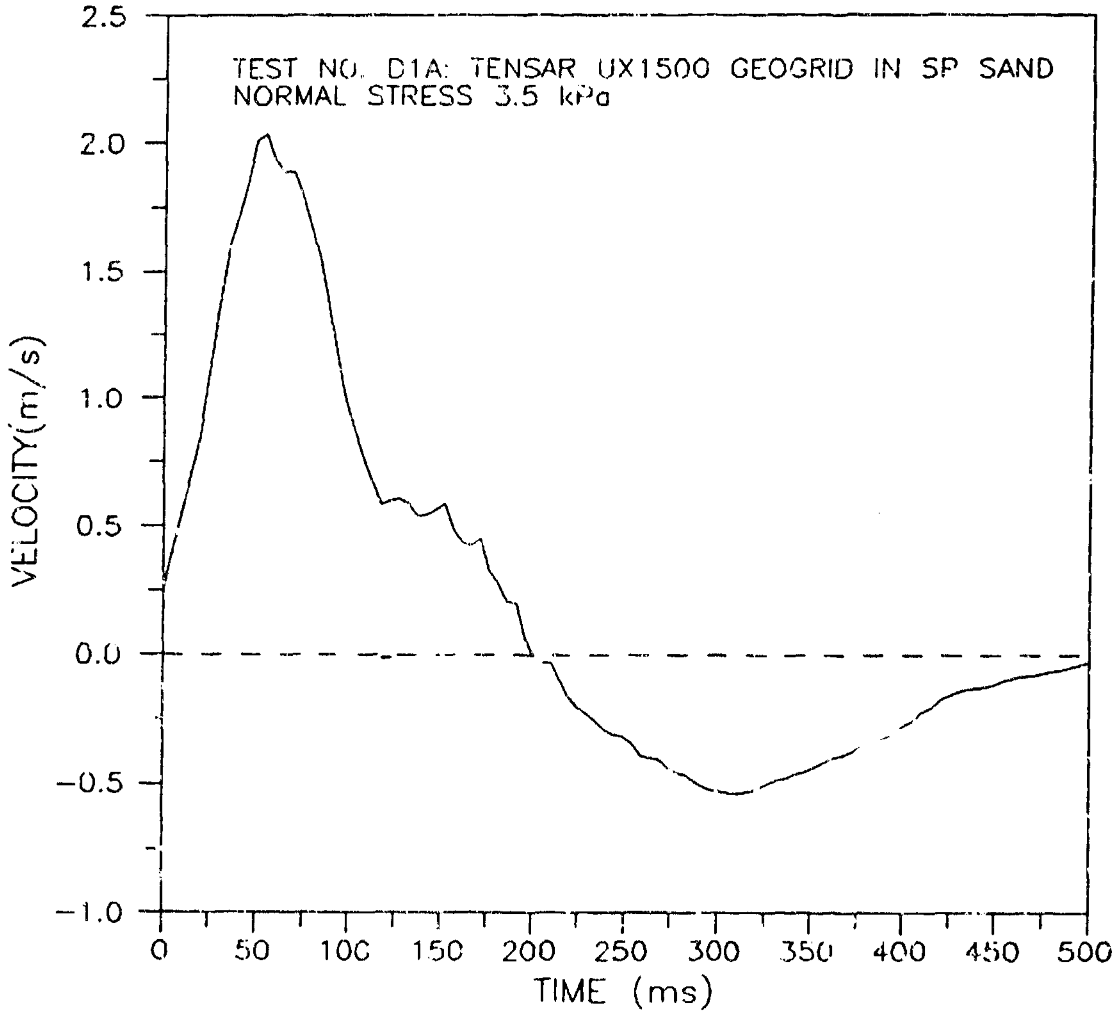

Figure 27. Velocity Time History at Pulling End of Tensar UX1500 Geogrid for Test D1A.

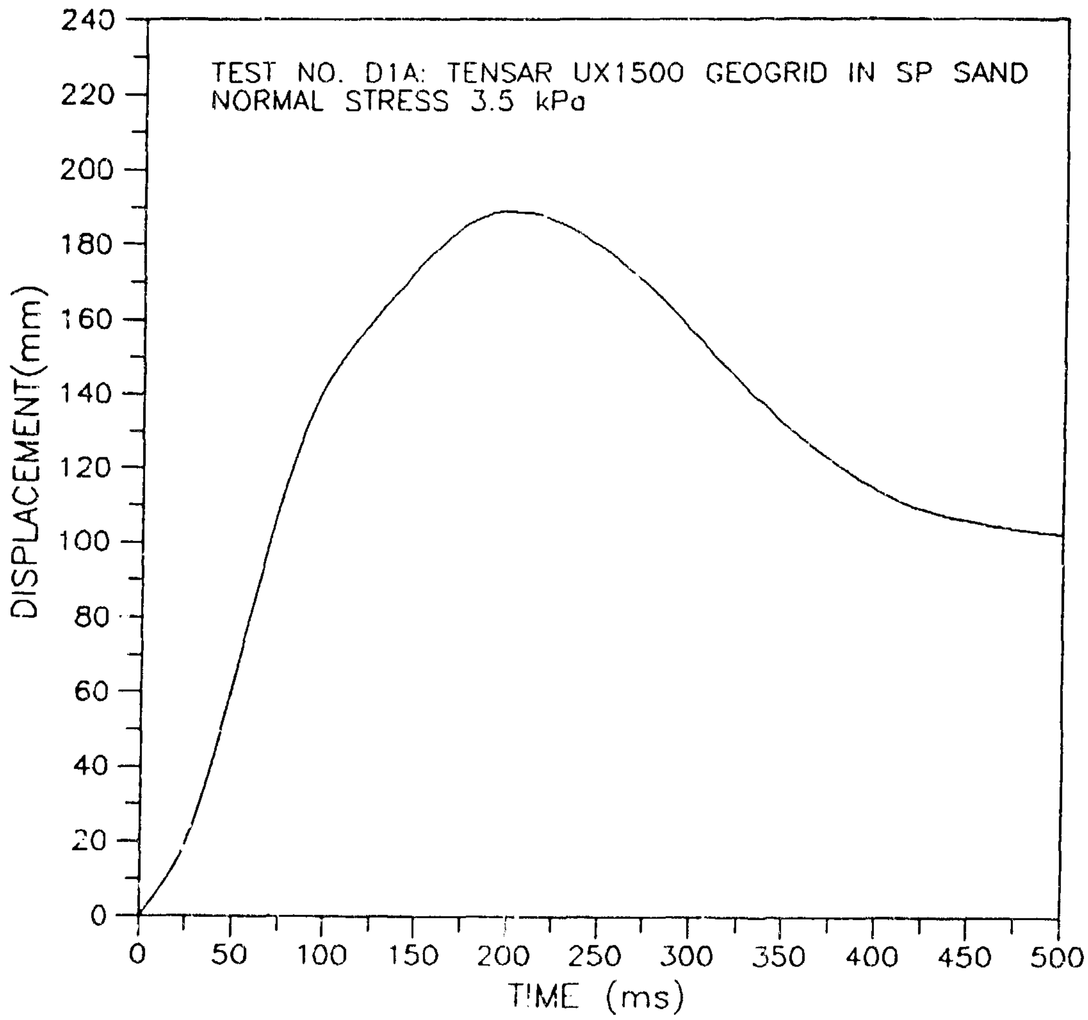

Figure 28. Displacement Time History at Pulling End of Tensar UX1500 Geogrid for Test D1A.

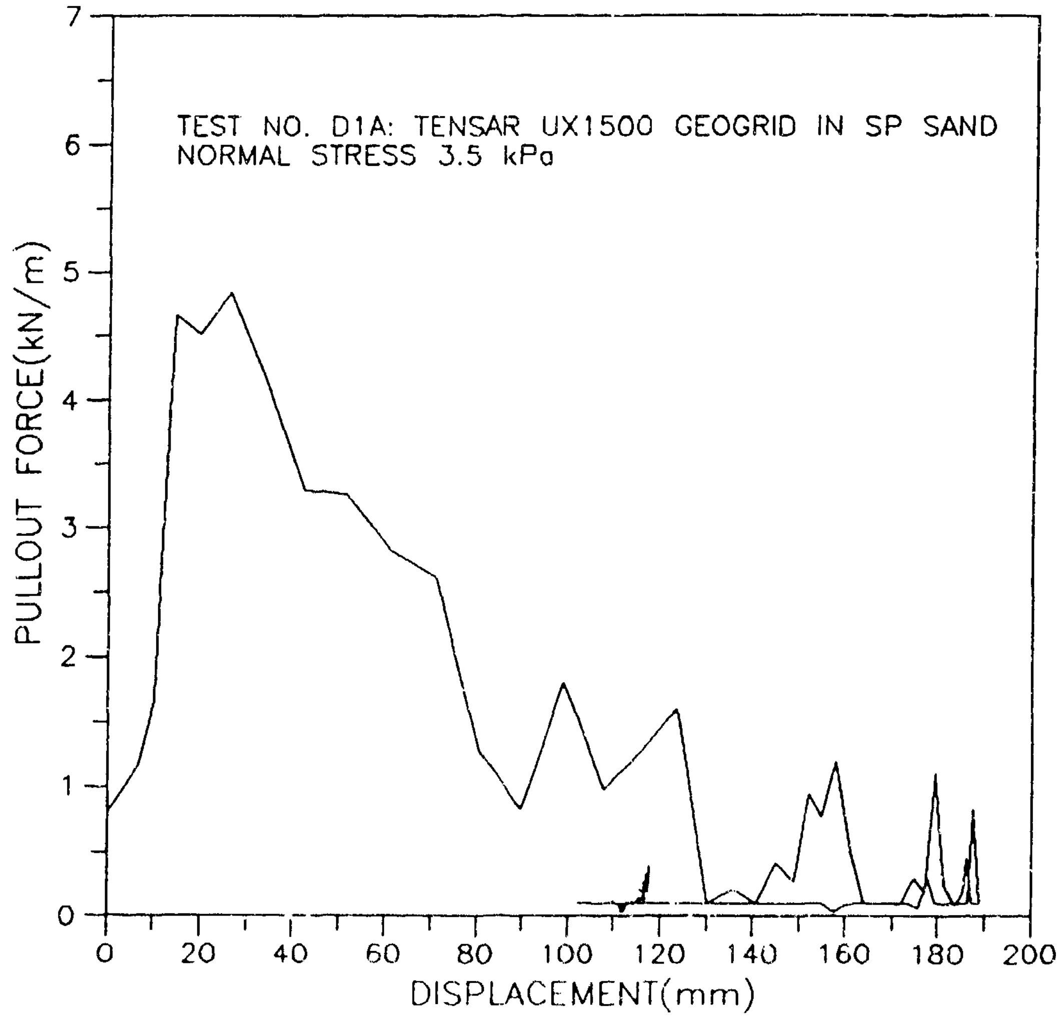

Figure 29. Dynamic Pullout Response of Tensar UX1500 Geogrid for Test D1A.

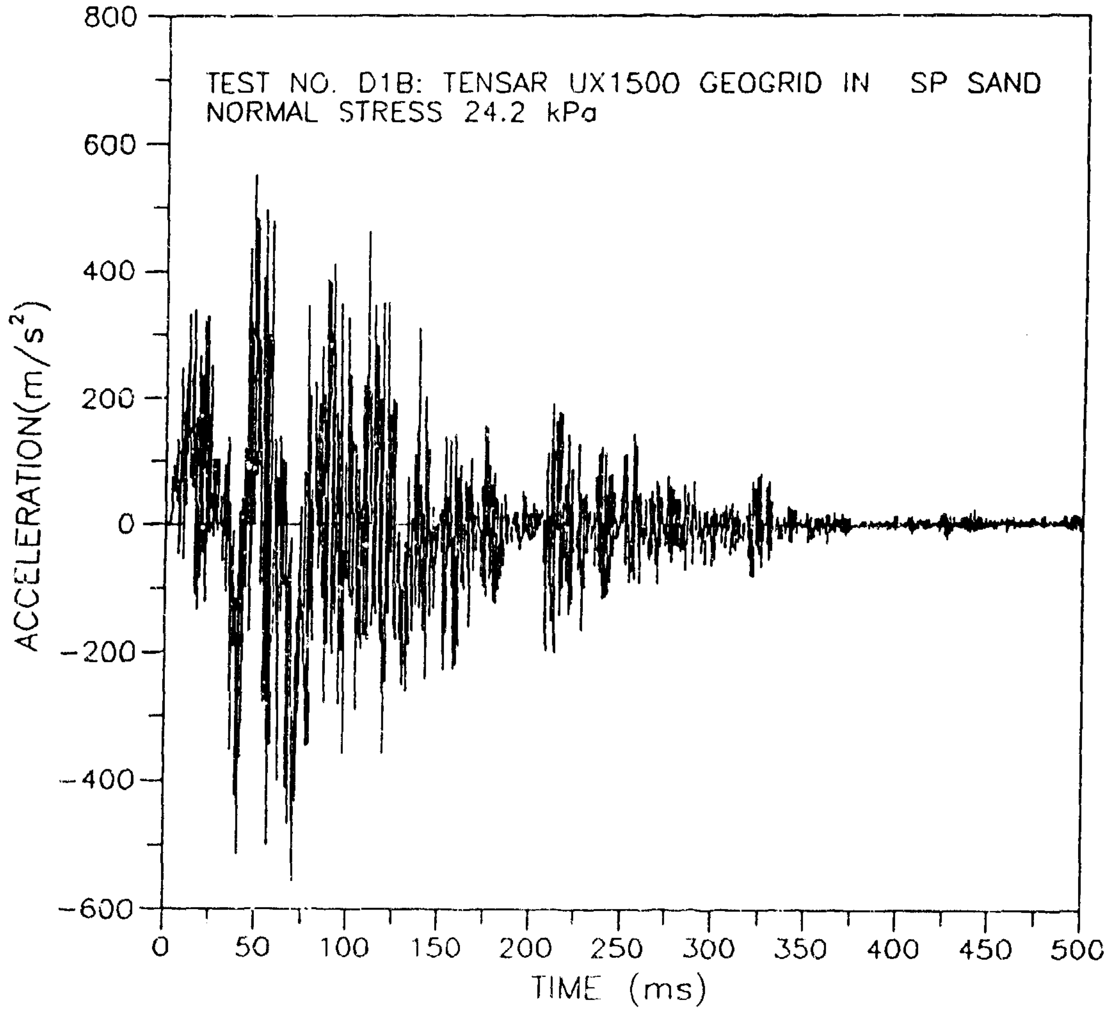

Figure 30. Measured Acceleration at Pulling End of Tensar UX1500 Geogrid for Test D1B.

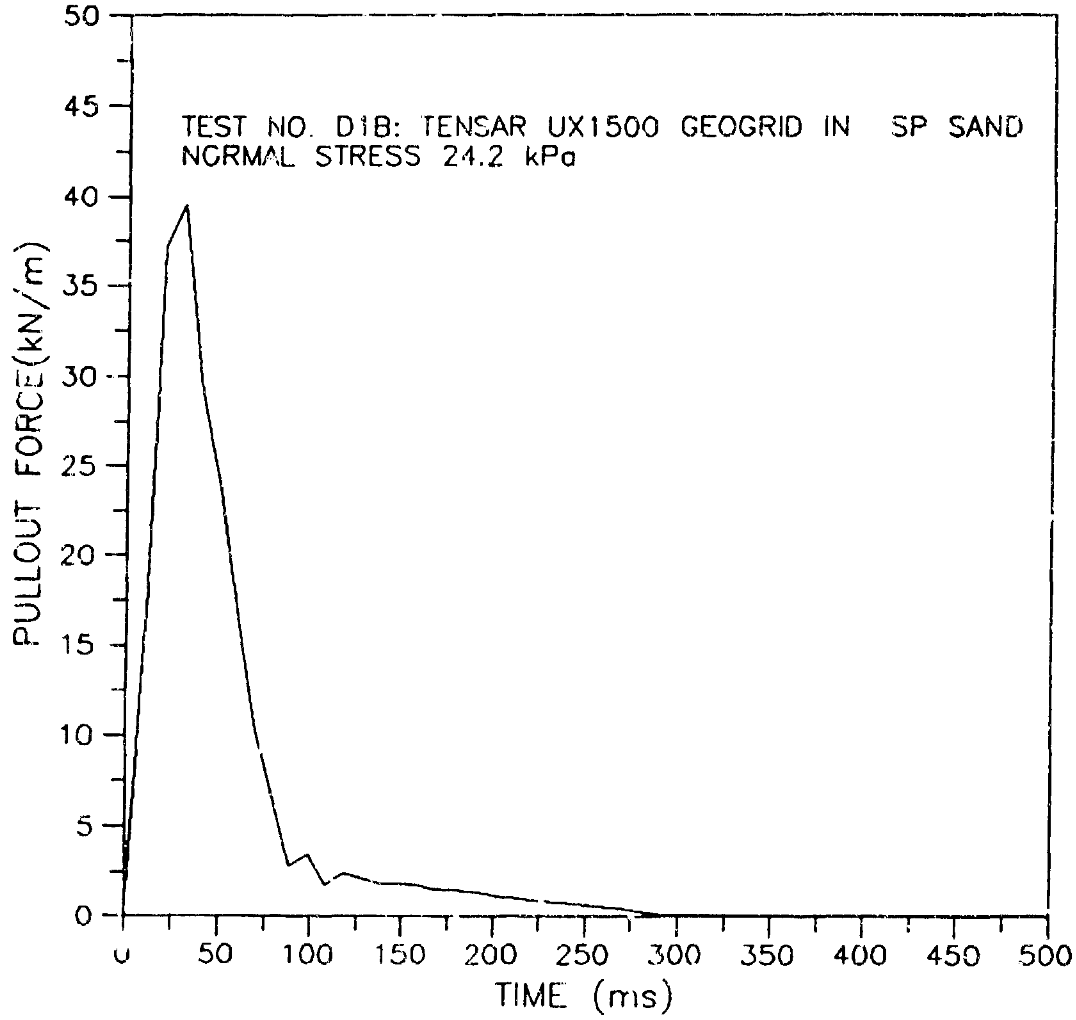

Figure 31. Measured Force at Pulling End of Tensar UX1500 Geogrid for Test D1B.

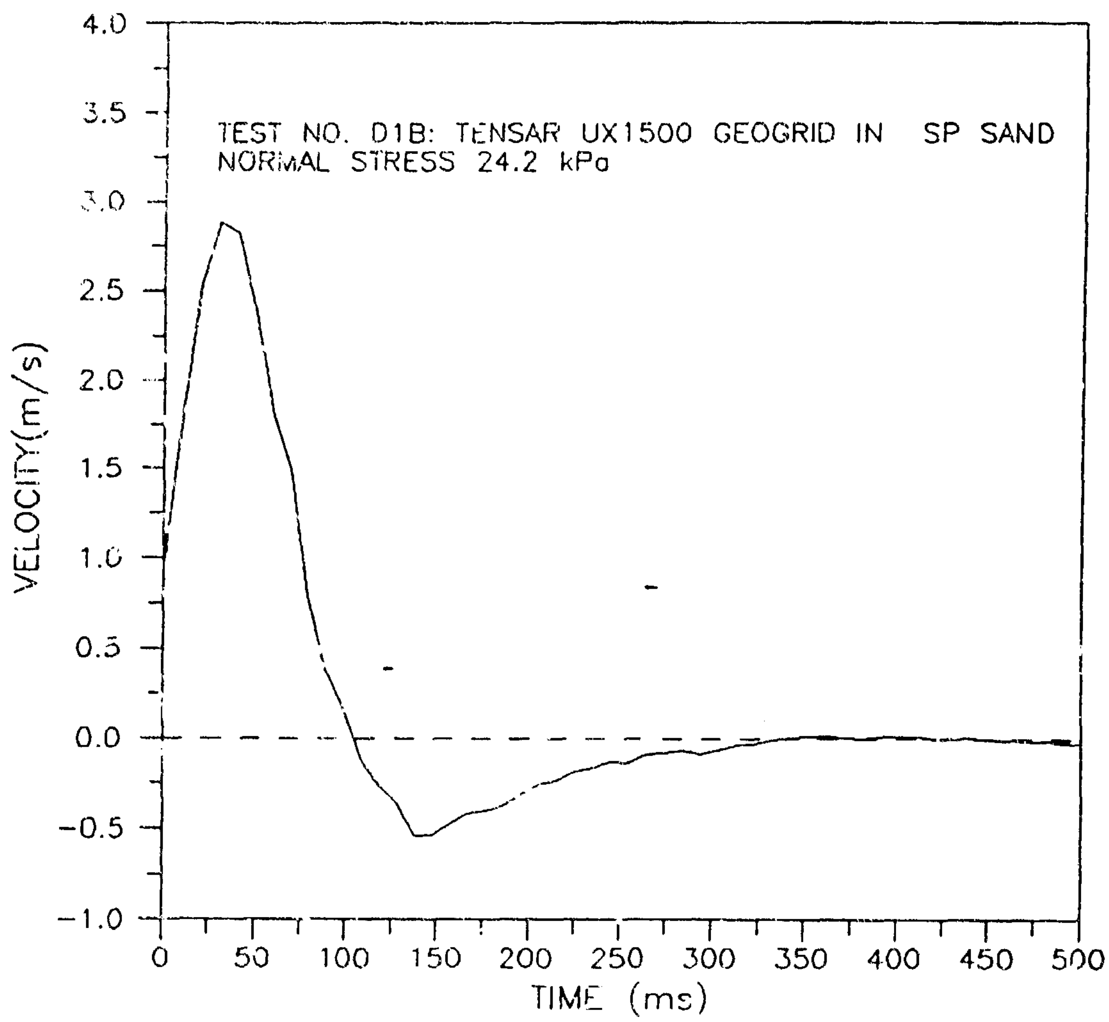

Figure 32. Velocity Time History at Pulling End of Tensar UX1500 Geogrid for Test D1B.

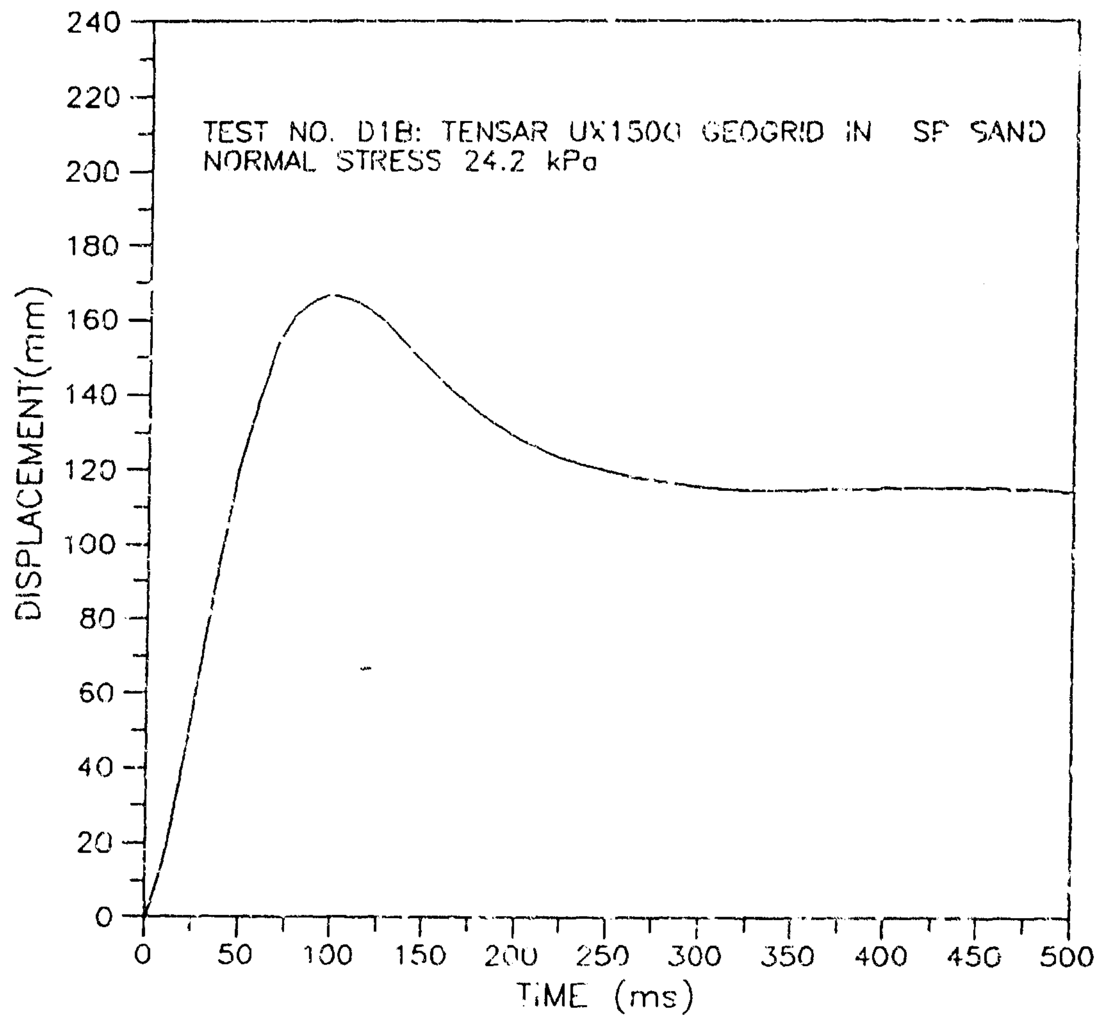

Figure 33. Displacement Time History at Pulling End of Tensar UX1500 Geogrid for Test D1B.

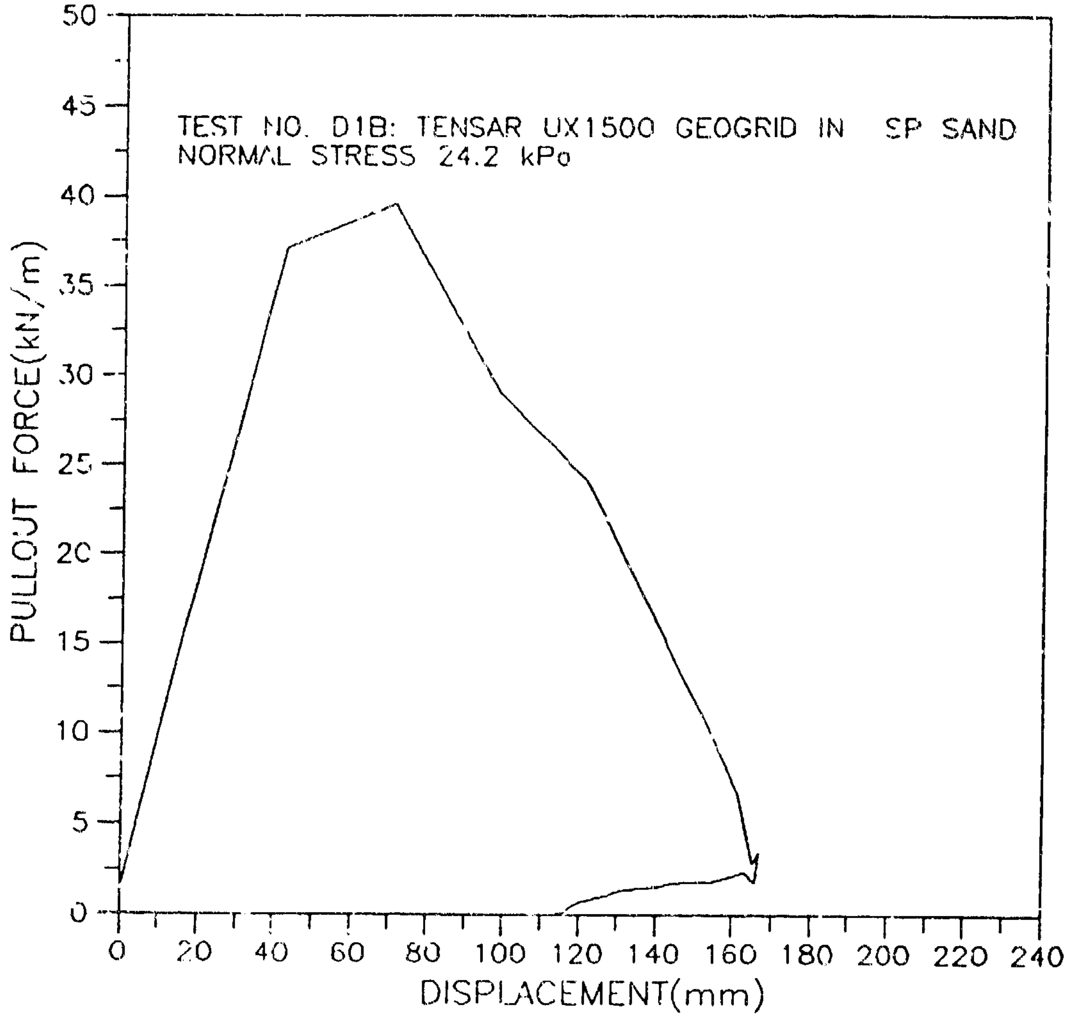

Figure 34. Dynamic Pullout Response of Tensar UX1500 Geogrid for Test D1B.

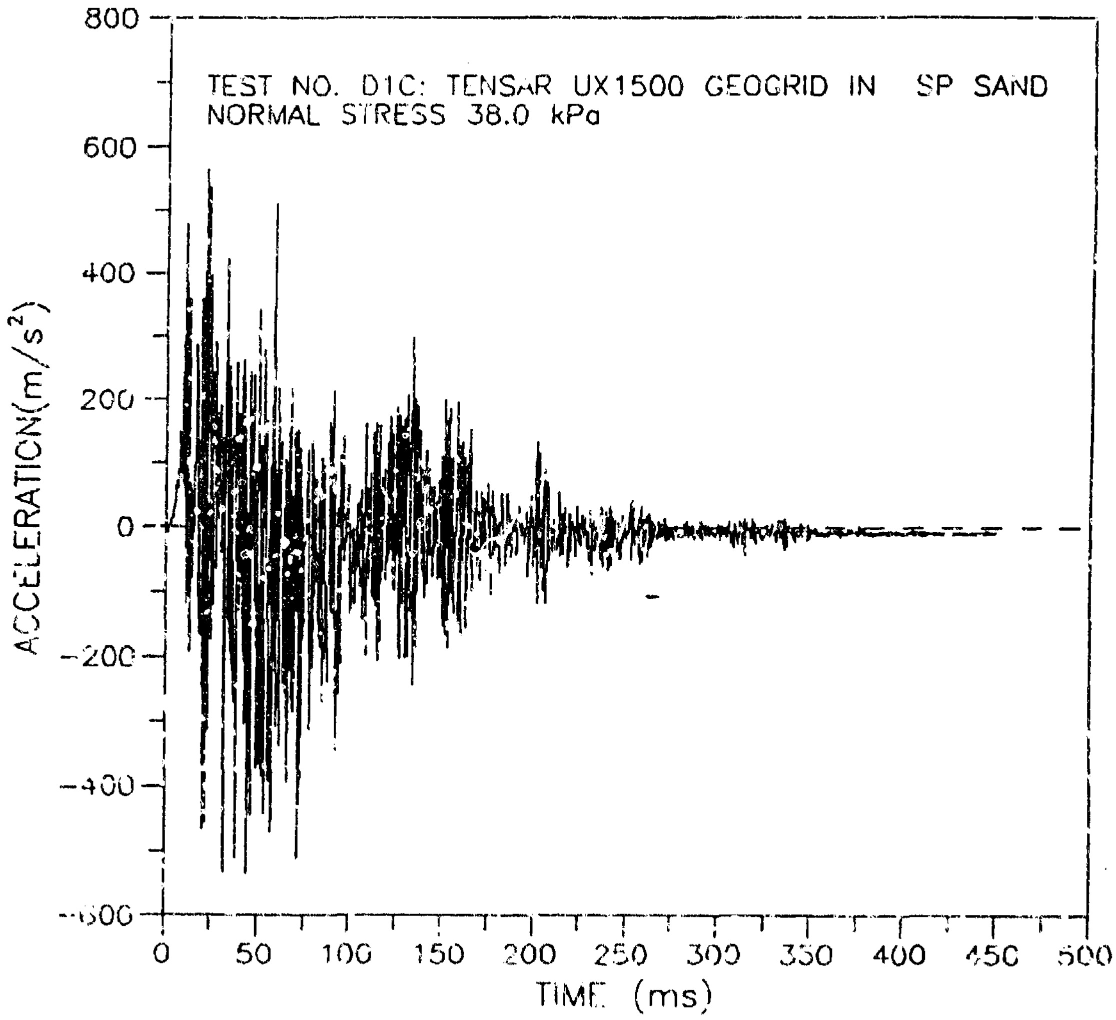

Figure 35. Measured Acceleration at Pulling End of Tensar UX1500 Geogrid for Test DIC.

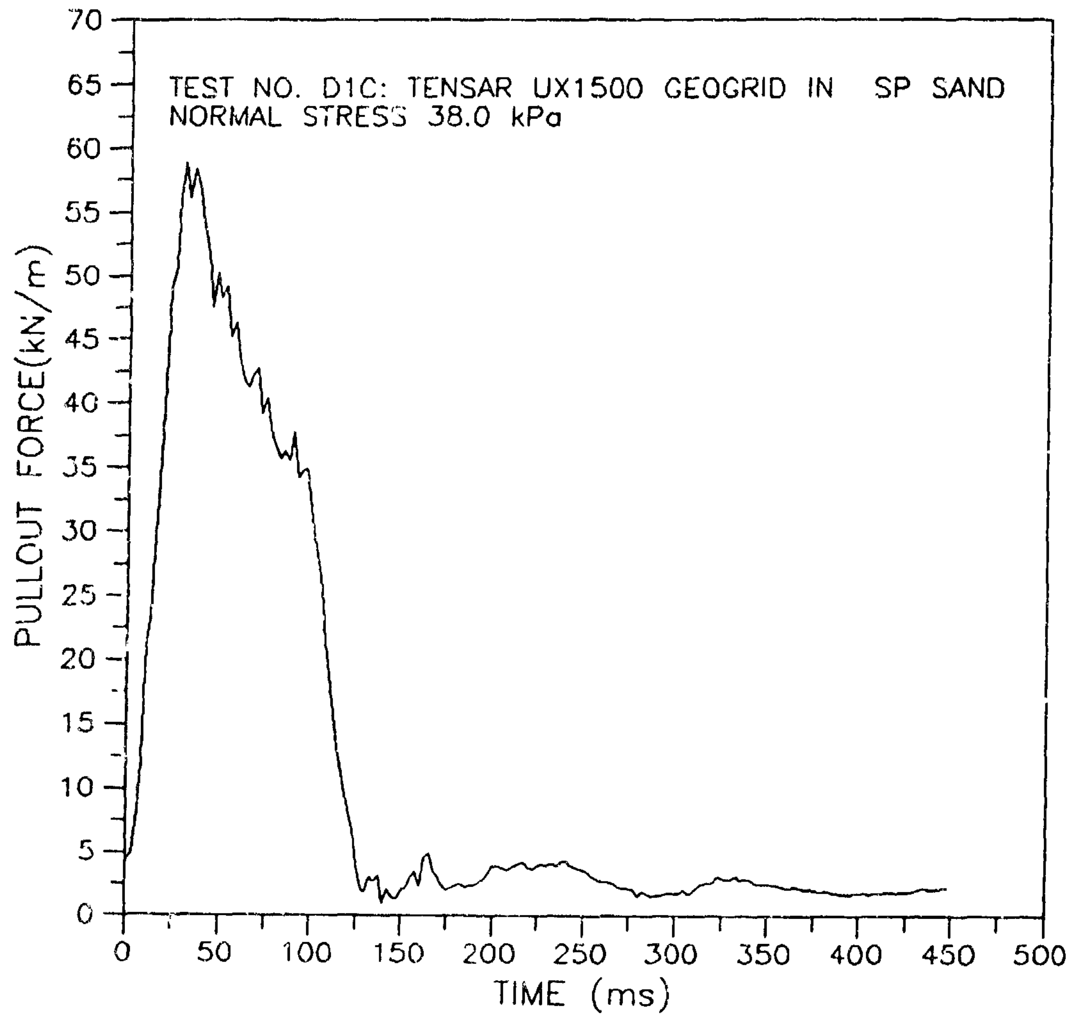

Figure 36. Measured Force at Pulling End of Tensar UX1500 Geogrid for Test D1C.

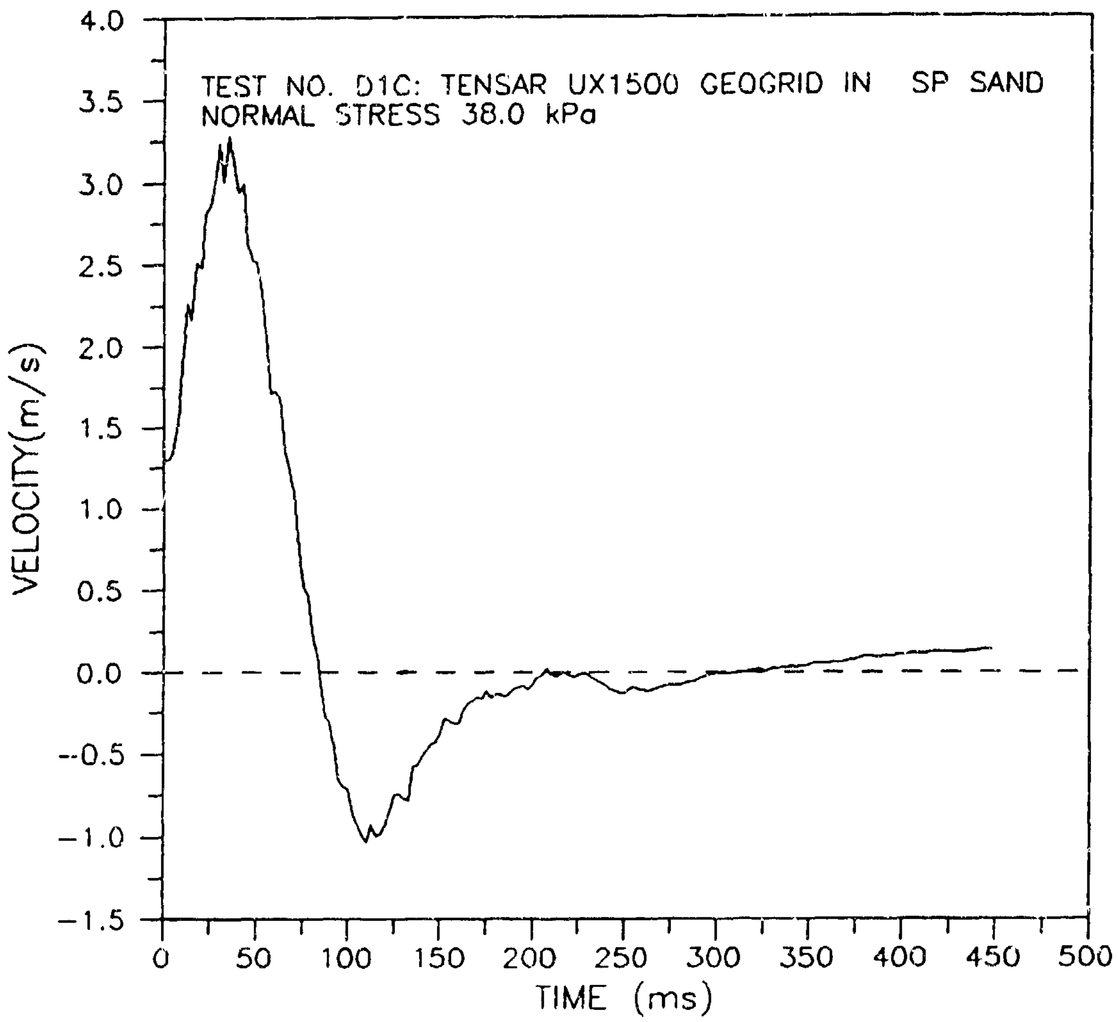

Figure 37. Velocity Time History at Pulling End of Tensar UX1500 Geogrid for Test D1C.

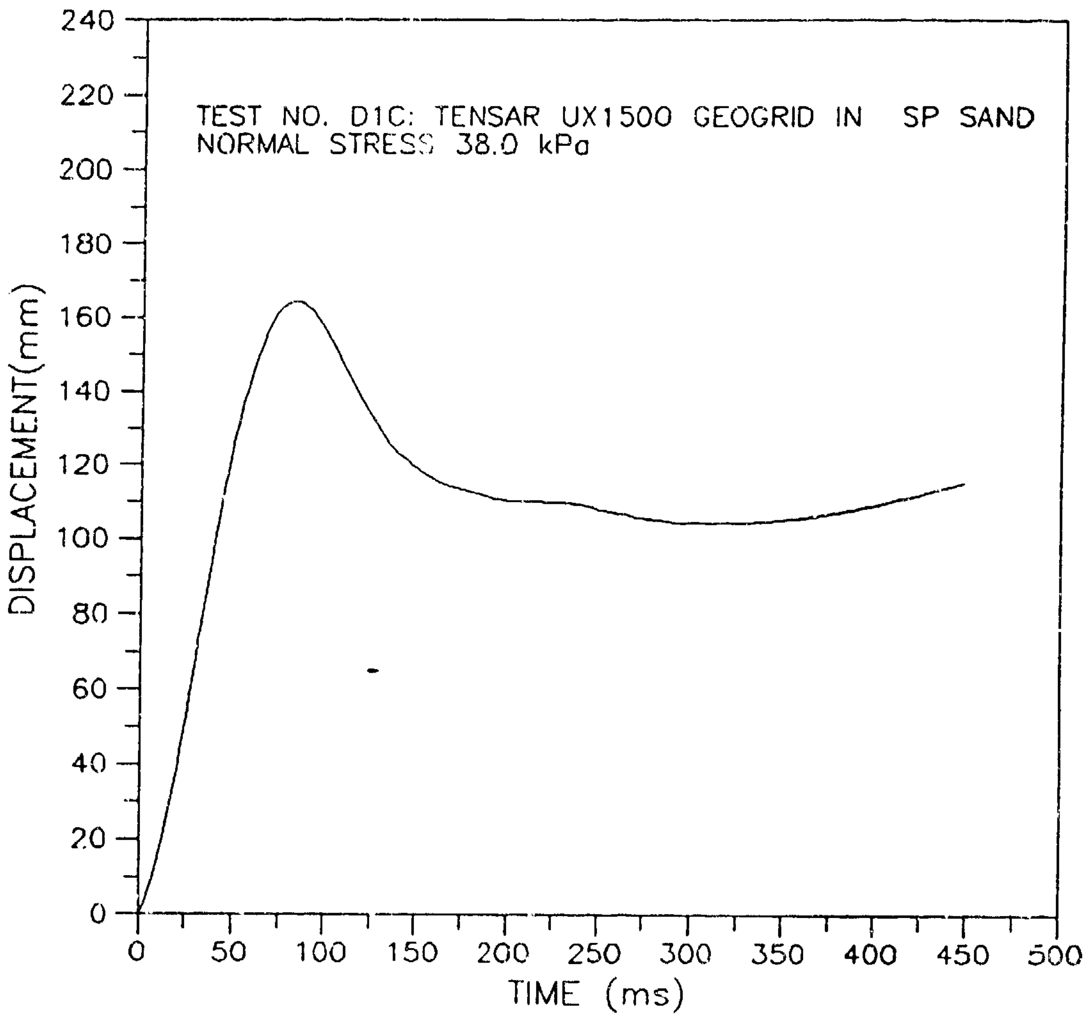

Figure 38. Displacement Time History at Pulling End of Tensar UX1500 Geogrid for Test D1C.

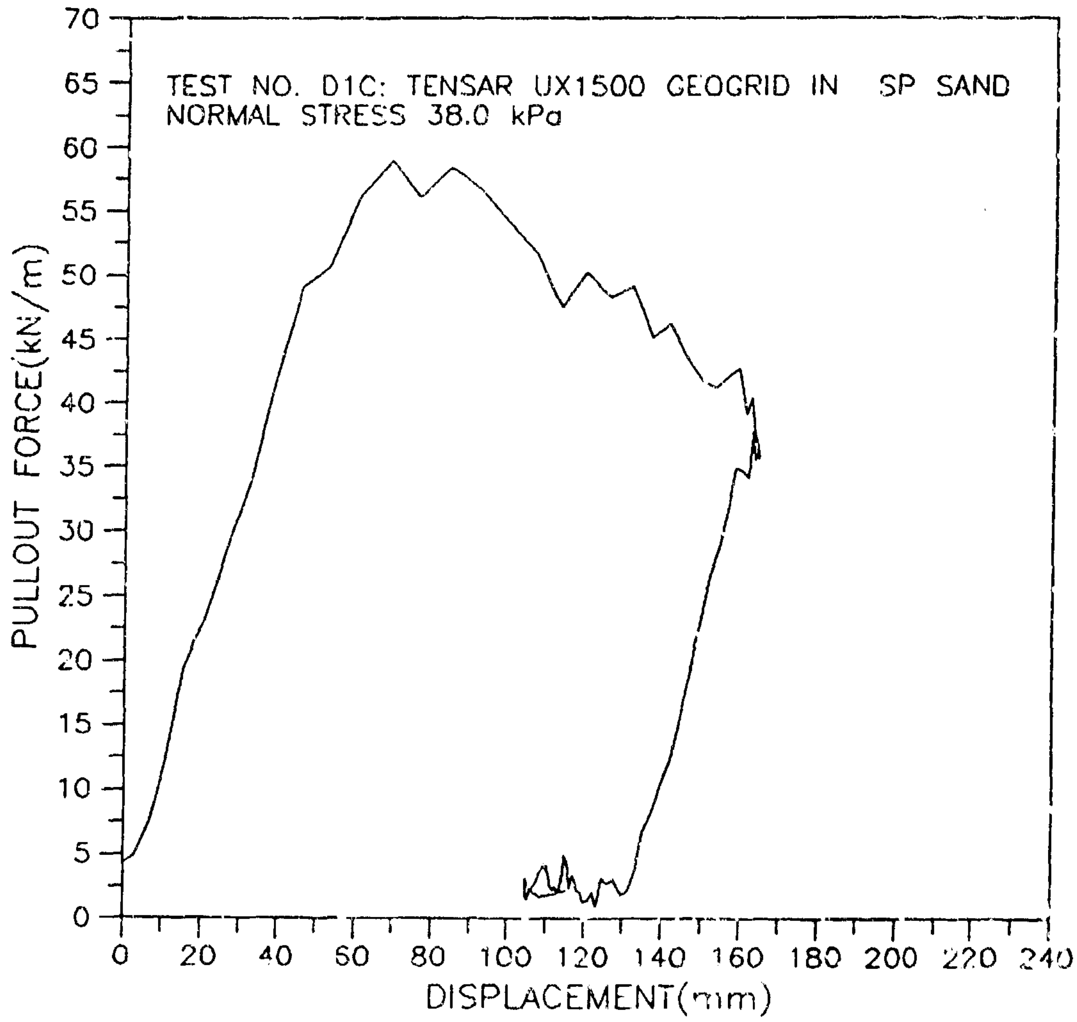

Figure 39. Dynamic Pullout Response of Tensar UX1500 Geogrid for Test D1C.

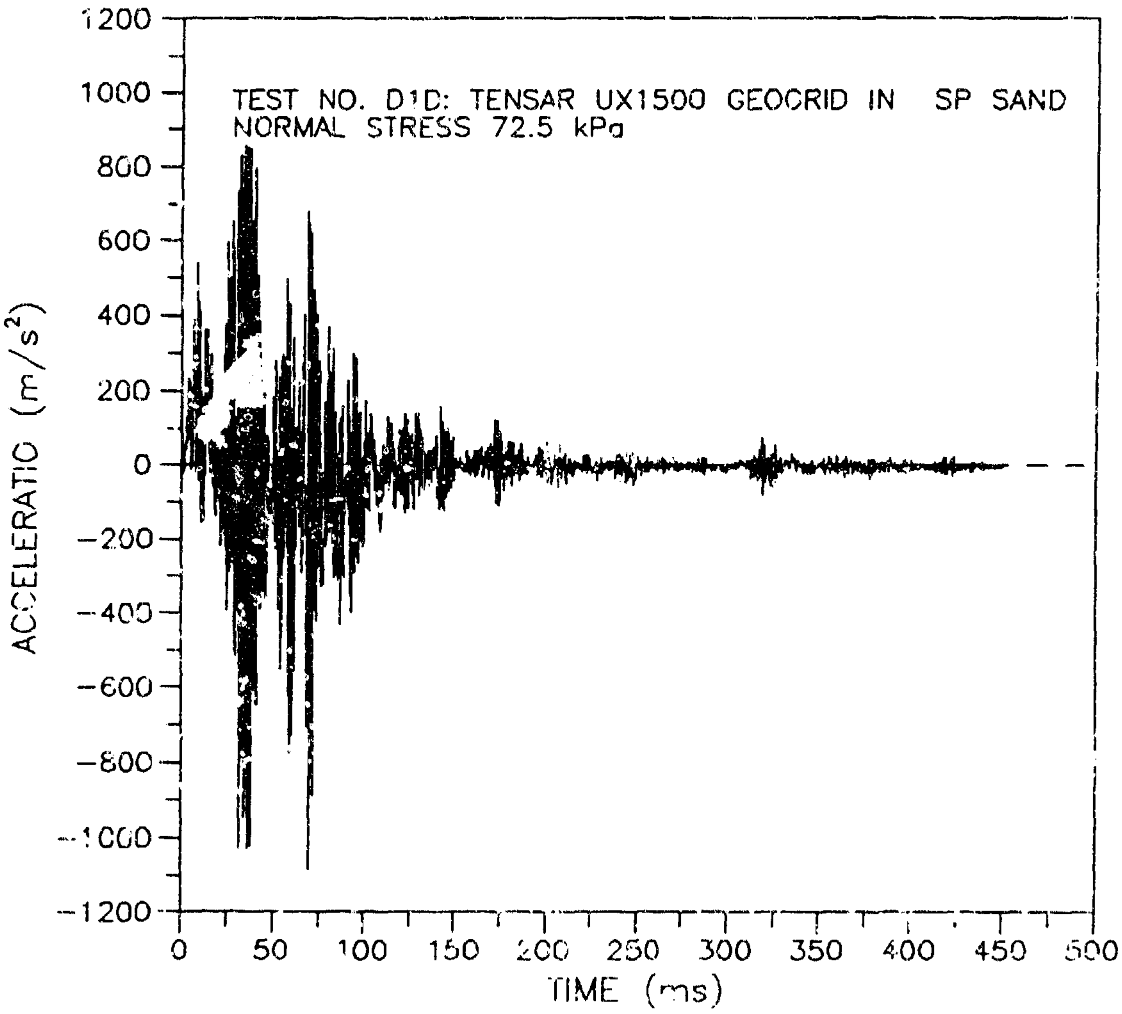

Figure 40. Measured Acceleration at Pulling End of Tensar UX1500 Geogrid for Test D1D.

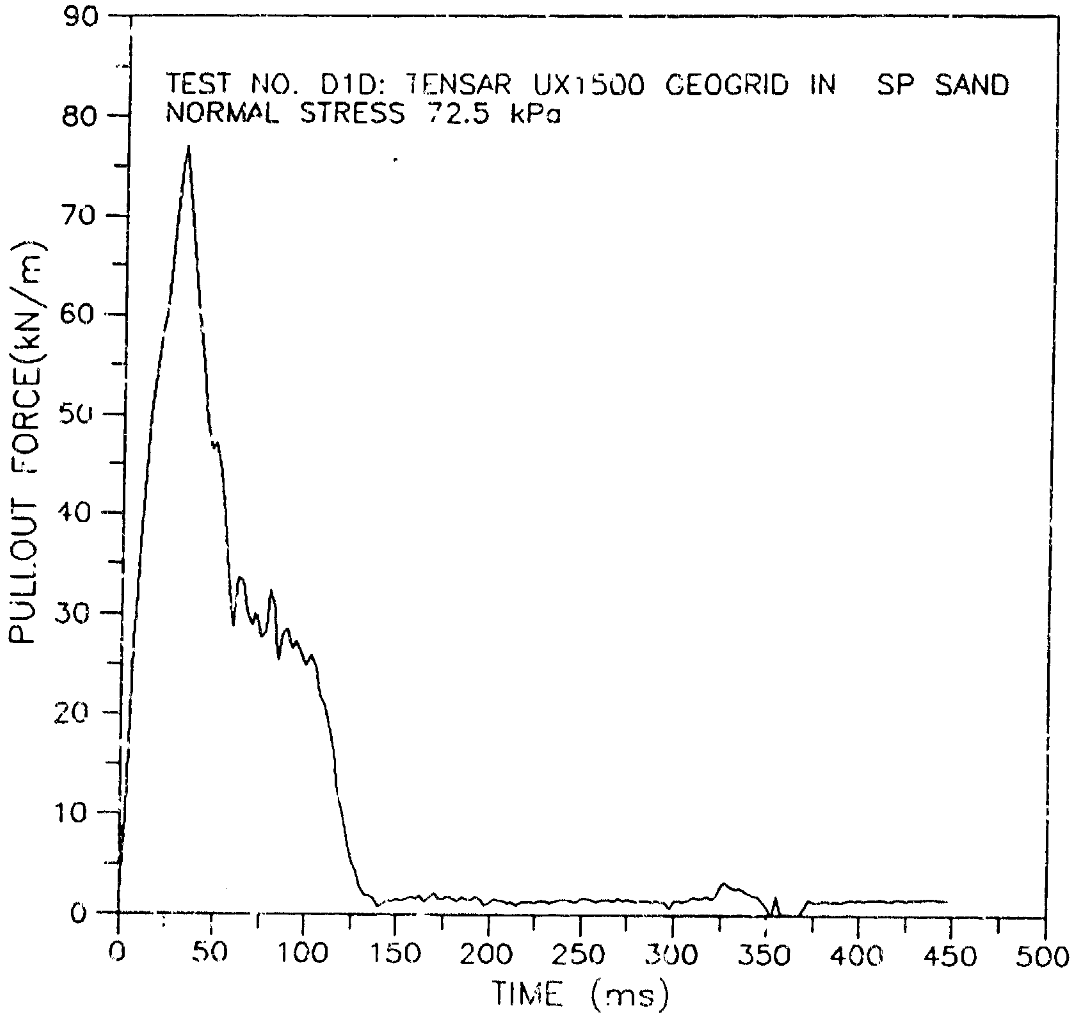

Figure 41. Measured Force at Pulling End of Tensar UX1500 Geogrid for Test D1D.

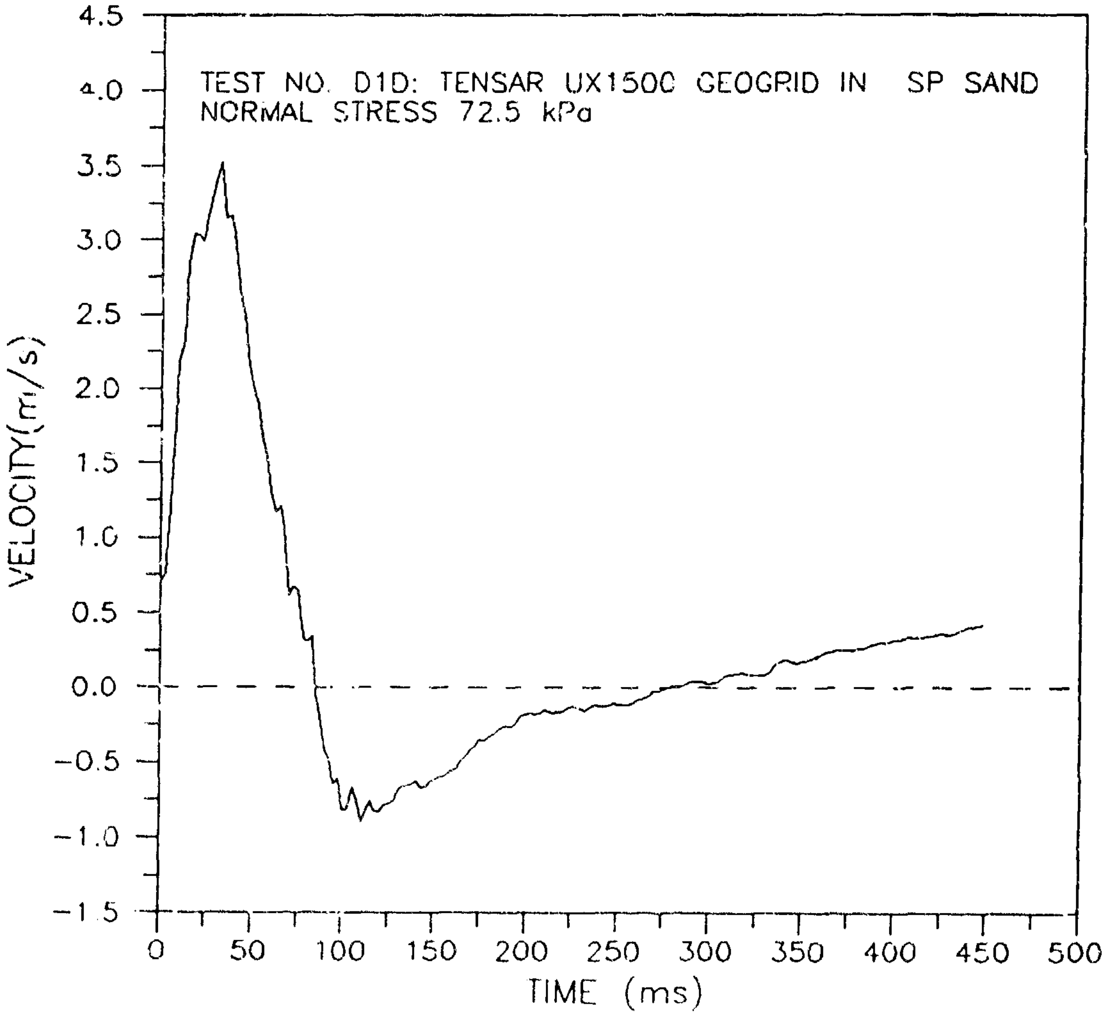

Figure 42. Velocity Time History at Pulling End of Tensar UX1500 Geogrid for Test D1D.

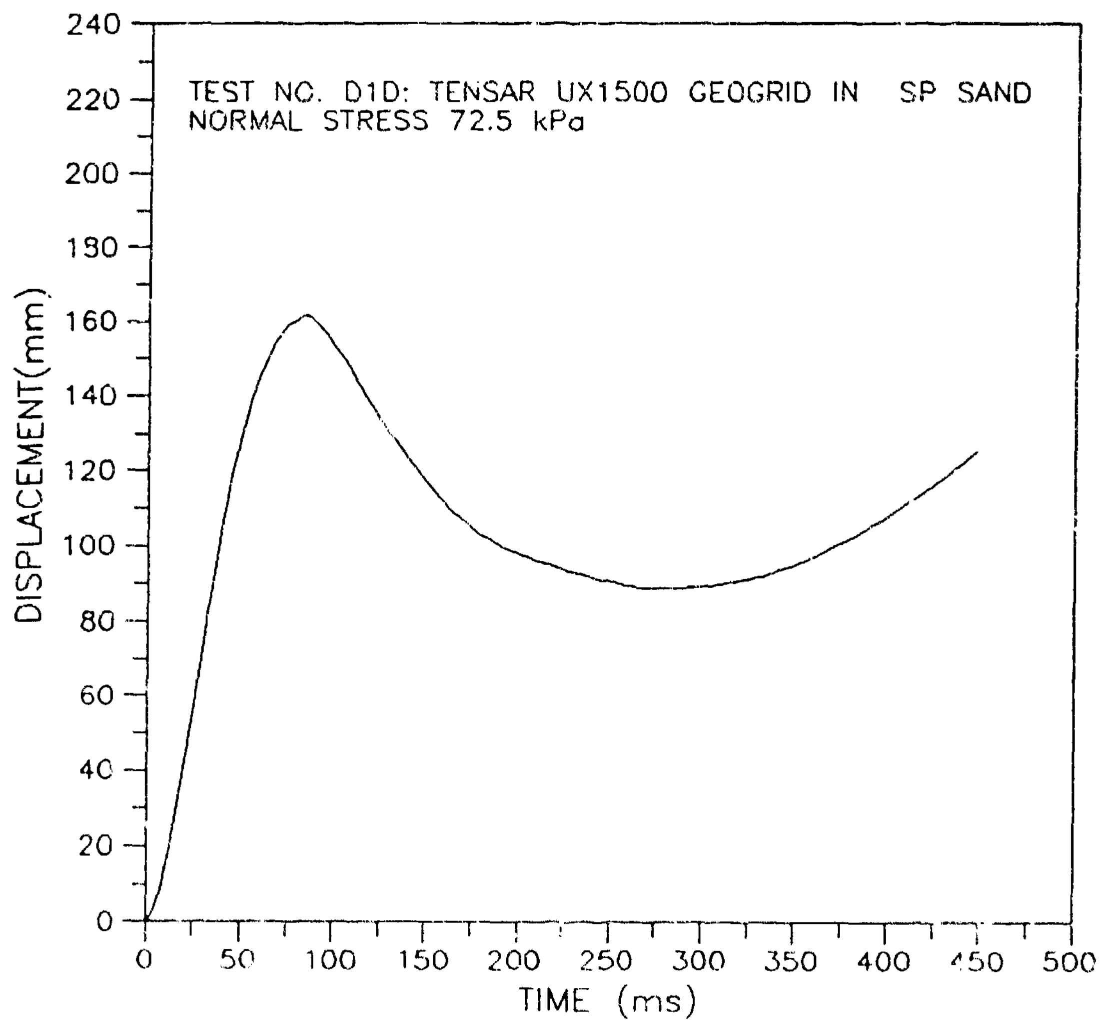

Figure 43. Displacement Time History at Pulling End of Tensar UX1500 Geogrid for Test DID.

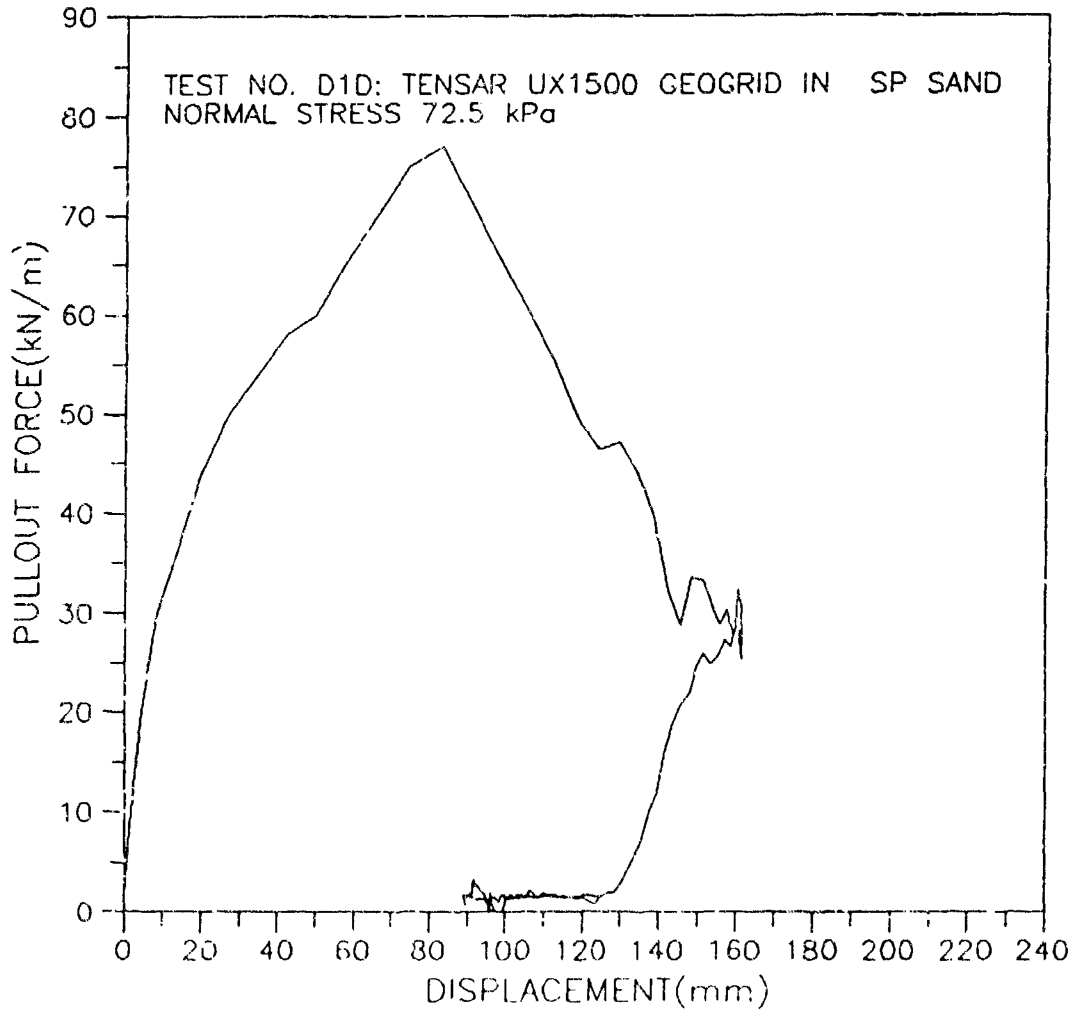

Figure 44. Dynamic Pullout Response of Tensar UX1500 Geogrid for Test D1D.

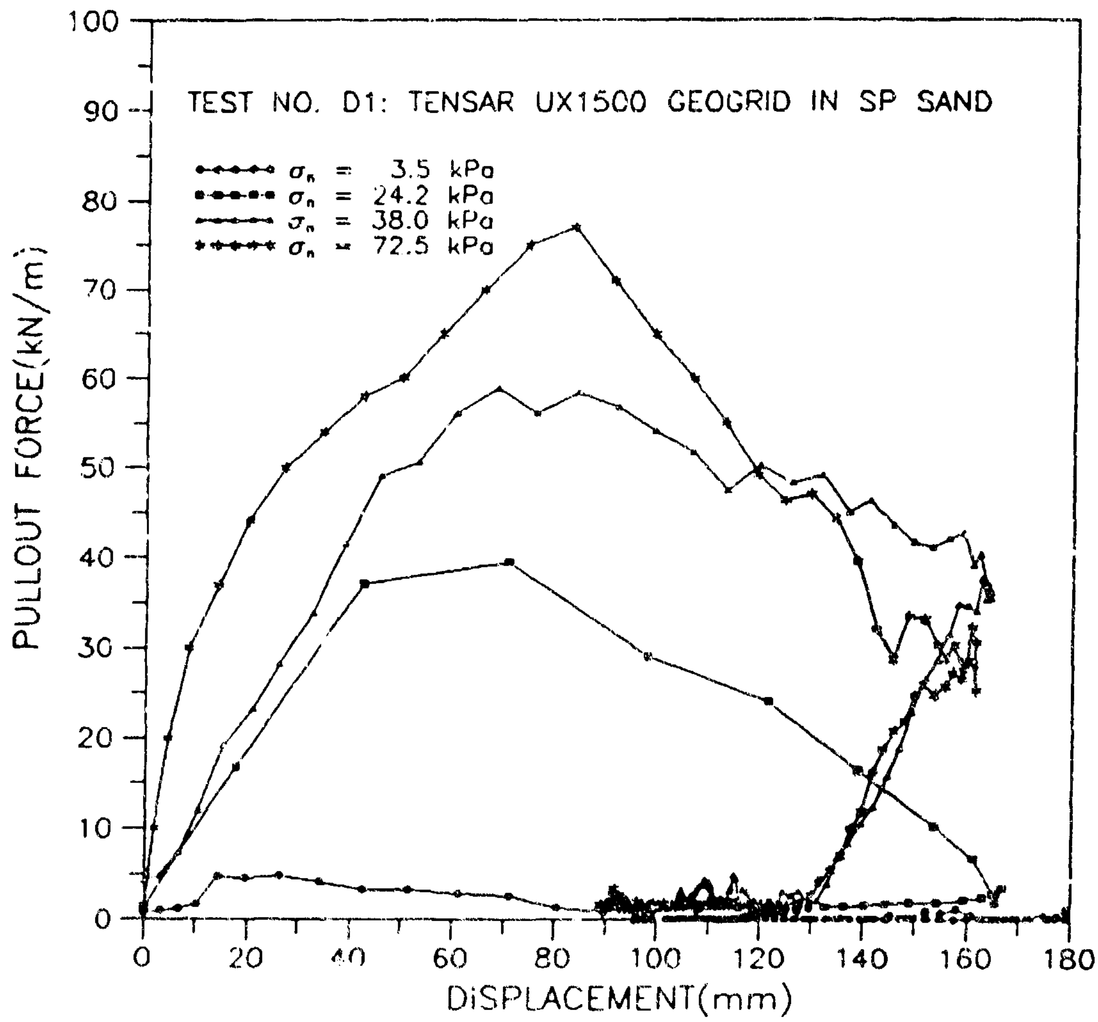

Figure 45. Dynamic Pullout Responses of Tensar UX1500 Geogrid for Test D1A, D1B, D1C, and D1D.

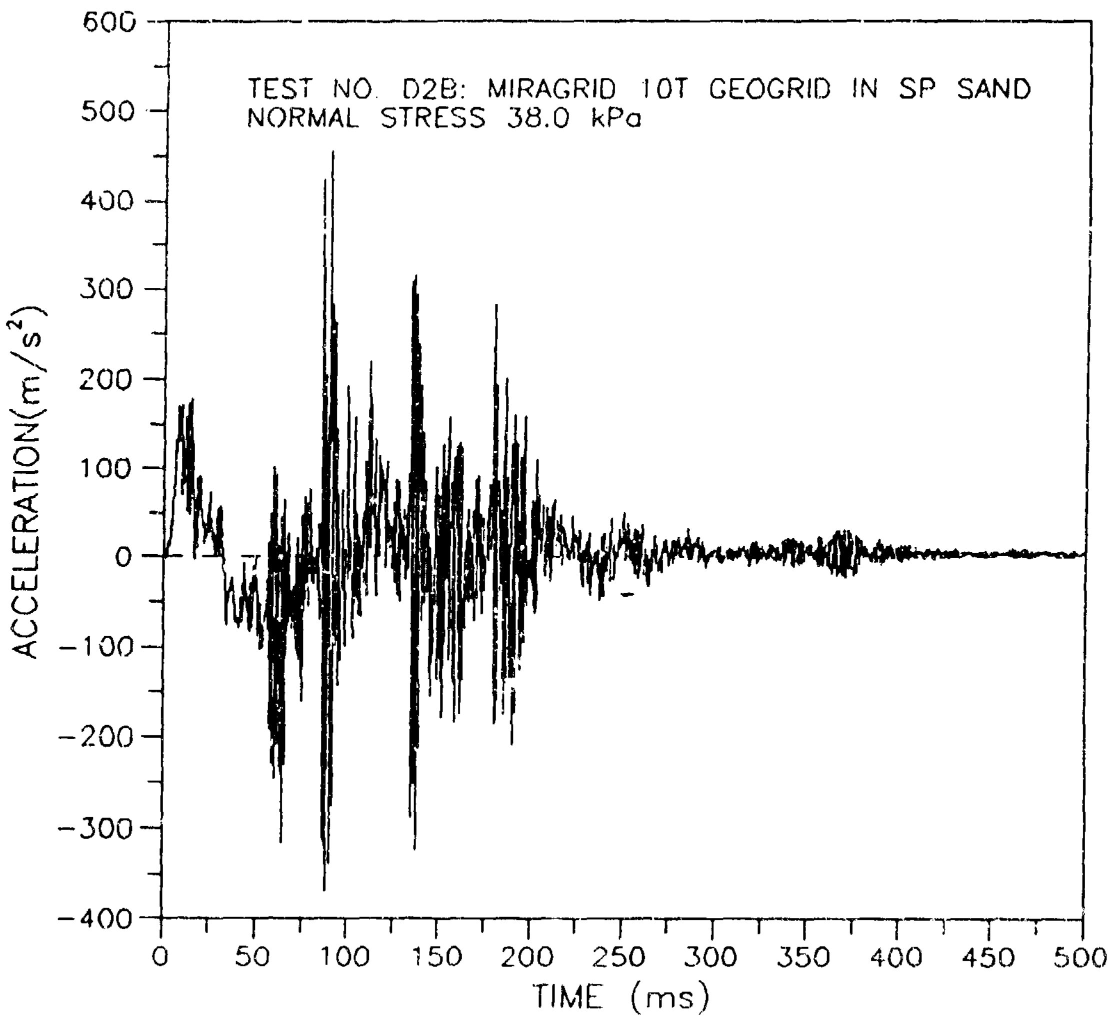

Figure 46. Measured Acceleration at Pulling End of Miragrid 10T Geogrid for Test D2B.

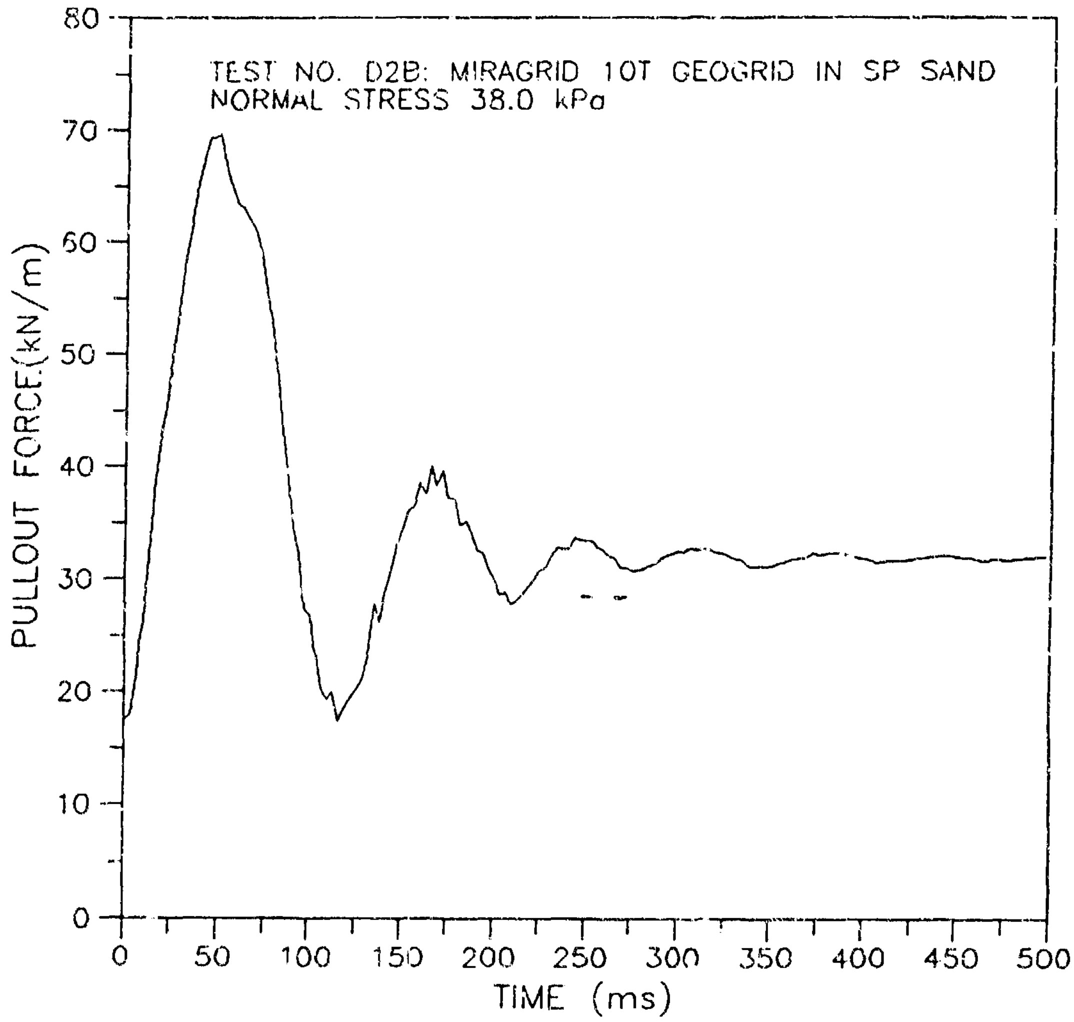

Figure 47. Measured Force at Pulling End of Miragrid 10T Geogrid for Test D2B.

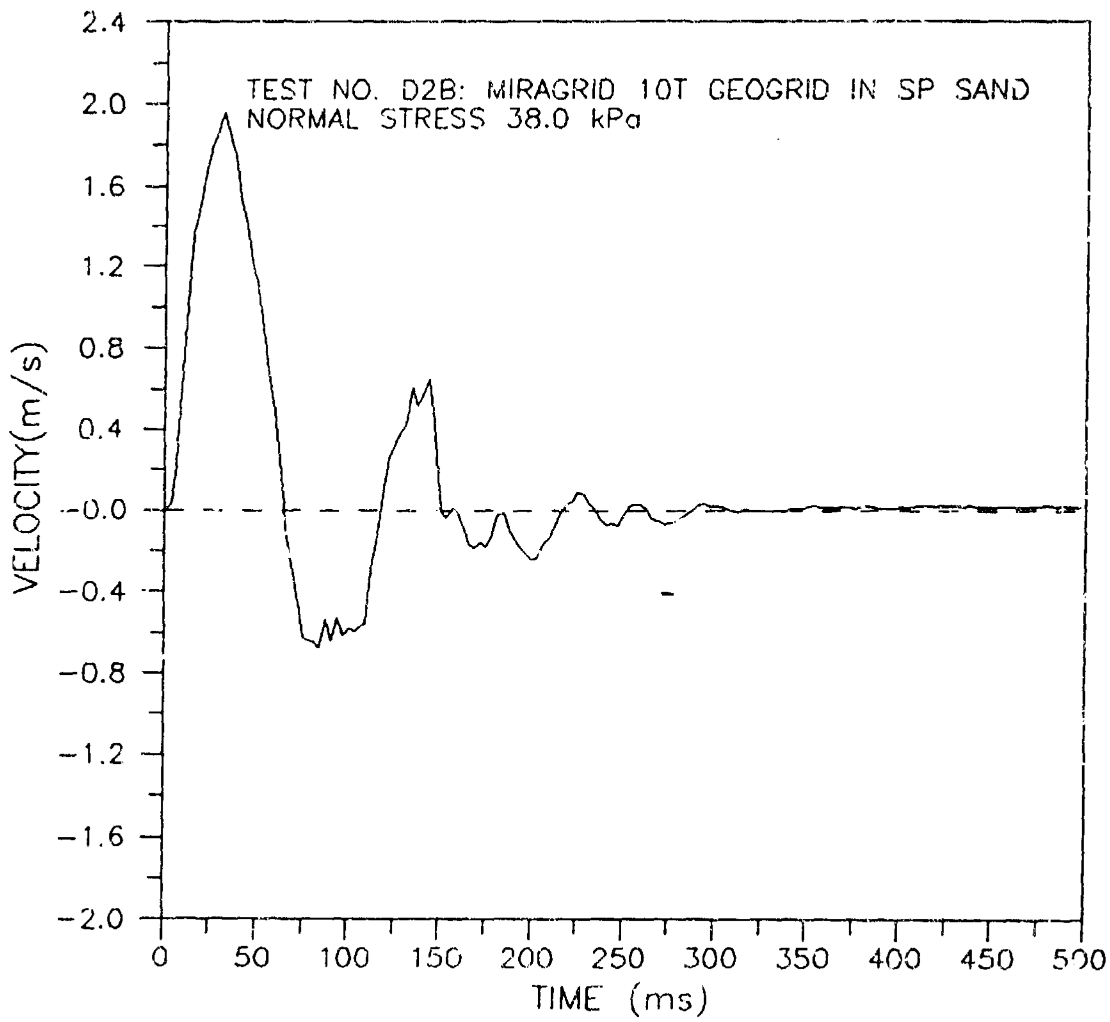

Figure 48. Velocity Time History at Pulling End of Miragrid 10T Geogrid for Test D2B.

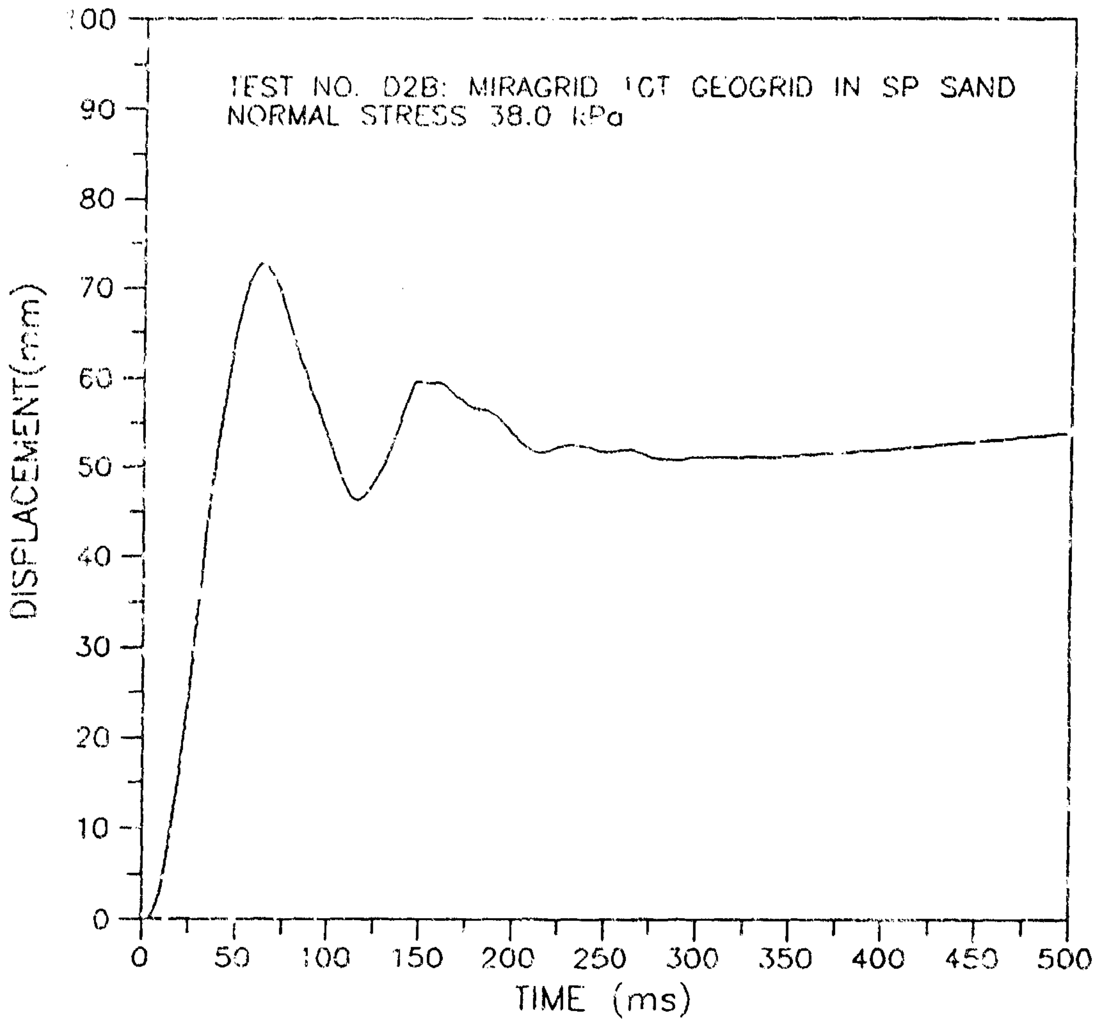

Figure 49. Displacement Time History at Pulling End of Miragrid 10T Geogrid for Test D2B.

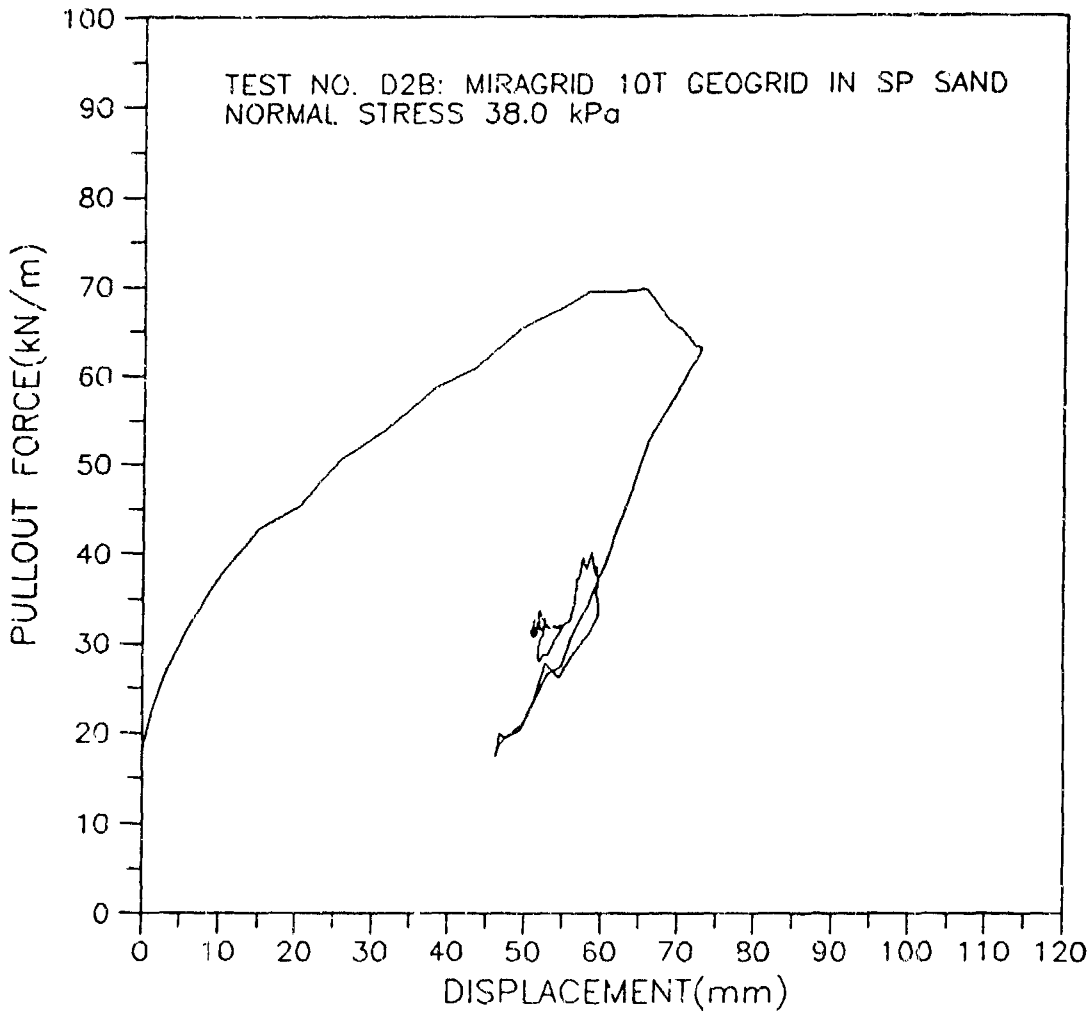

Figure 50. Dynamic Pullout Response of Miragrid 10T Geogrid for Test D2B.

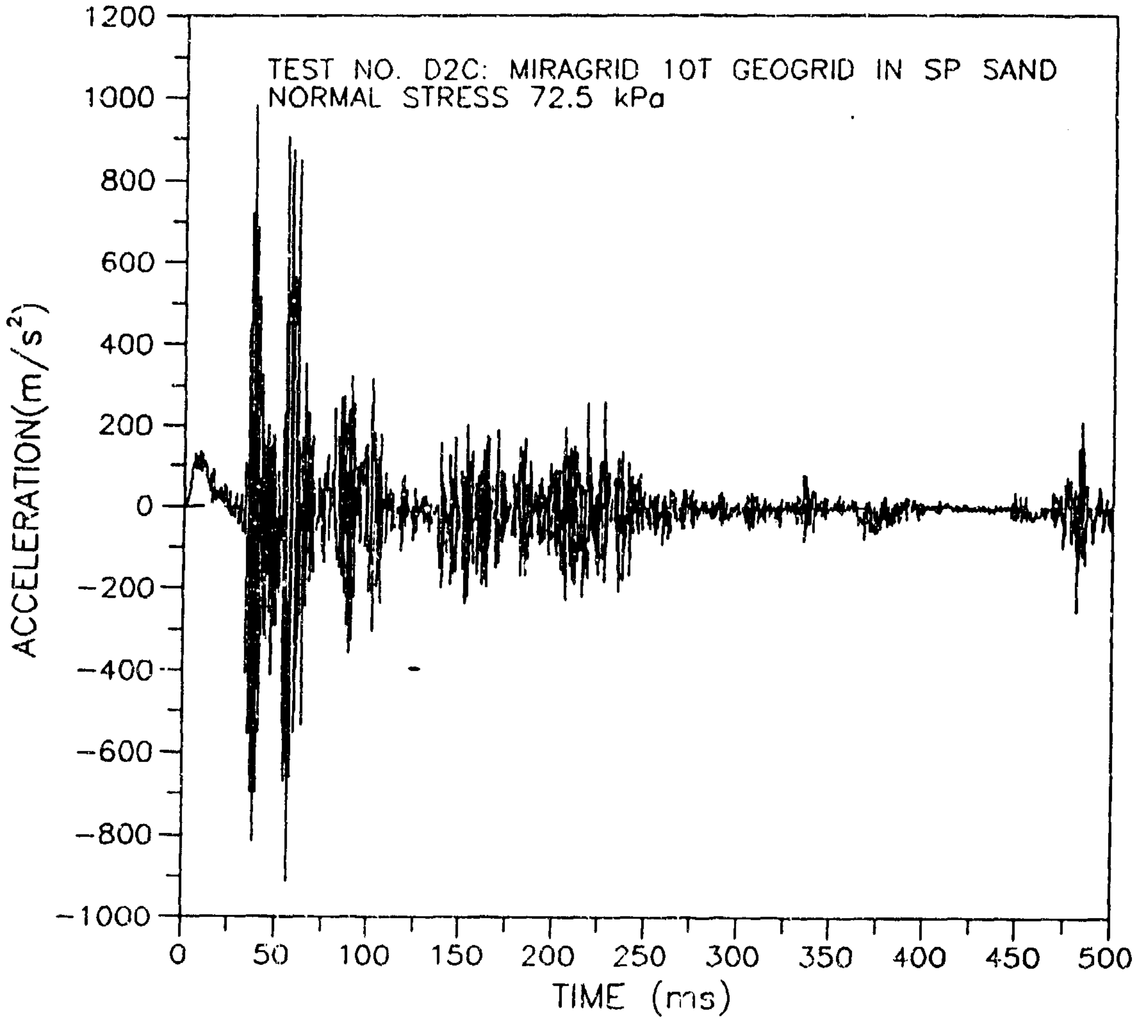

Figure 51. Measured Acceleration at Pulling End of Miragrid 10T Geogrid for Test D2C.

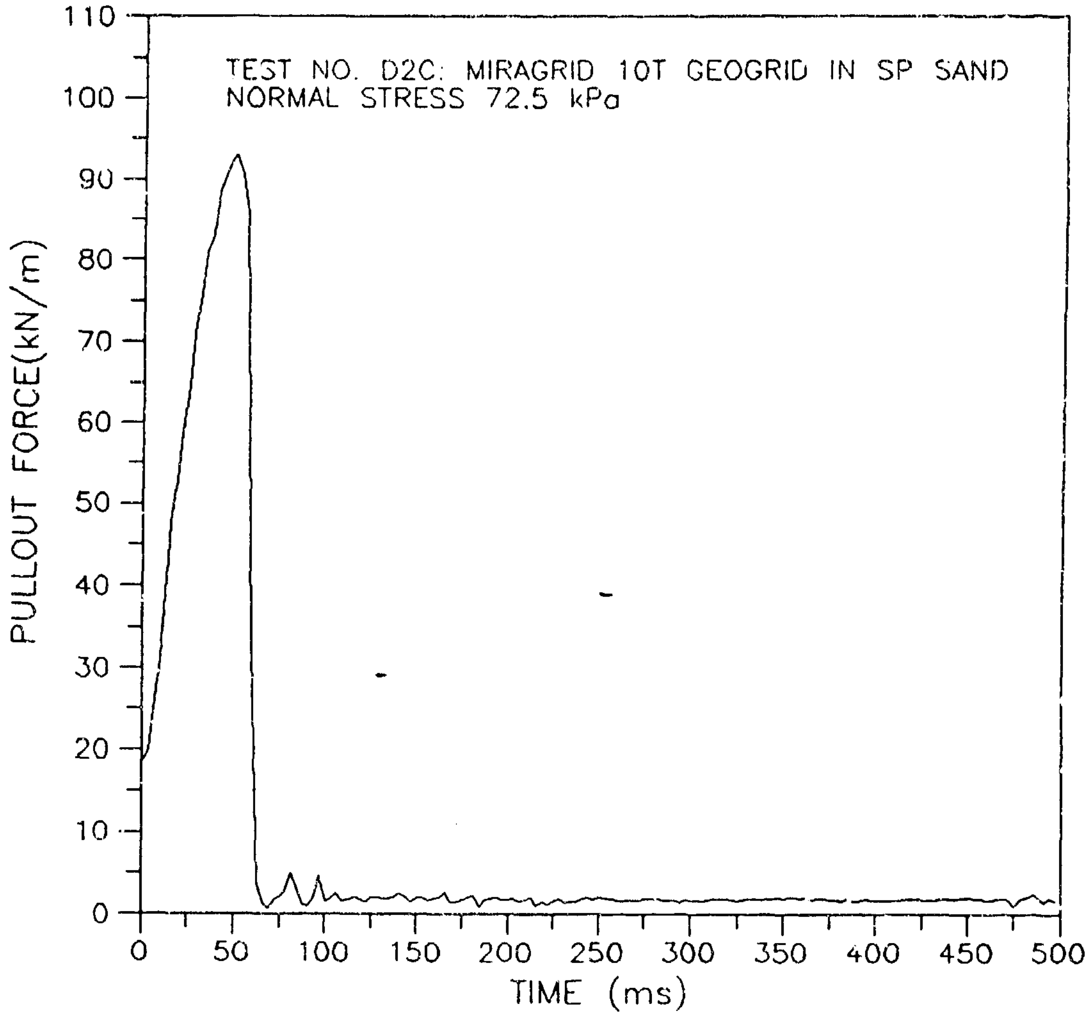

Figure 52. Measured Force at Pulling End of Miragrid 10T Geogrid for Test D2C.

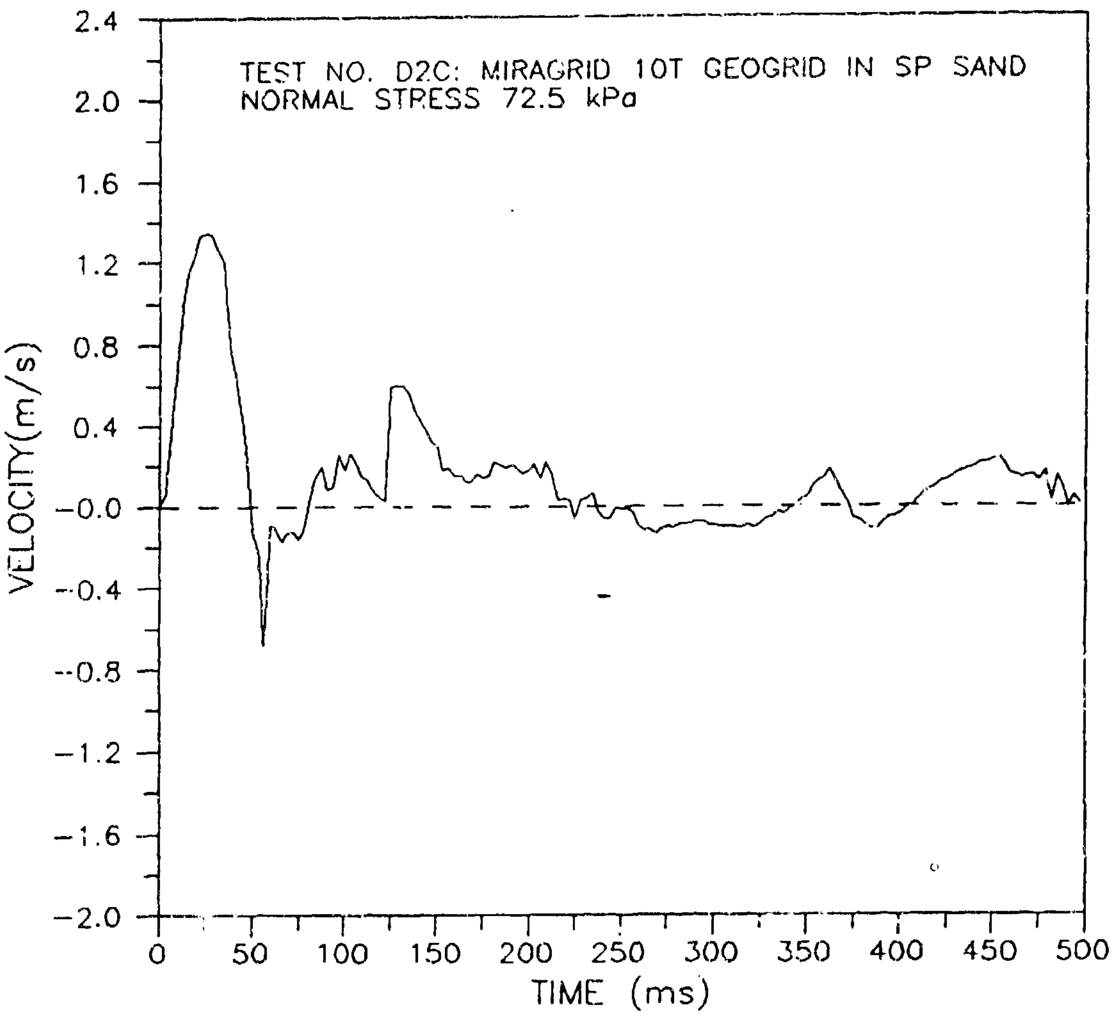

Figure 53. Velocity Time History at Pulling End of Miragrid 10T Geogrid for Test D2C.

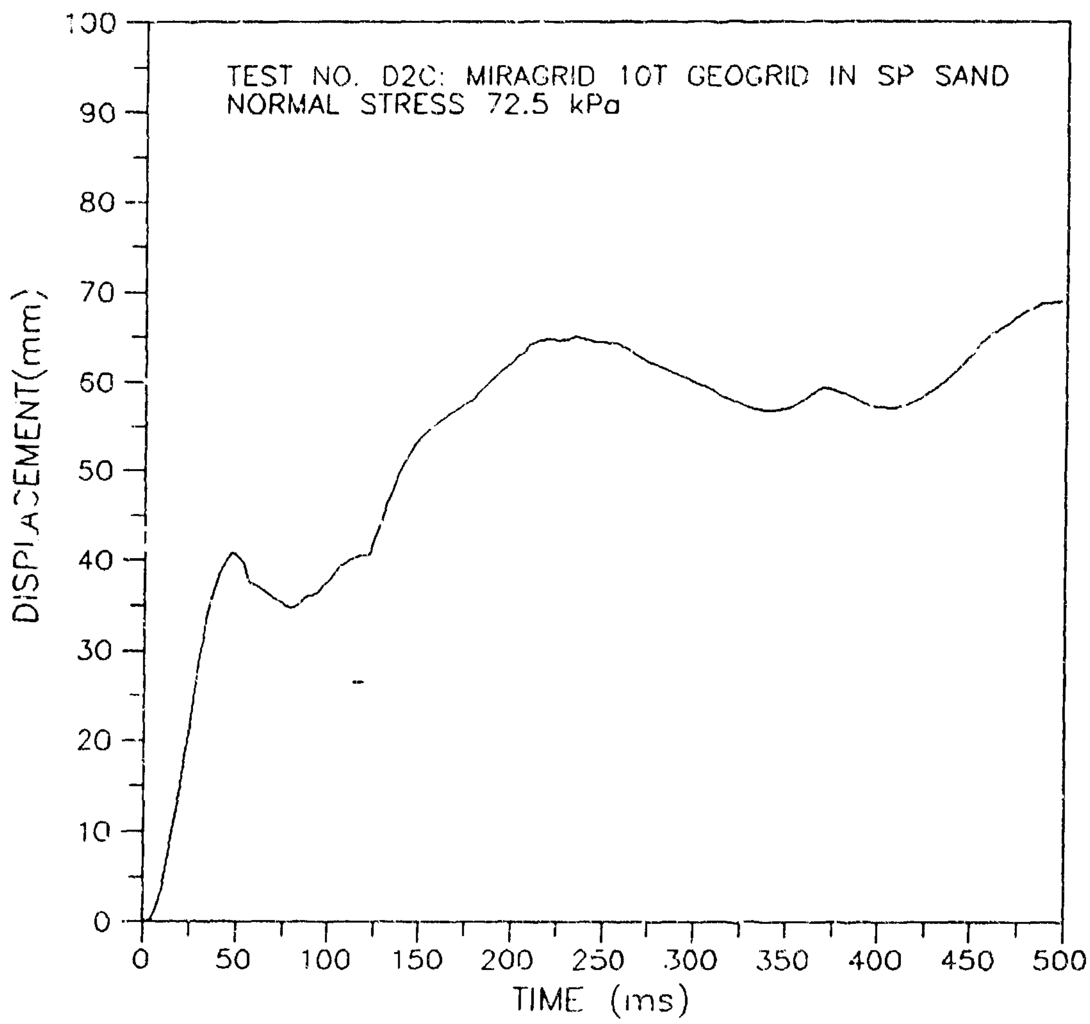

Figure 54. Displacement Time History at Pulling End of Miragrid 10T Geogrid for Test D2C.

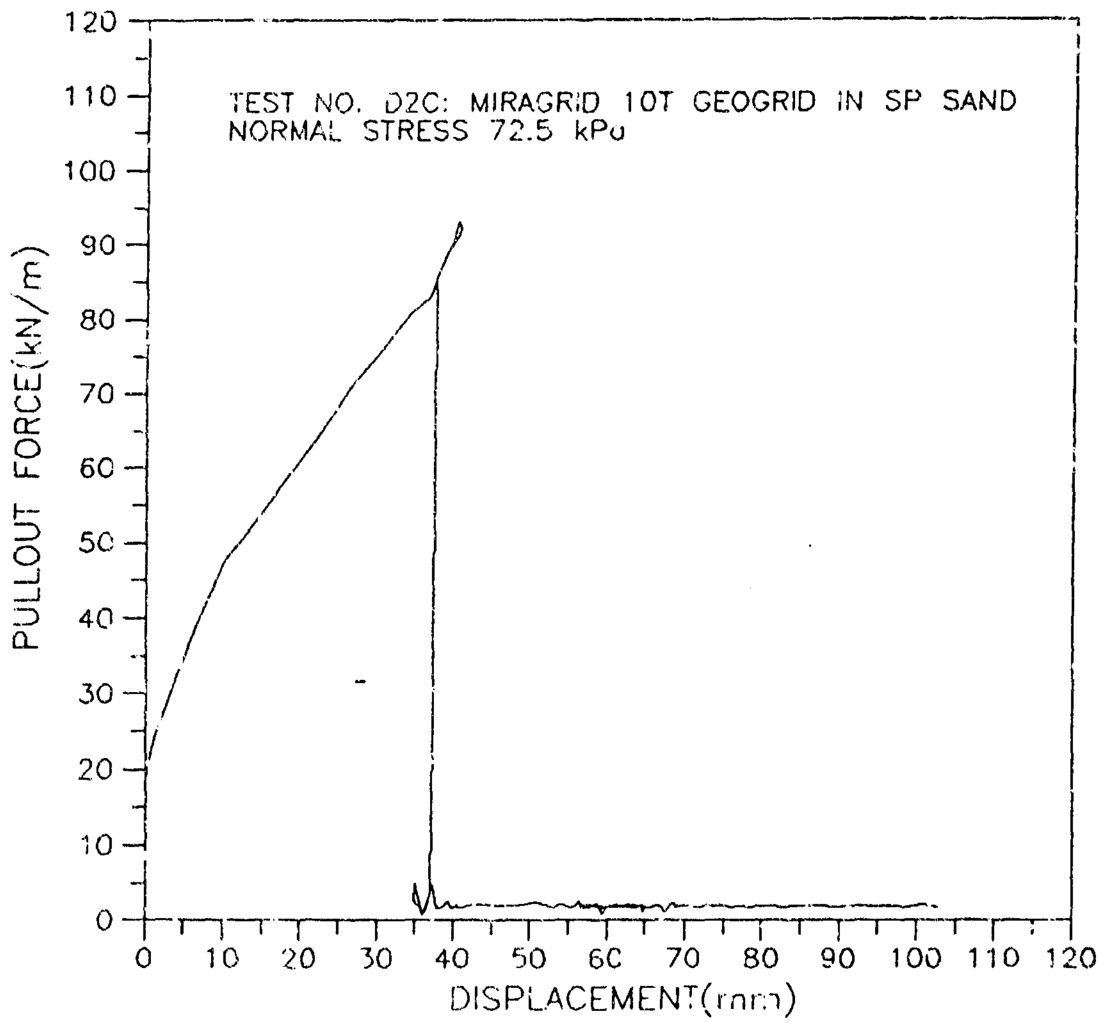

Figure 55. Dynamic Pullout Response of Miragrid 10T Geogrid for Test D2C.

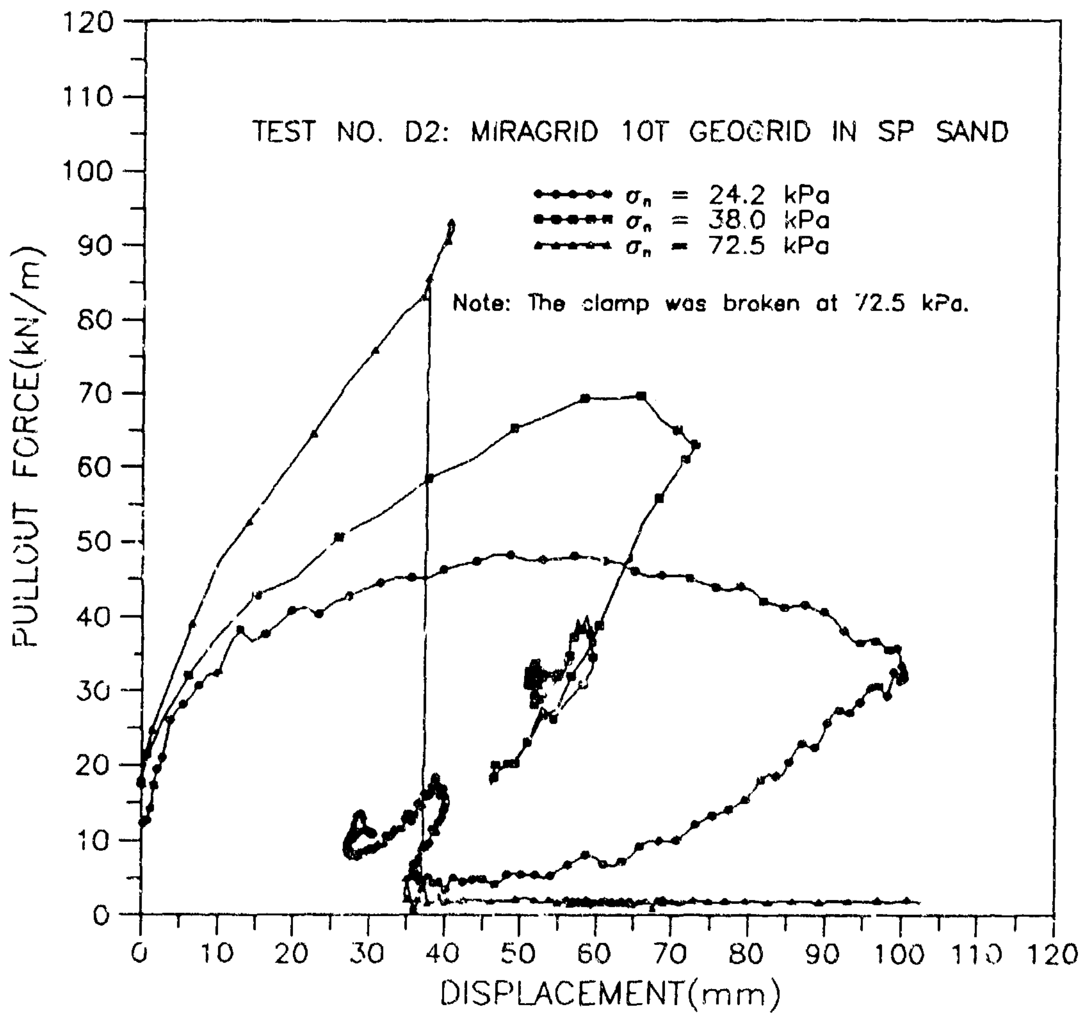

Figure 56. Dynamic Pullout Response of Miragrid 10T Geogrid for Test D2A, D2B, and D2C.

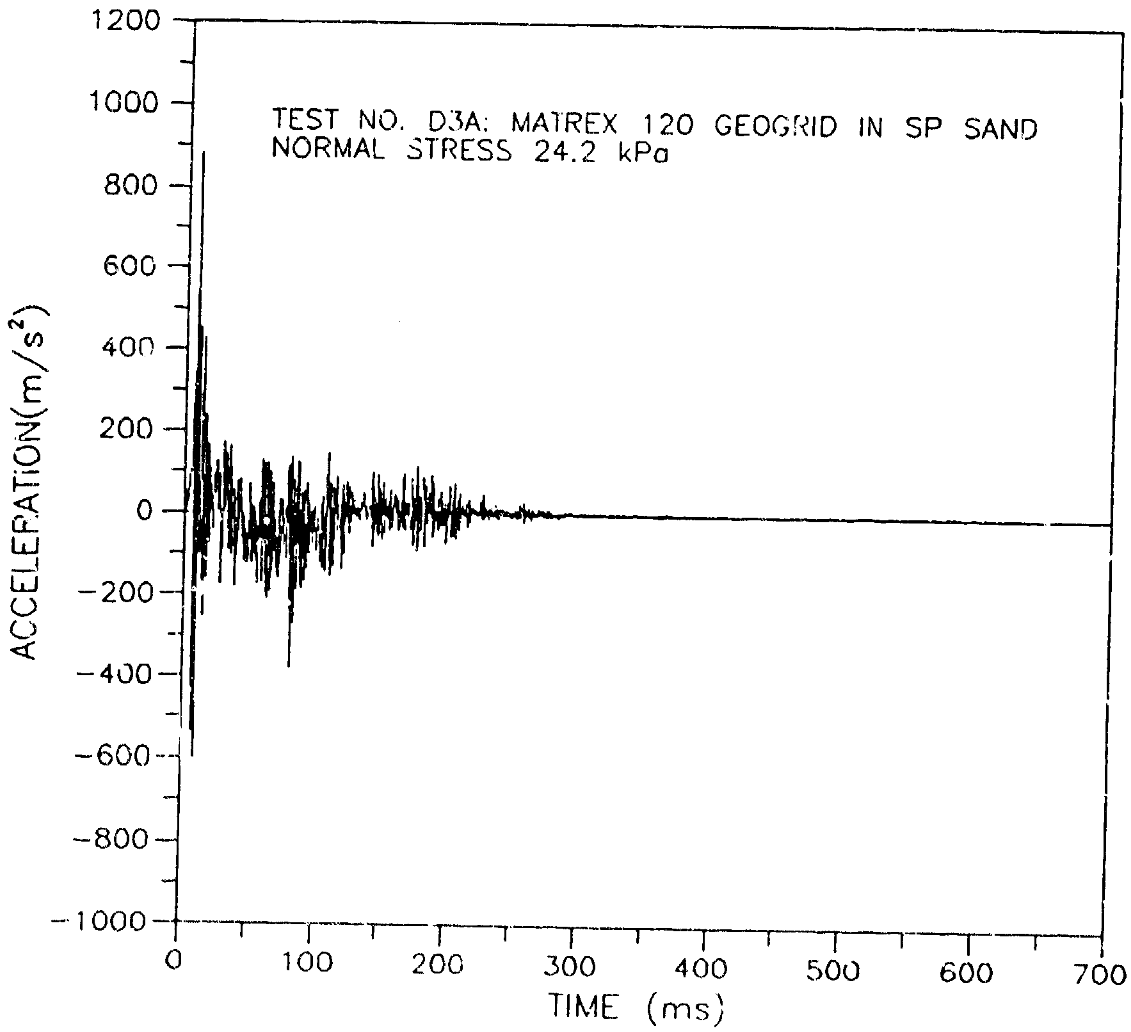

Figure 57. Measured Acceleration at Pulling End of Matrex 120 Geogrid for Test D3A.

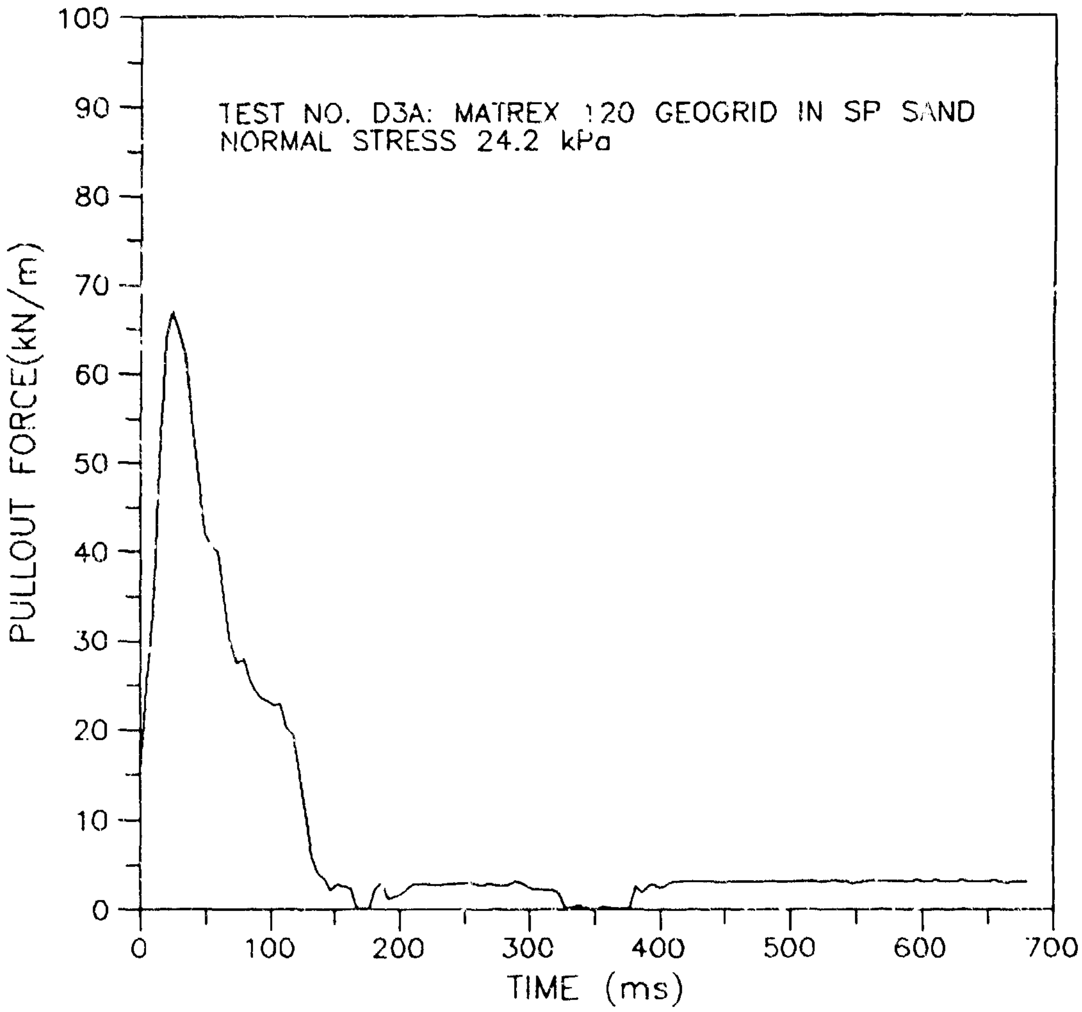

Figure 58. Measured Force at Pulling End of Matrex 120 Geogrid for Test D3A.

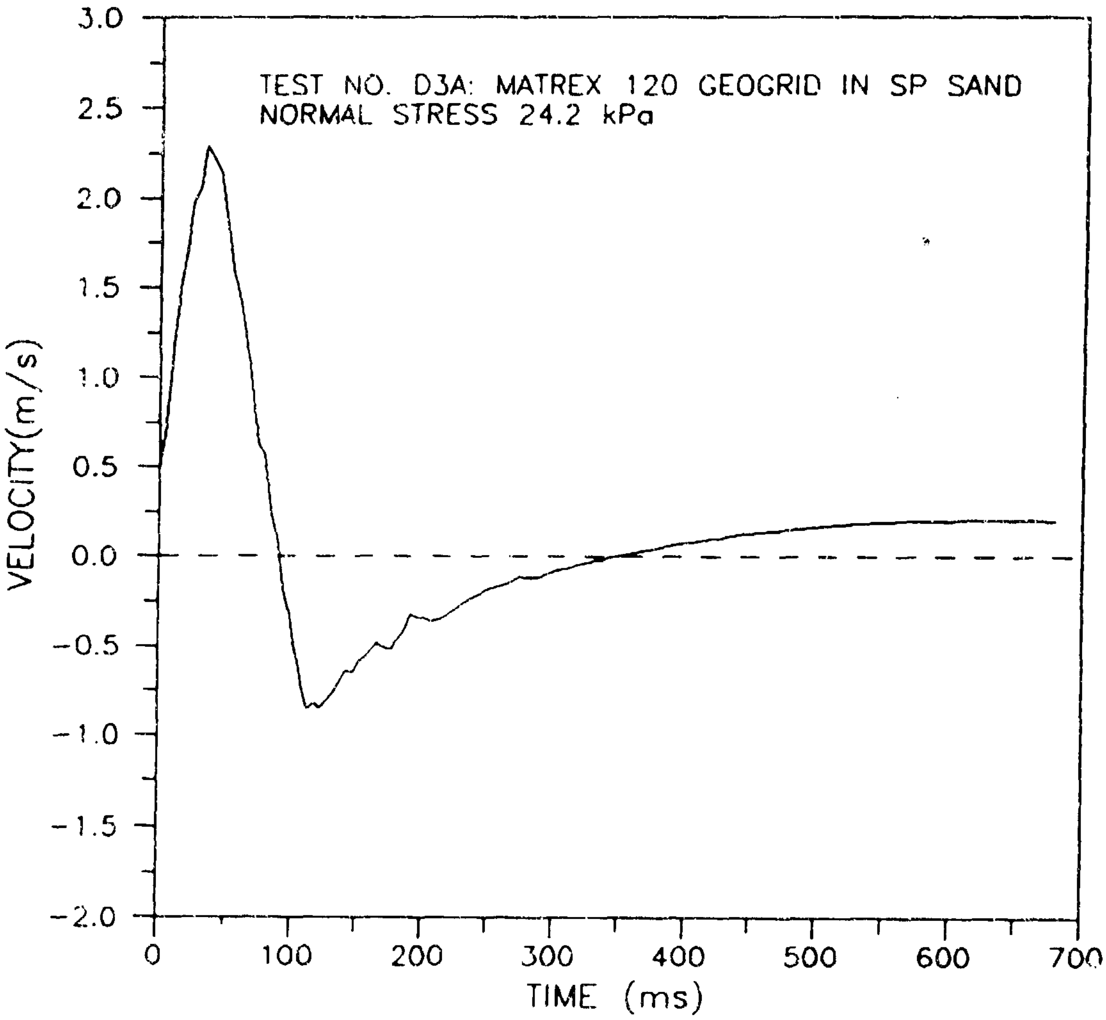

Figure 59. Velocity Time History at Pulling End of Matrex 120 Geogrid for Test D3A.

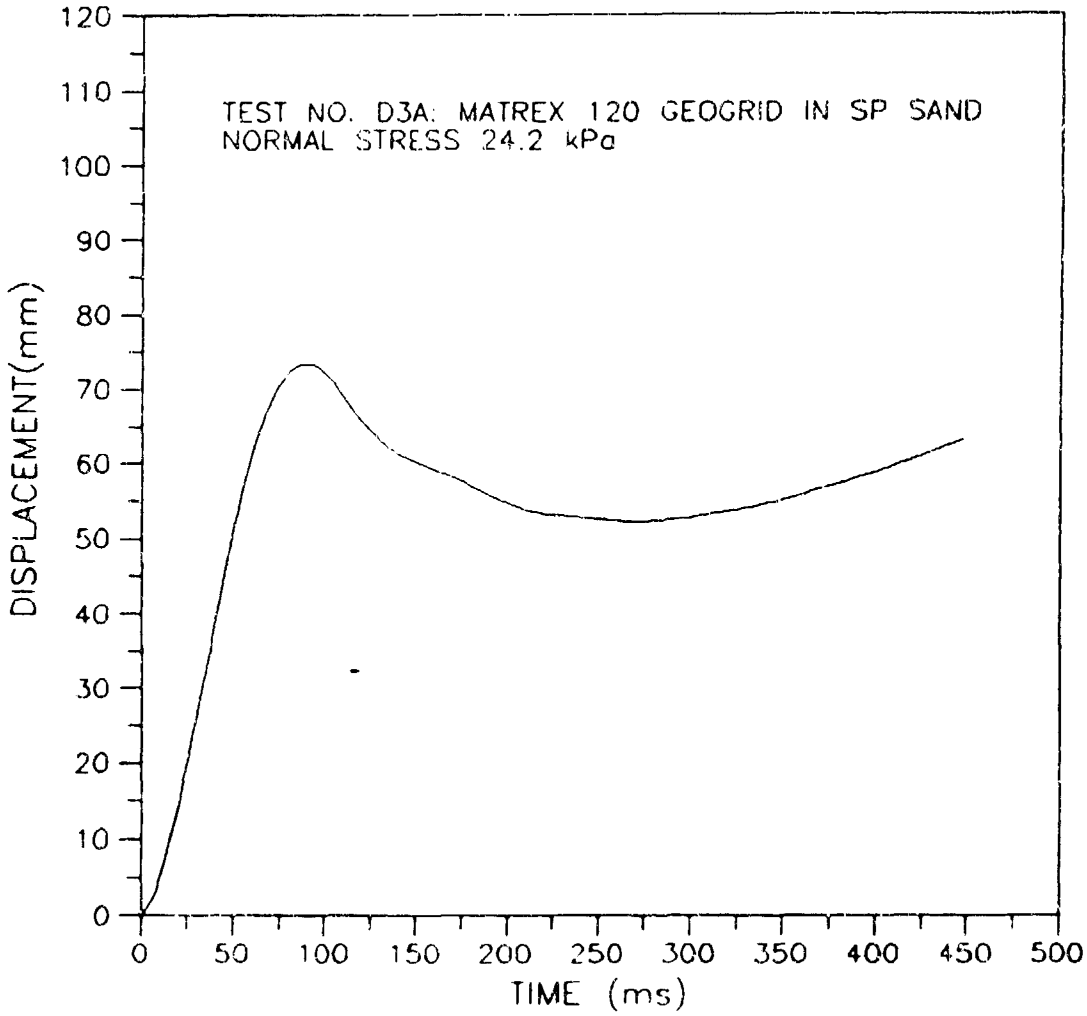

Figure 60. Displacement Time History at Pulling End of Matrex 120 Geogrid for Test D3A.

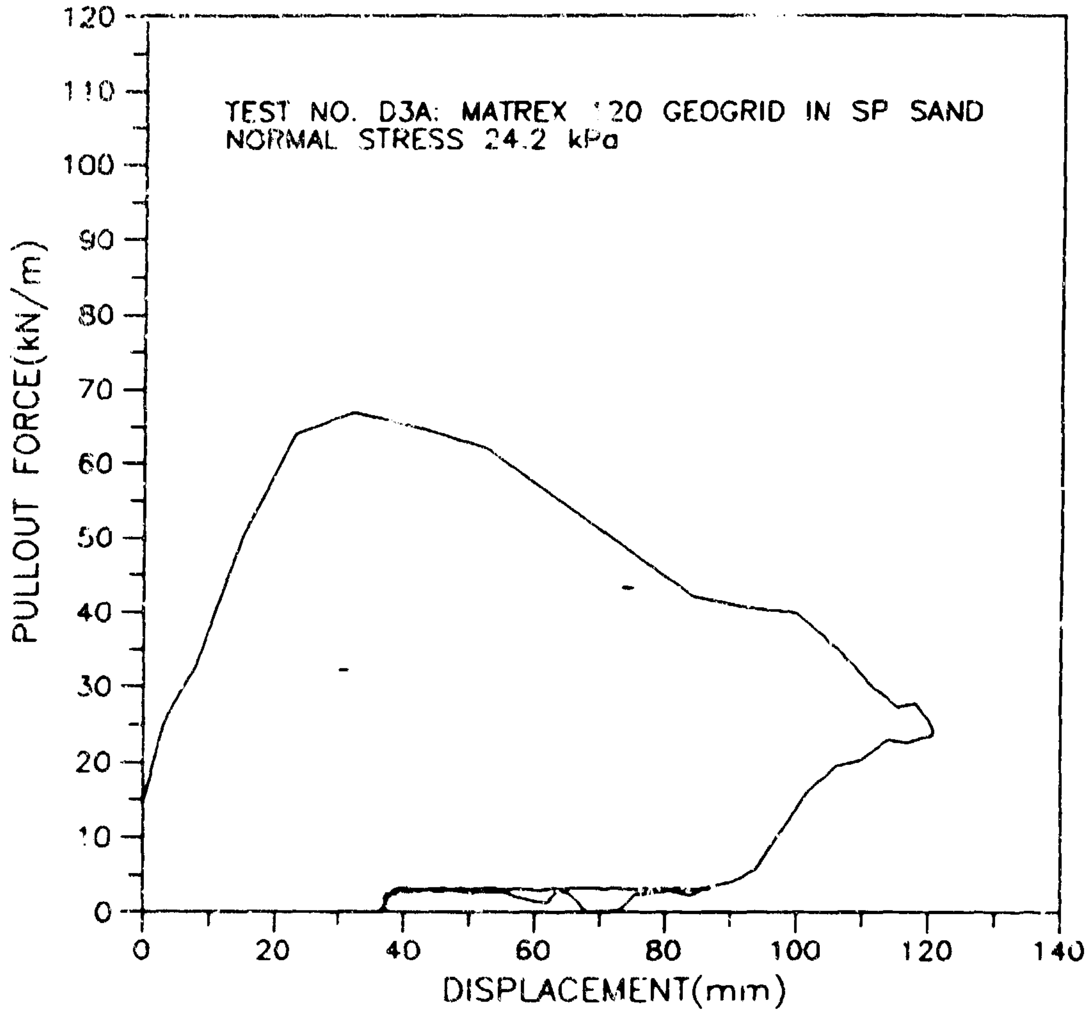

Figure 51. Dynamic Pullout Response of Matrex 120 Geogrid for Test D3A.

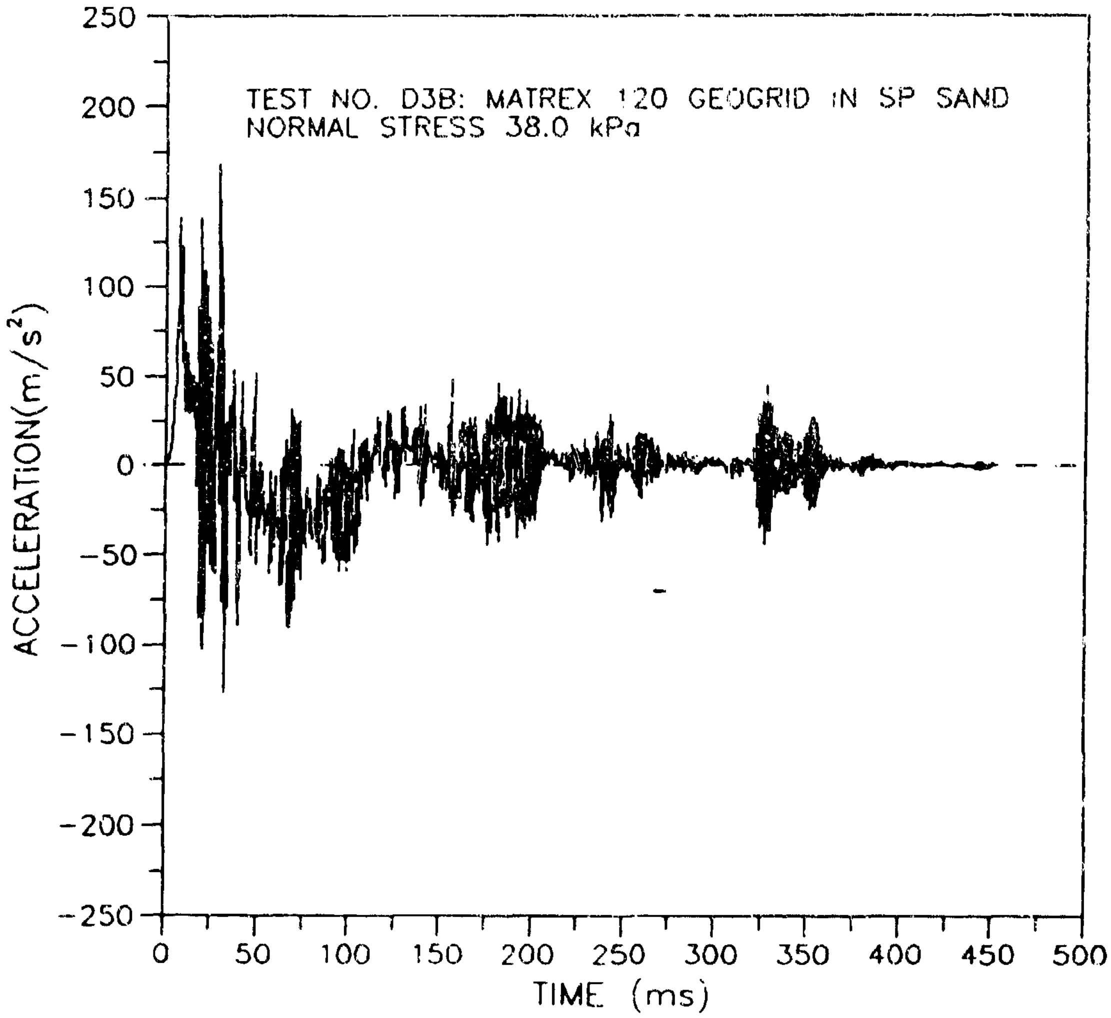

Figure 62. Measured Acceleration at Pulling End of Matrex 120 Geogrid for Test D3B.

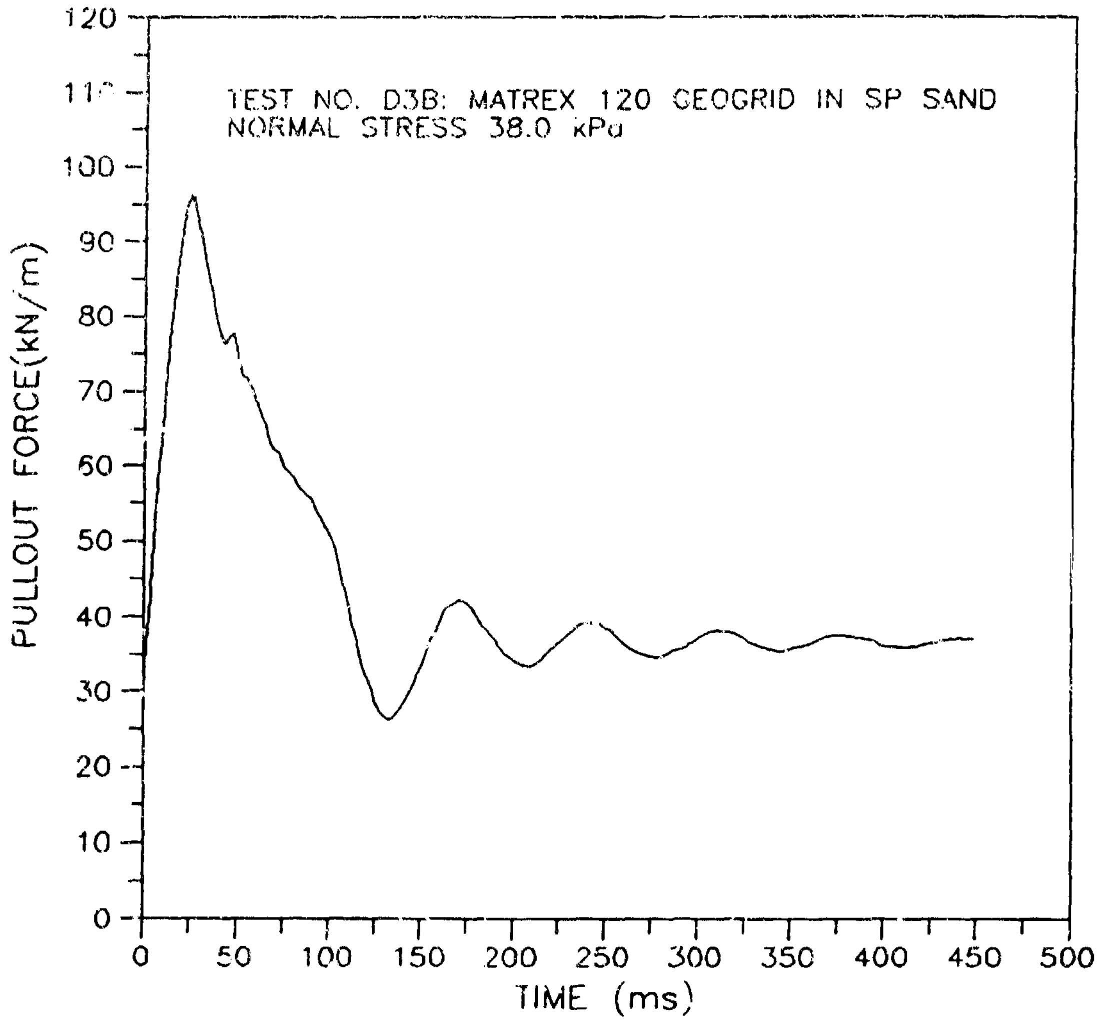

Figure 63. Measured Force at Pulling End of Matrex 120 Geogrid for Test D3B.

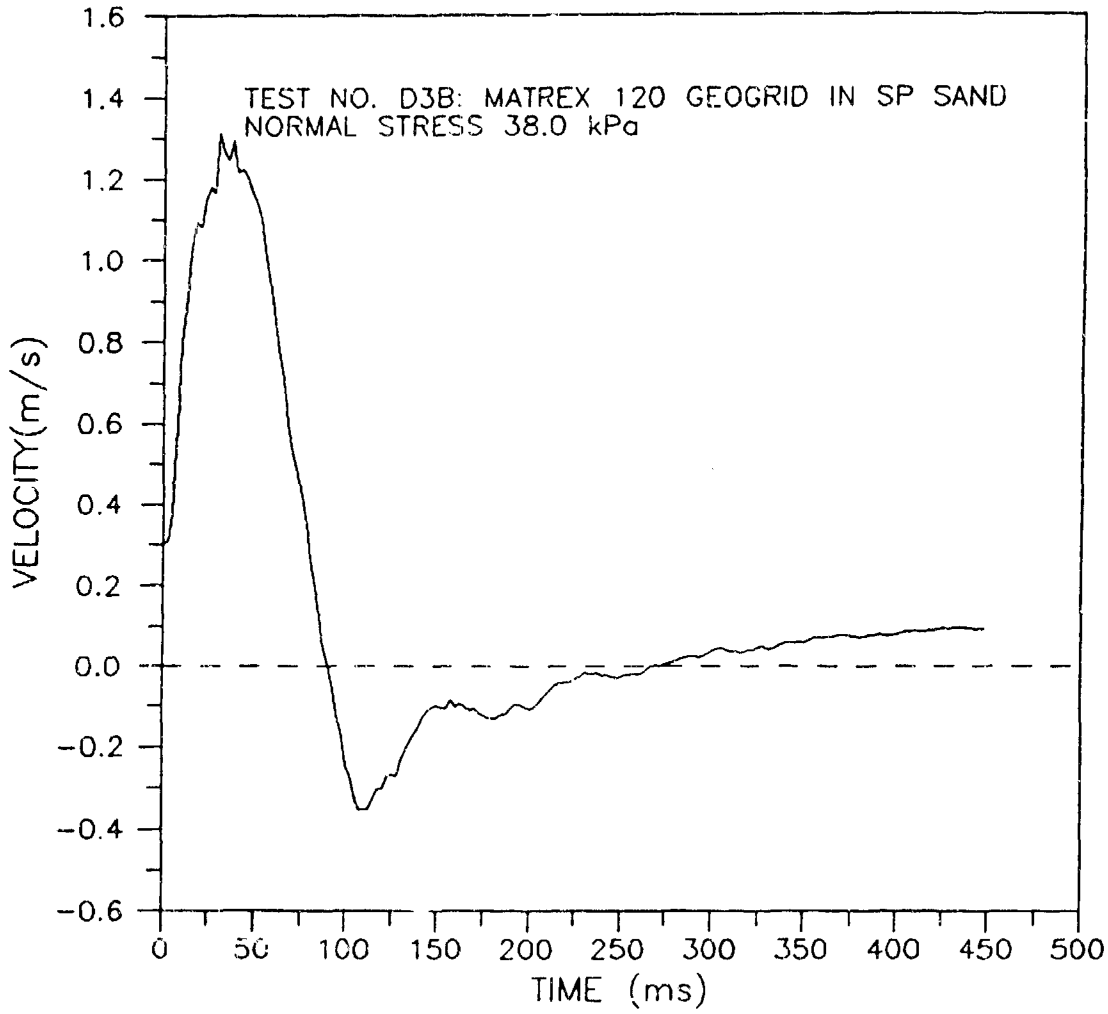

Figure 64. Velocity Time History at Pulling End of Matrex 120 Geogrid for Test D3B.

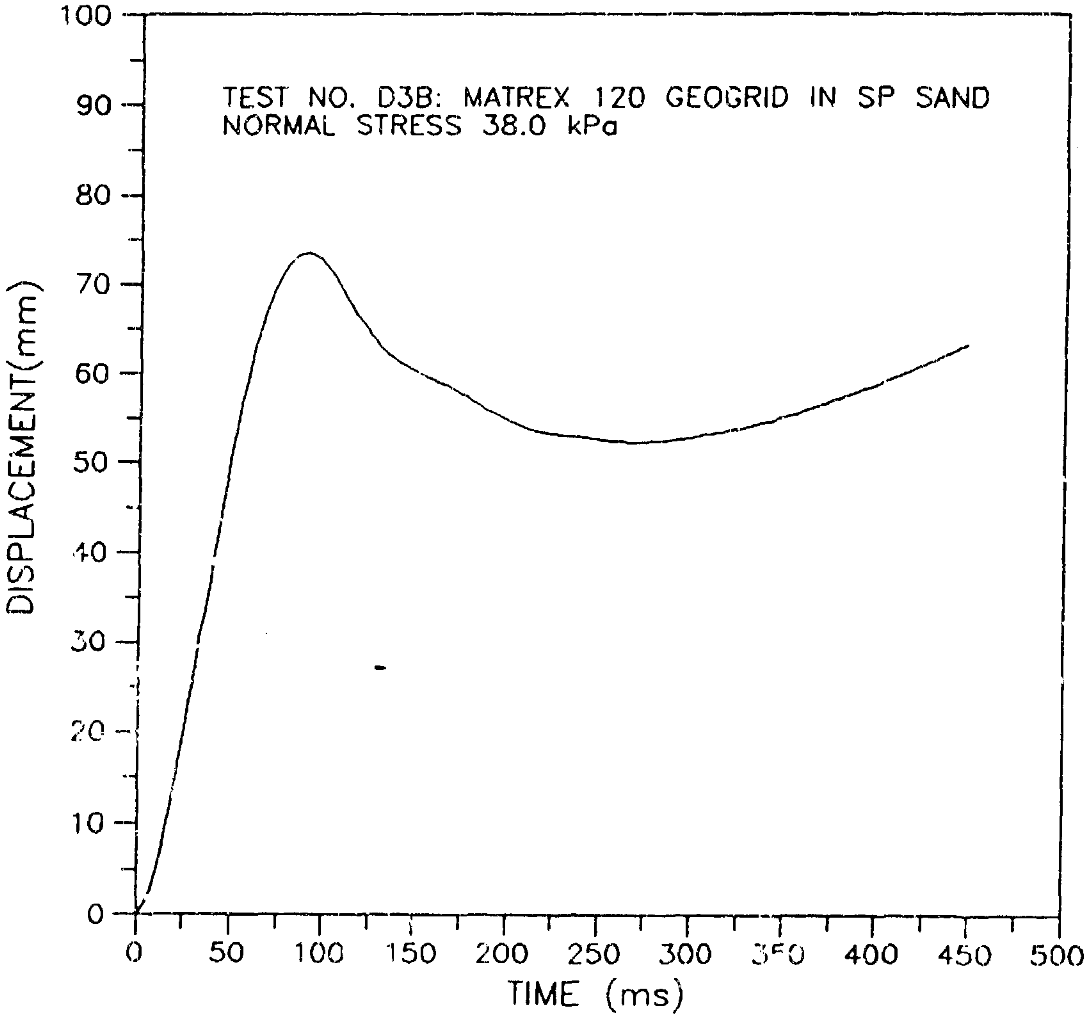

Figure 65. Displacement Time History at Pulling End of Matrex 120 Geogrid for Test D3B.

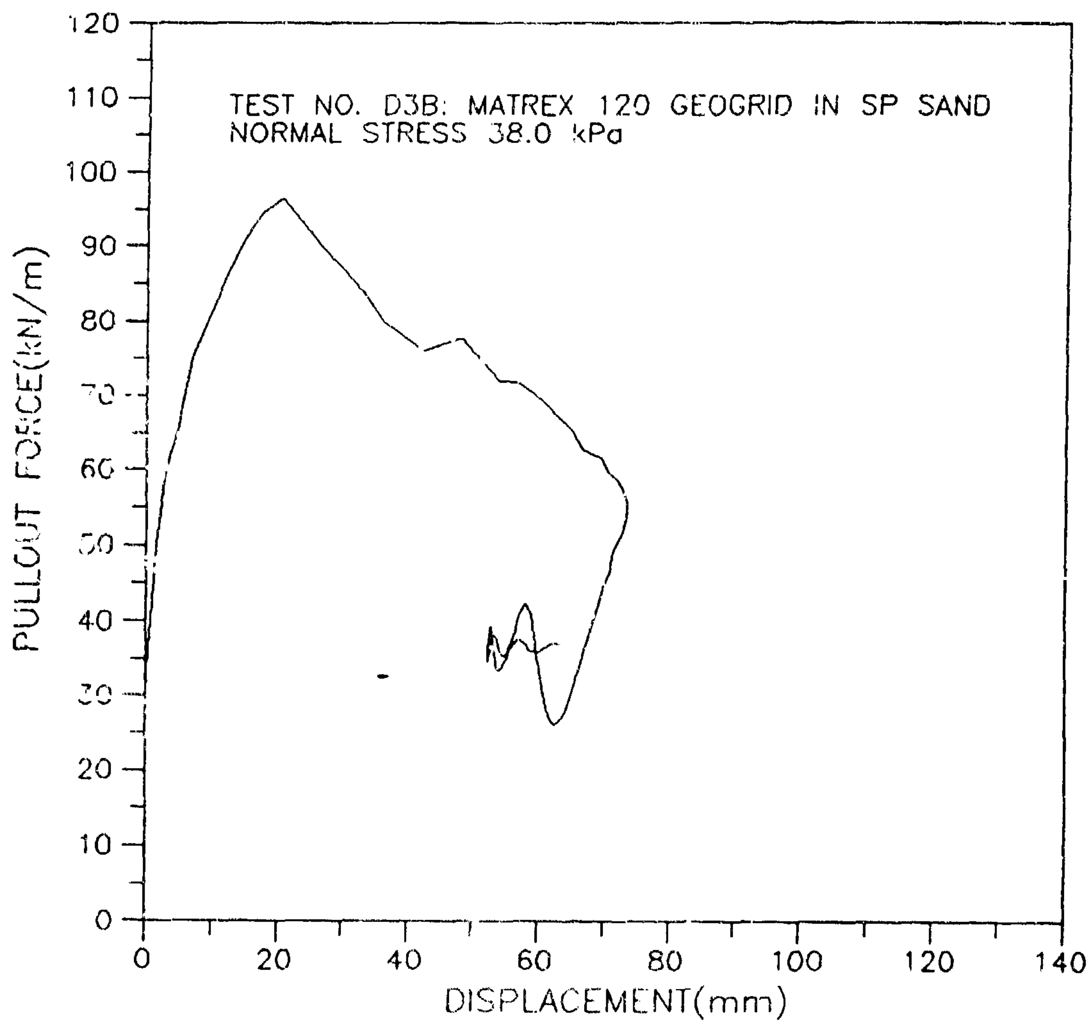

Figure 66. Dynamic Pullout Response of Matrex 120 Geogrid for Test D3B.

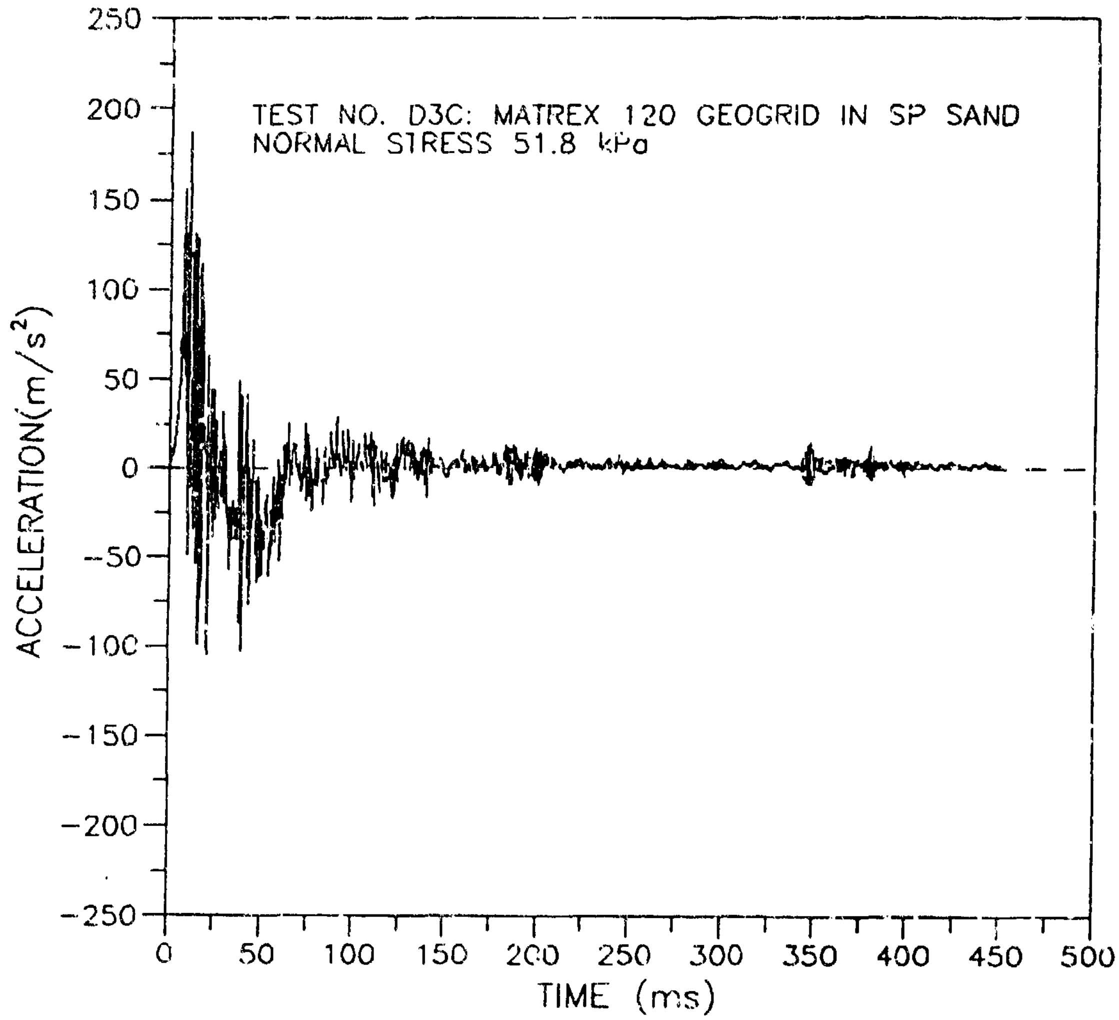

Figure 57. Measured Acceleration at Pulling End of Matrex 120 Geogrid for Test D3C.

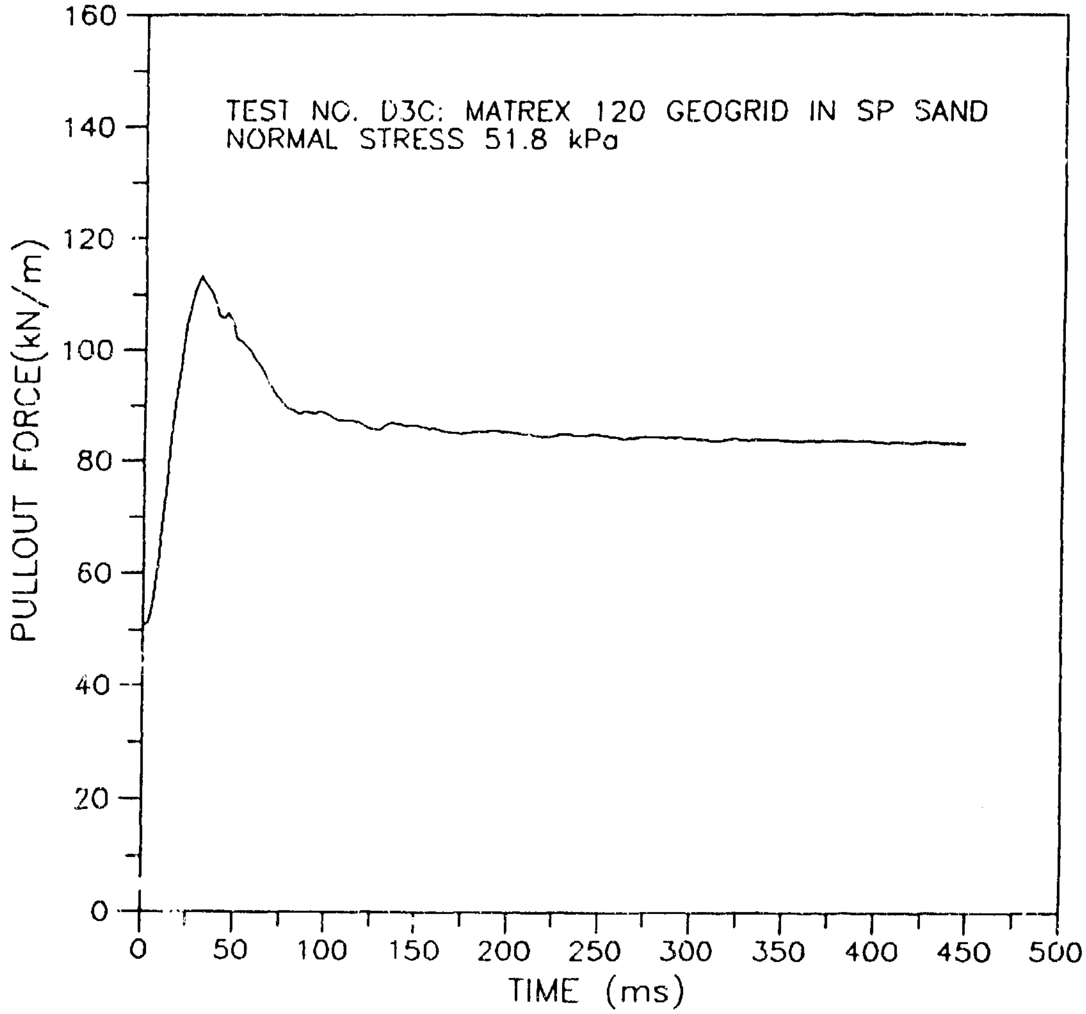

Figure 68. Measured Force at Pulling End of Matrex 120 Geogrid for Test D3C.

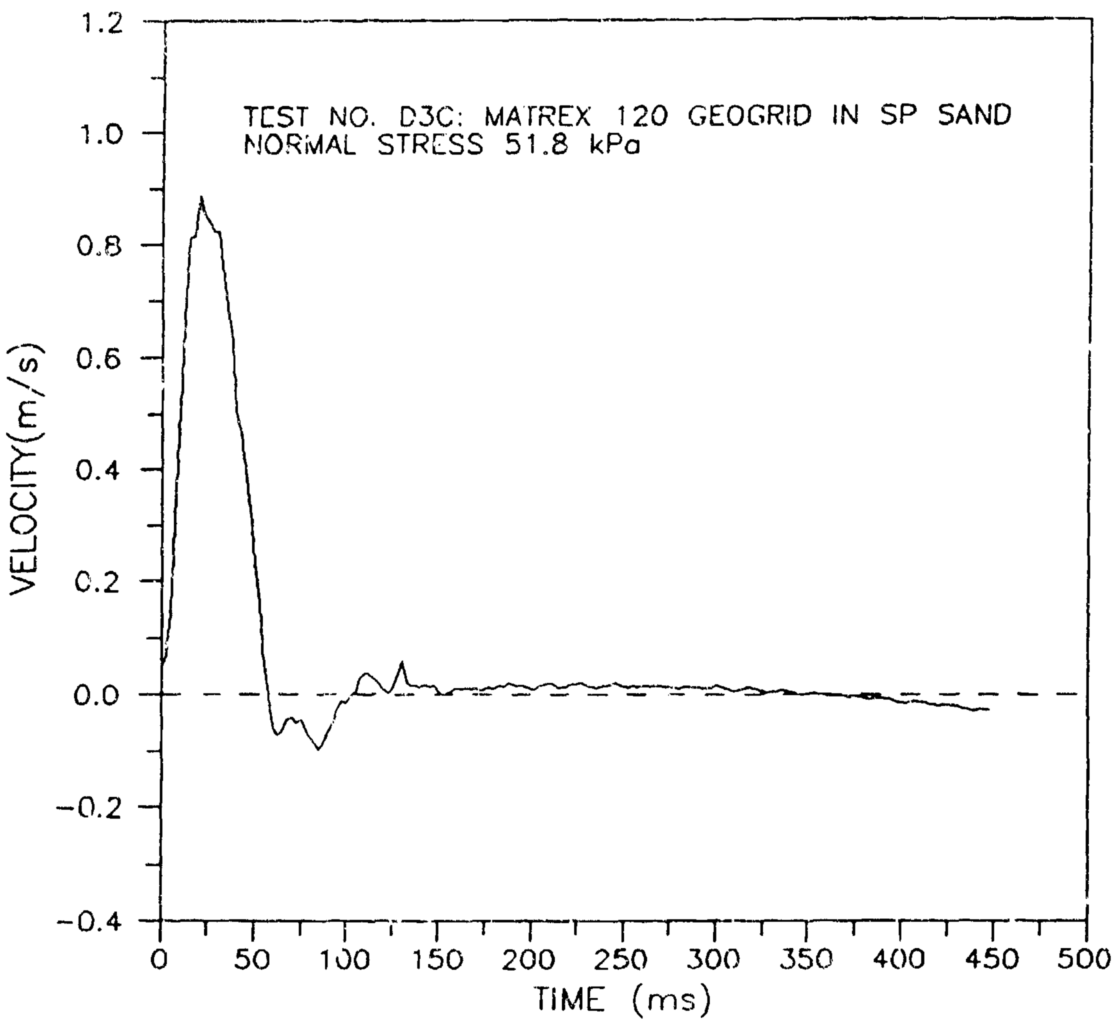

Figure 69. Velocity Time History at Pulling End of Matrex 120 Geogrid for Test D3C.

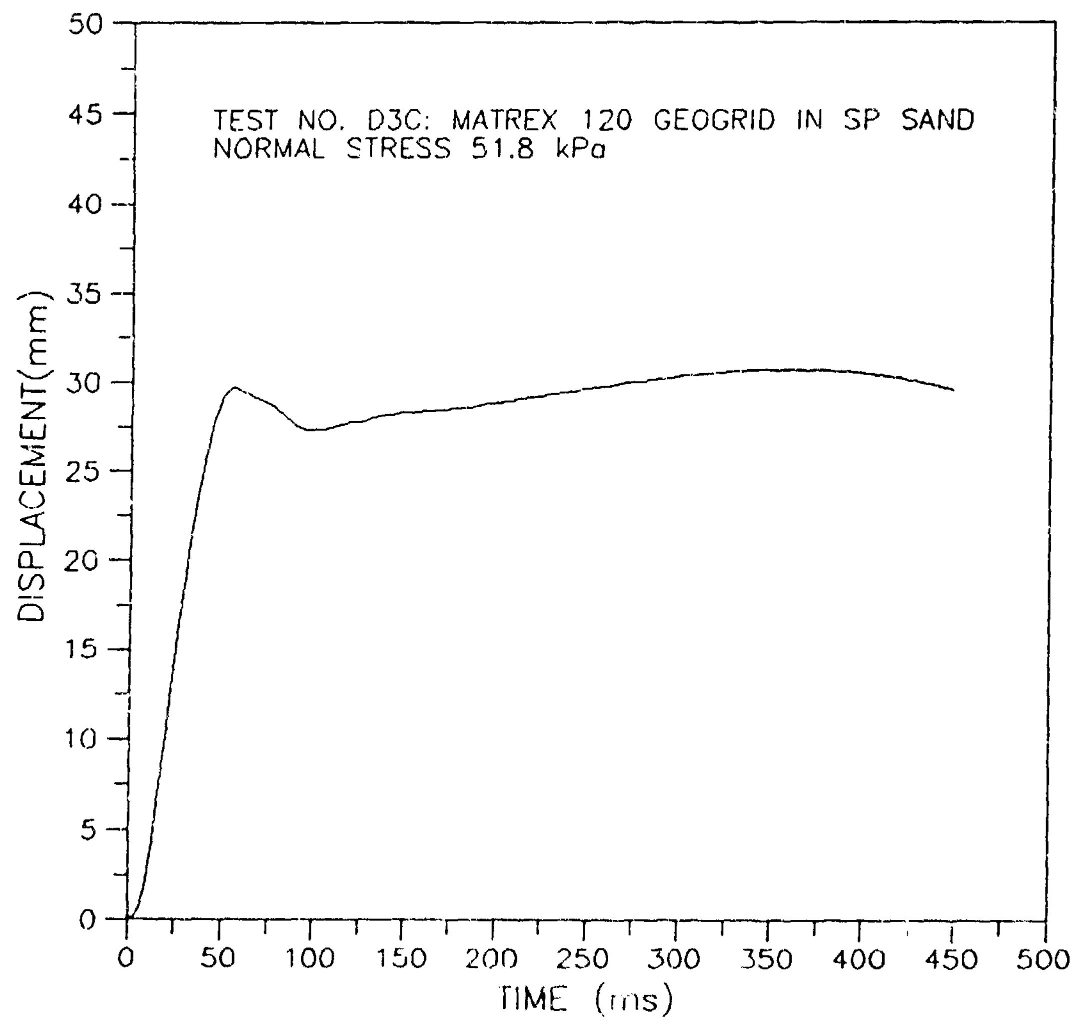

Figure 70. Displacement Time History at Pulling End of Matrex 120 Geogrid for Test D3C.

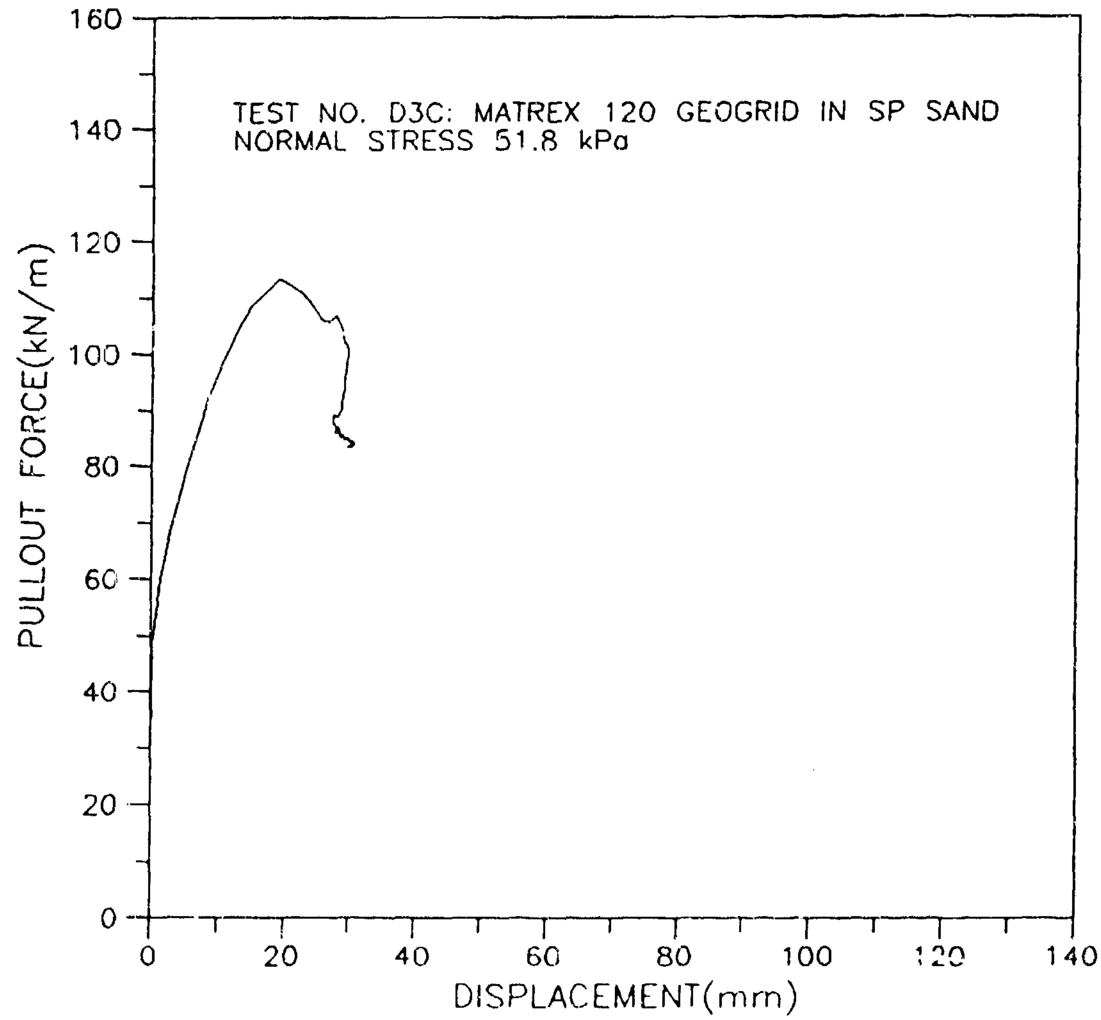

Figure 71. Dynamic Pullout Response of Matrex 120 Geogrid for Test D3C.

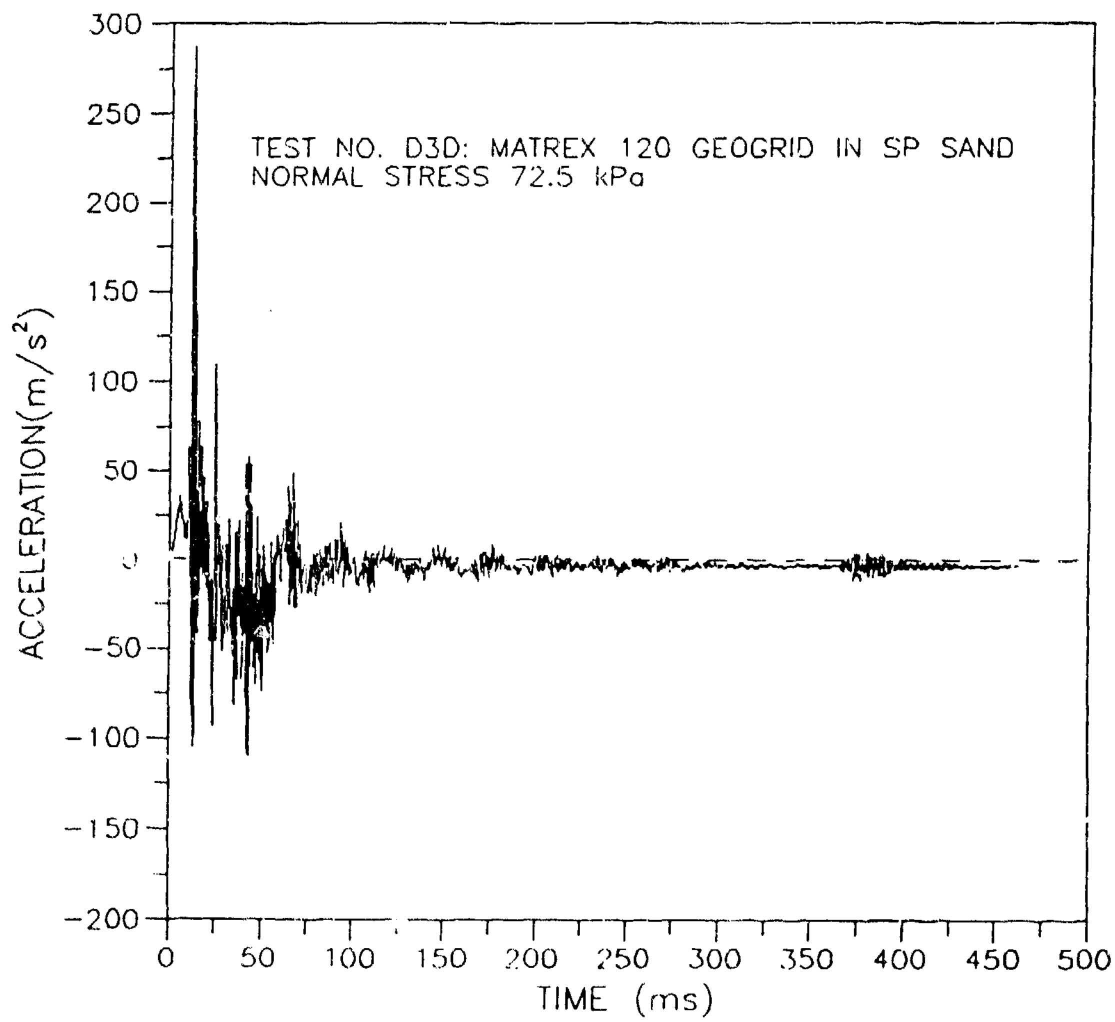

Figure 72. Measured Acceleration at Pulling End of Matrex 120 Geogrid for Test D3D.

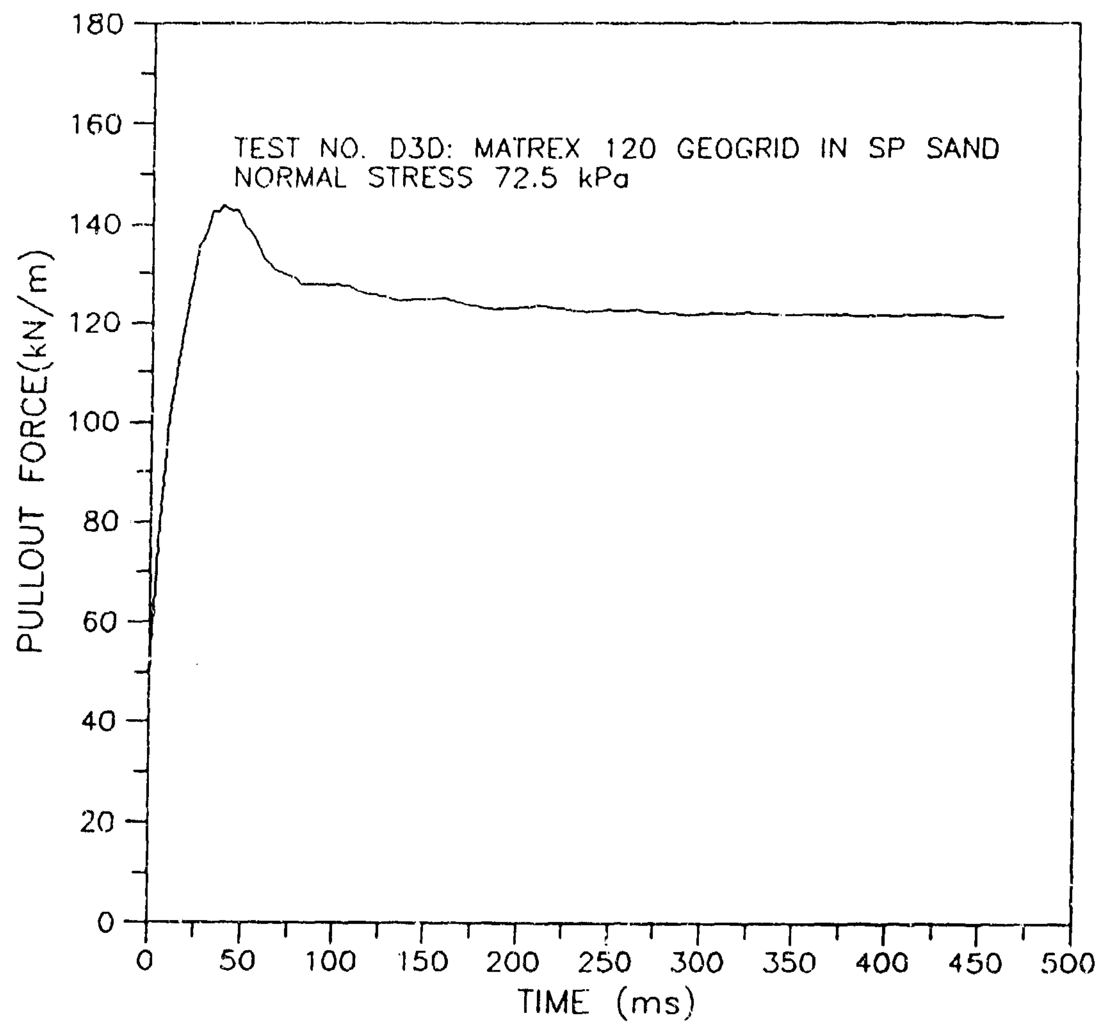

Figure 73. Measured Force at Pulling End of Matrex 120 Geogrid for Test D3D.

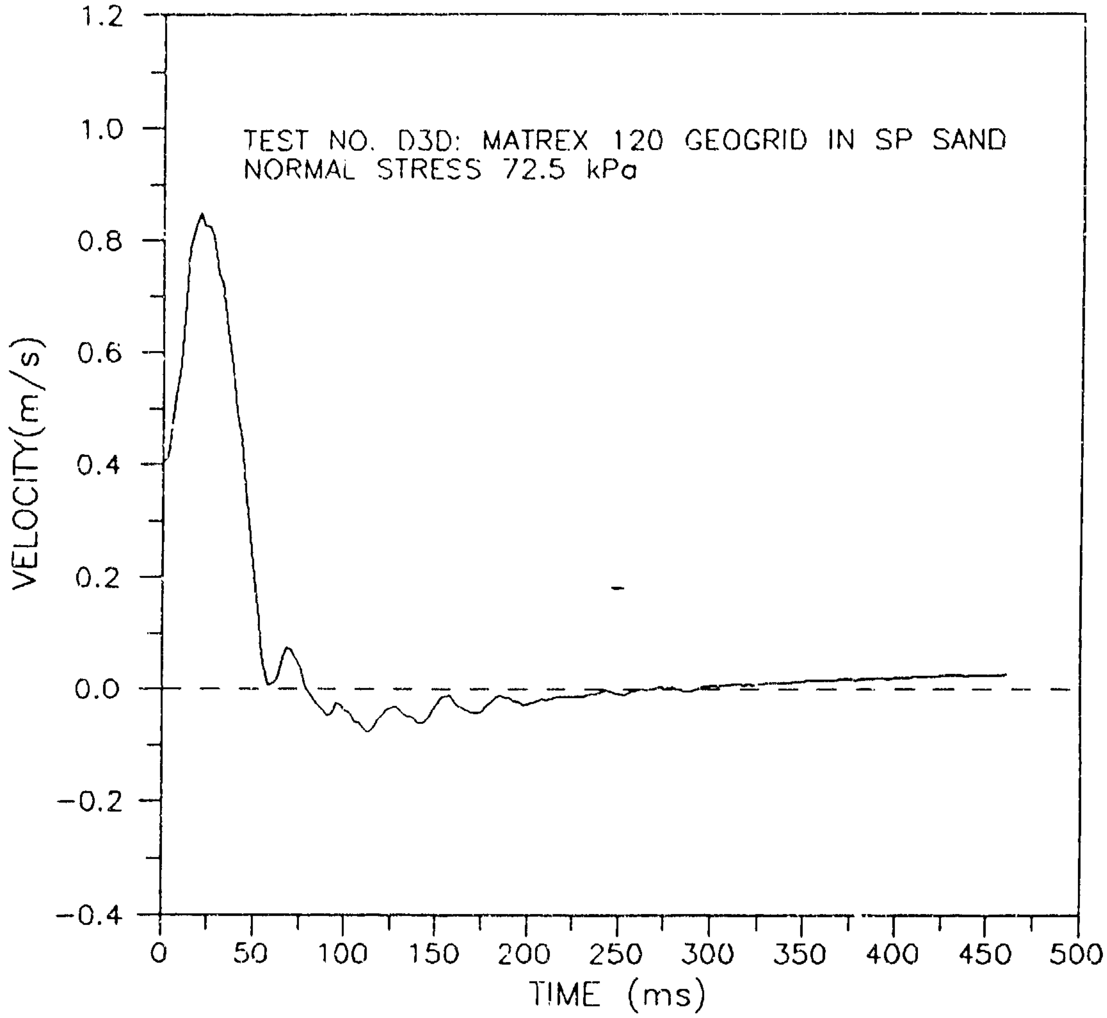

Figure 74. Velocity Time History at Pulling End of Matrex 120 Geogrid for Test D3D.

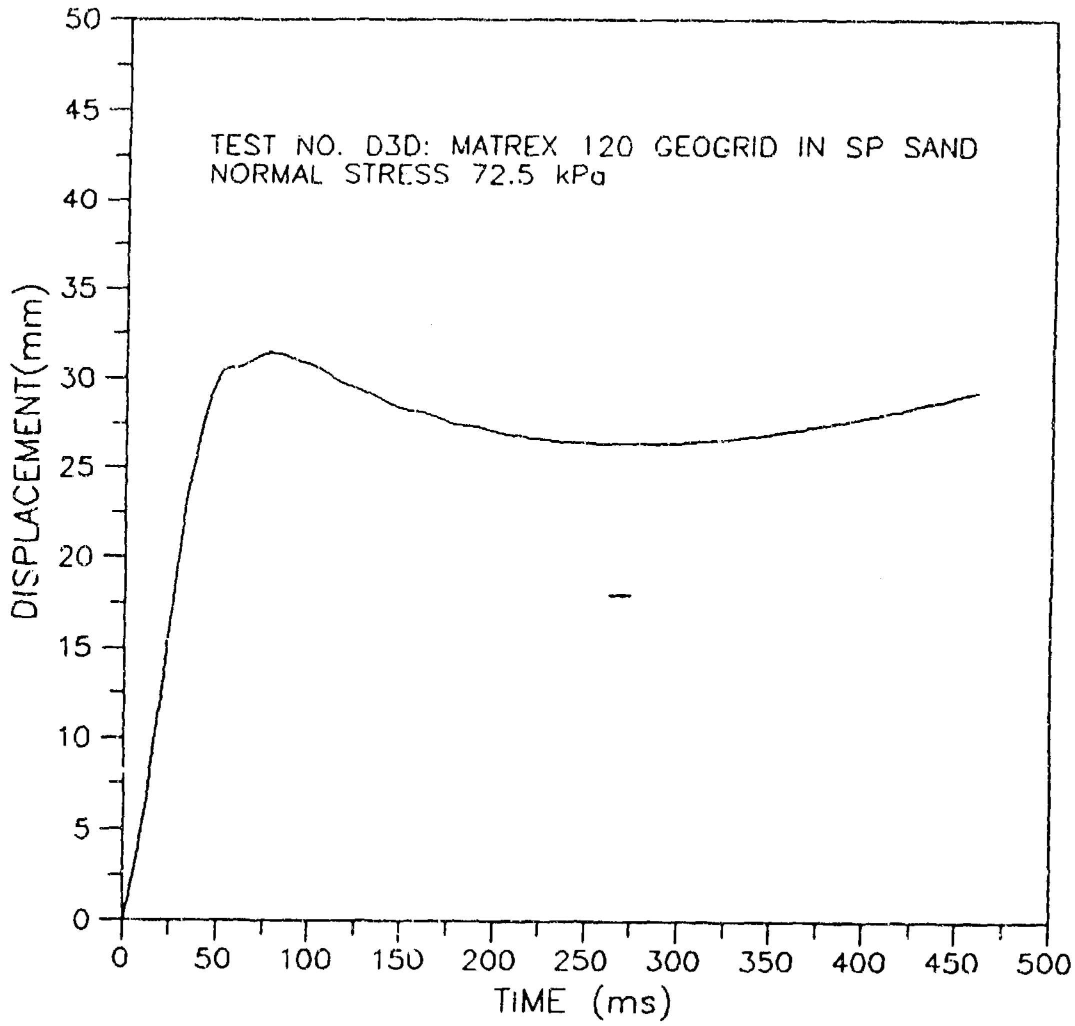

Figure 75. Displacement Time History at Pulling End of Matrex 120 Geogrid for Test D3D.

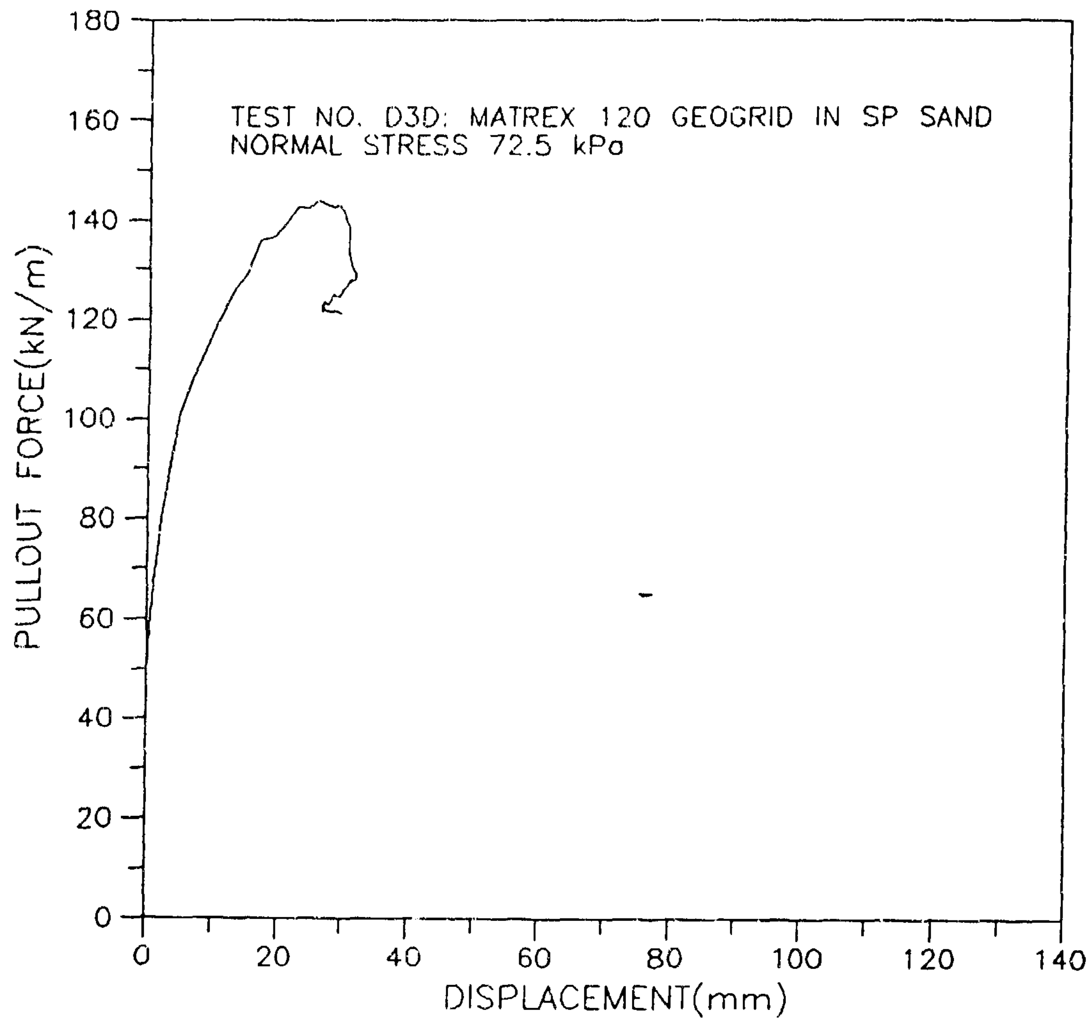

Figure 76. Dynamic Pullout Response of Matrex 120 Geogrid for Test D3D.

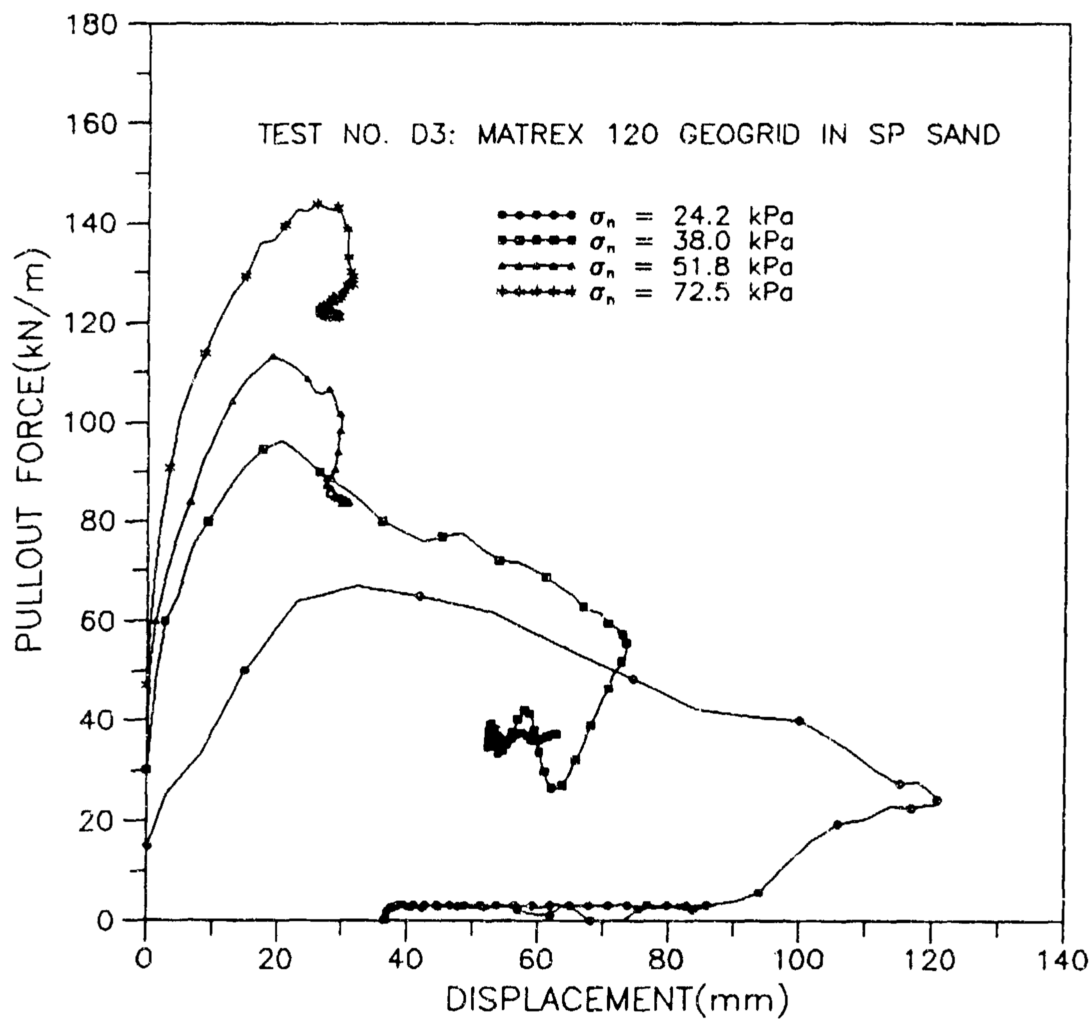

Figure 77. Dynamic Pullout Response of M· ·ex 120 Geogrid for Test D3A, D3B, D3C and D3D.

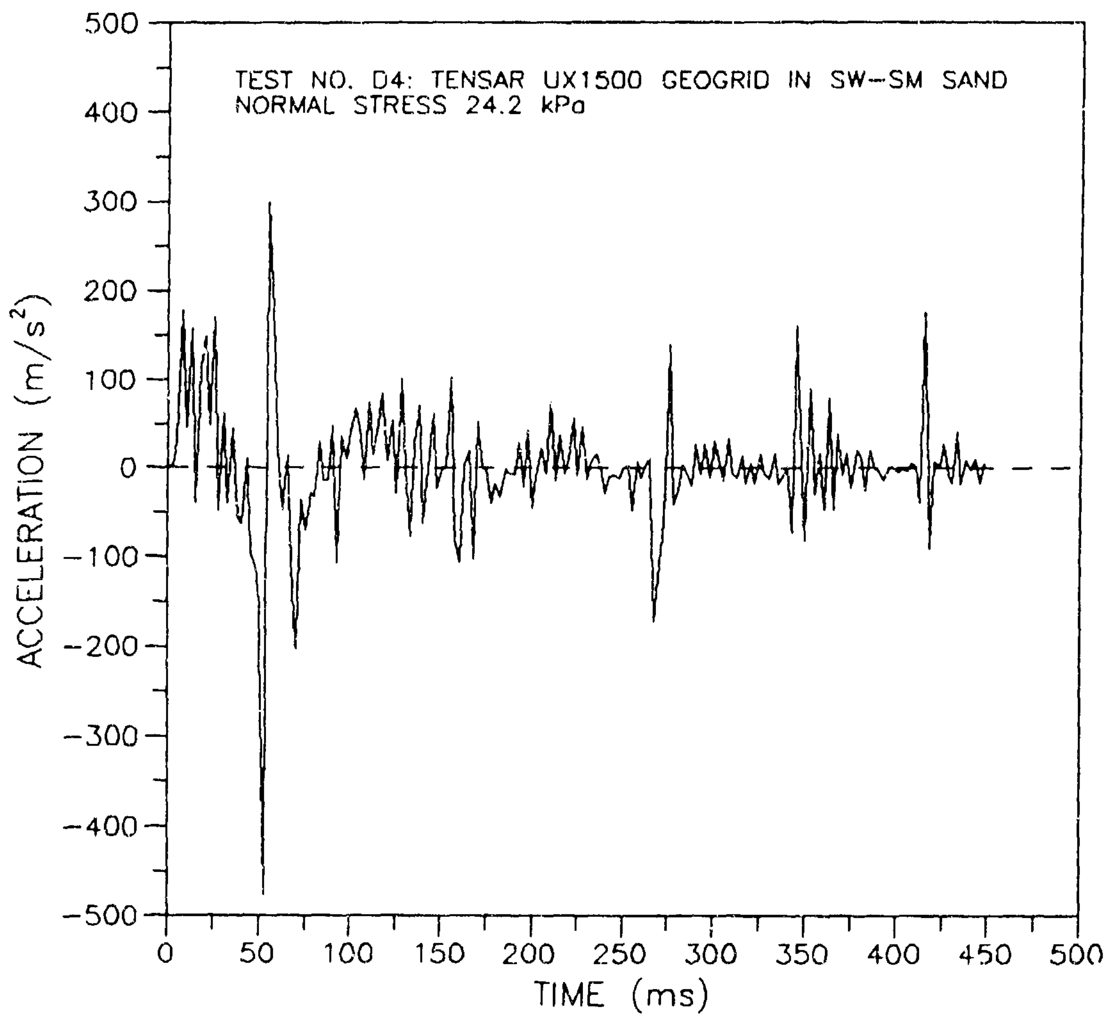

Figure 78. Measured Acceleration at Pulling End of Tensar UX1500 Geogrid for Test D4.

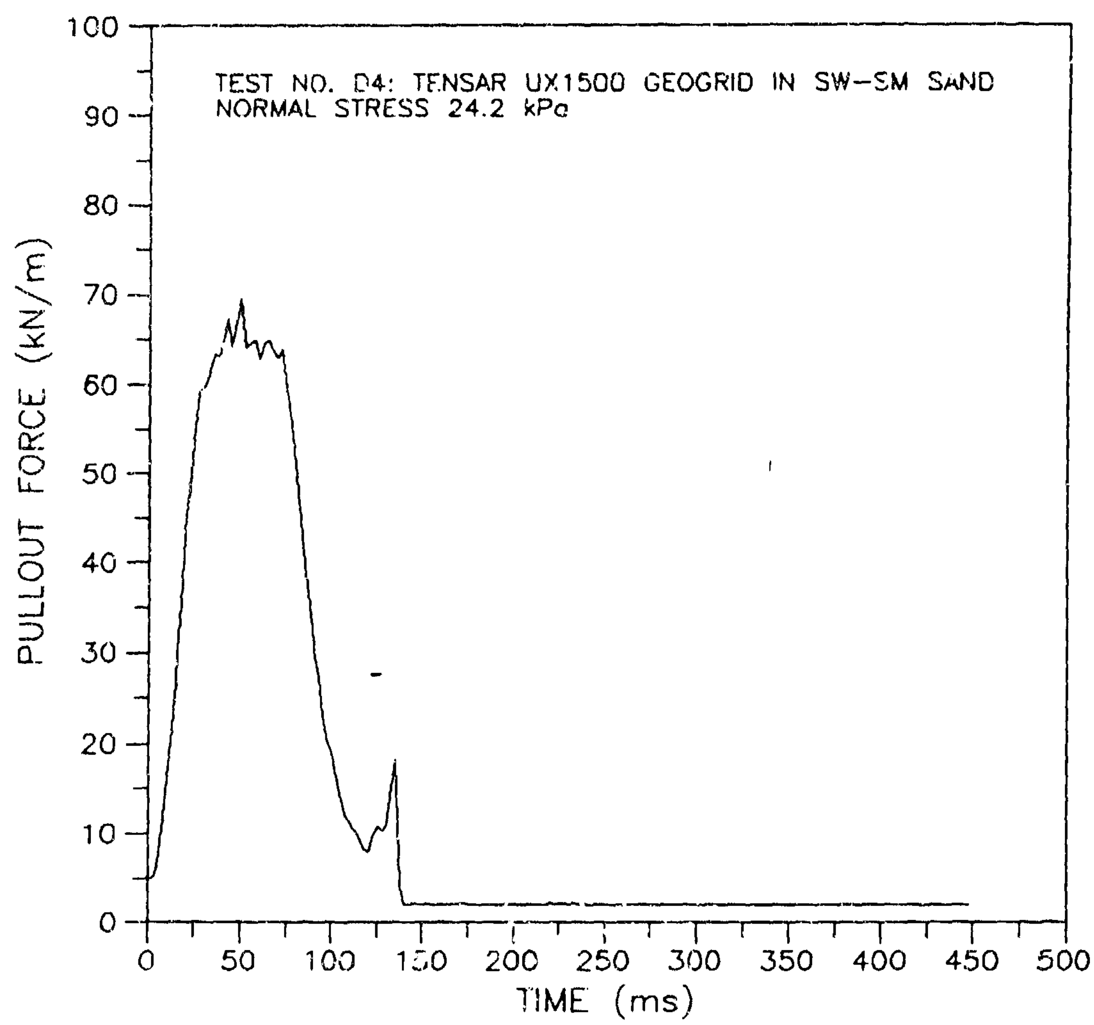

Figure 79. Measured Force at Pulling End of Tensar UX1500 Geogrid for Test D4.

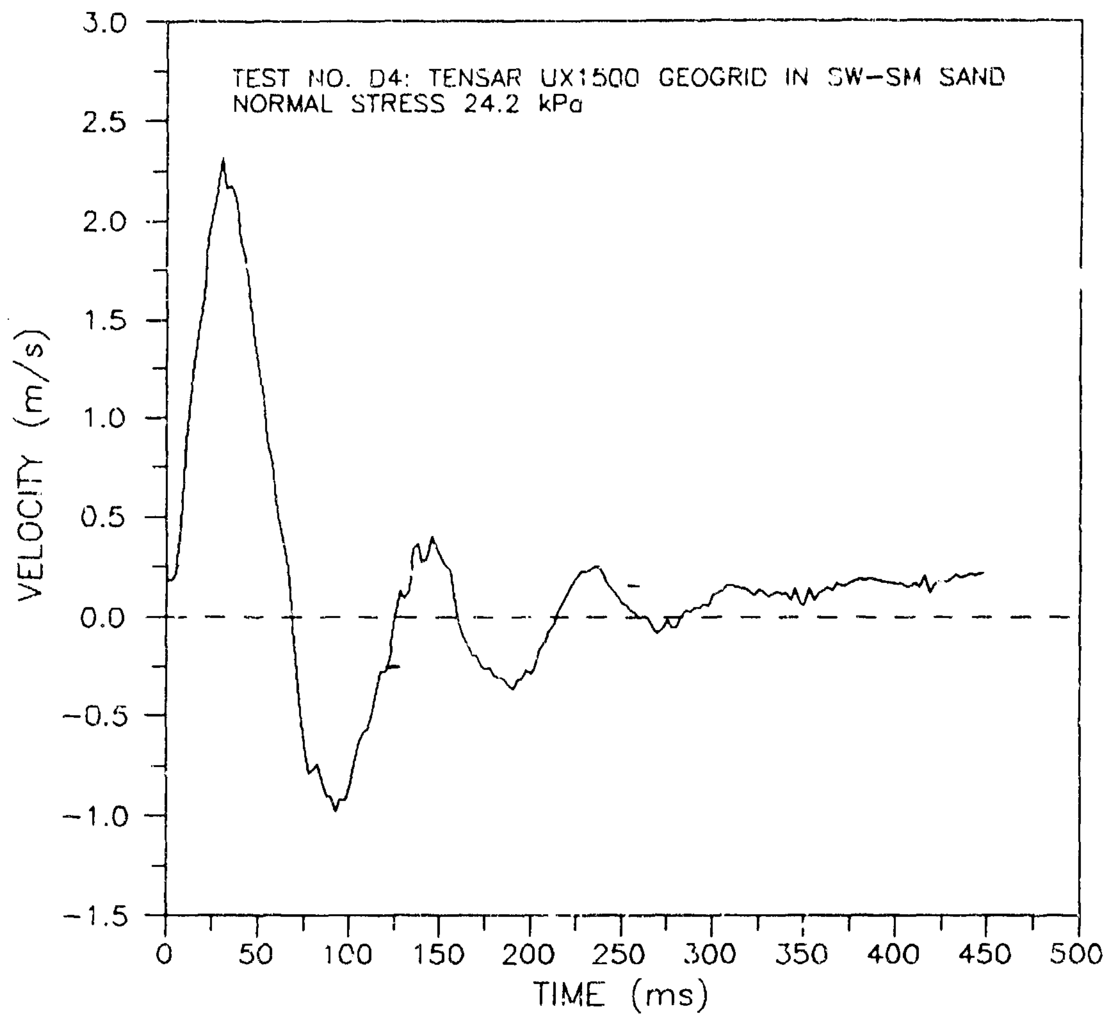

Figure 80. Velocity Time History at Pulling End of Tensar UX1500 Geogrid for Test D4.

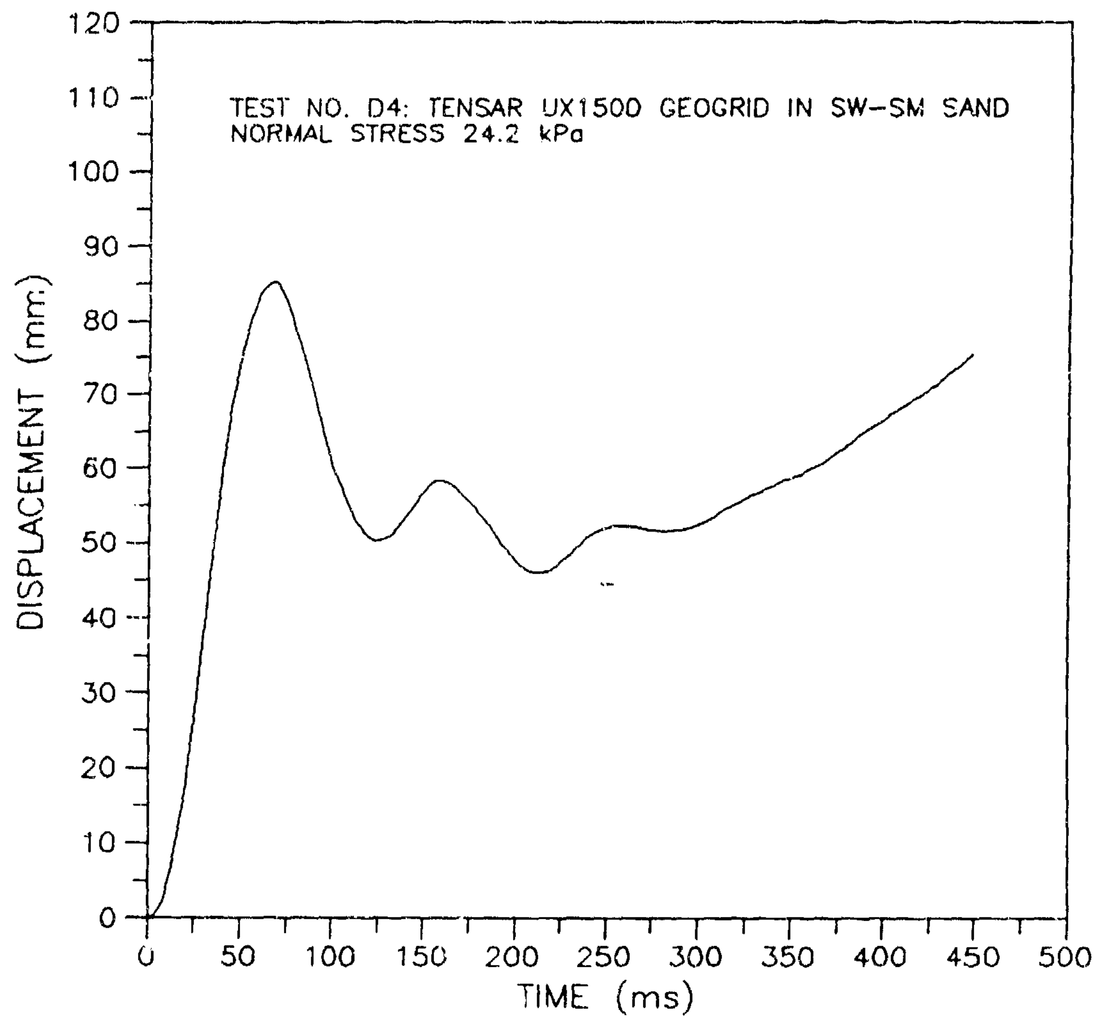

Figure 81. Displacement Time History at Pulling End of Tensar UX1500 Geogrid for Test D4.

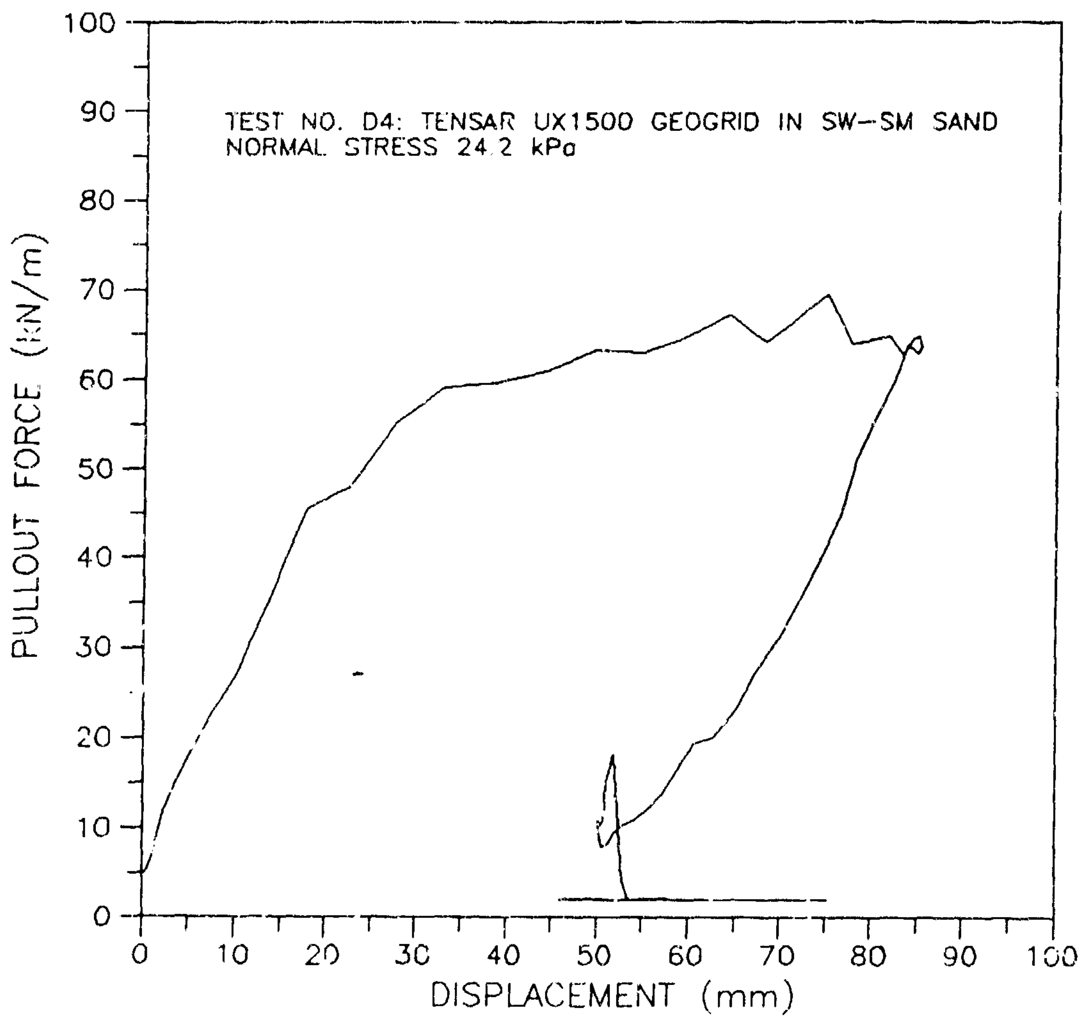

Figure 82. Dynamic Pullout Response of Tensar UX1500 Geogrid for Test D4.

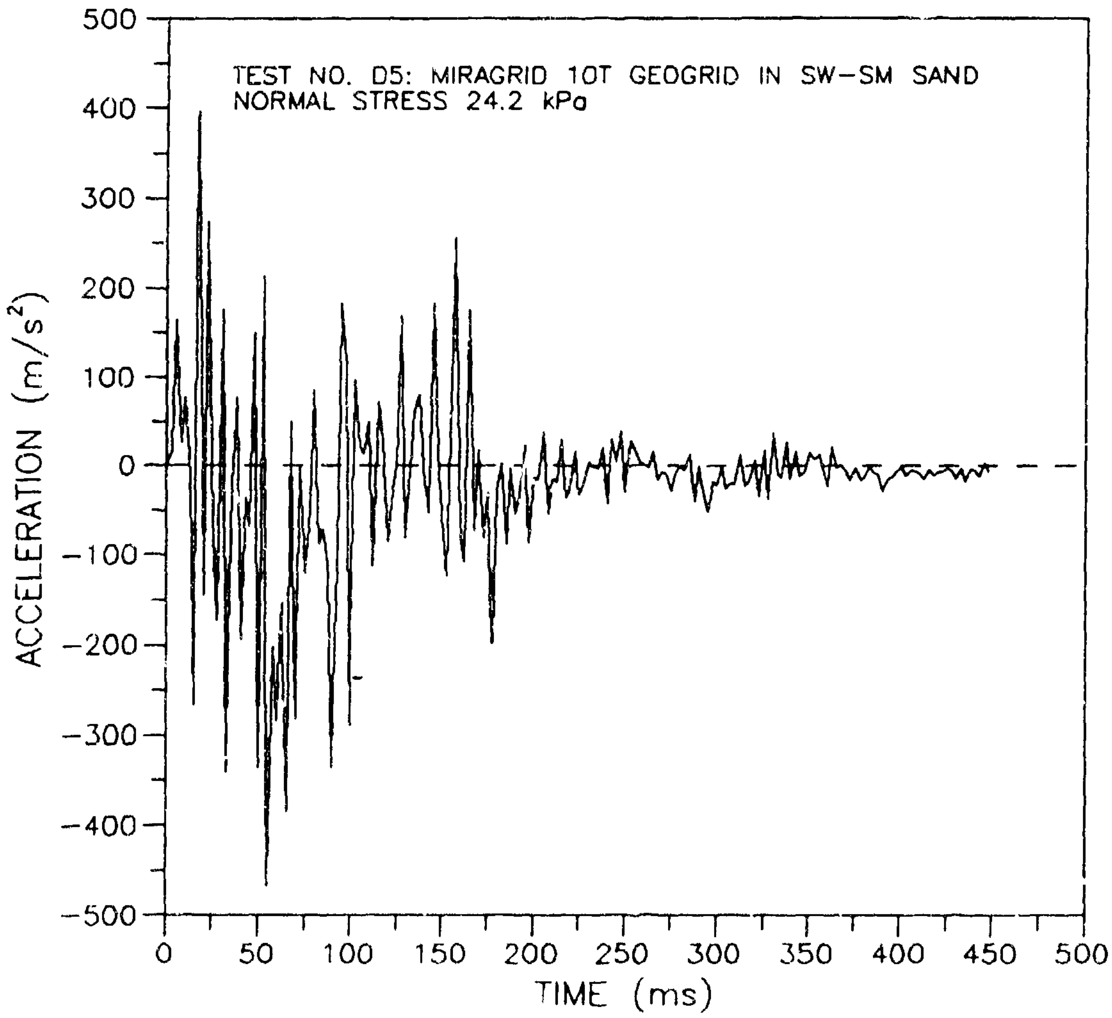

Figure 83. Measured Acceleration at Pulling End of M.ragrid 10T Geogrid for Test D5.

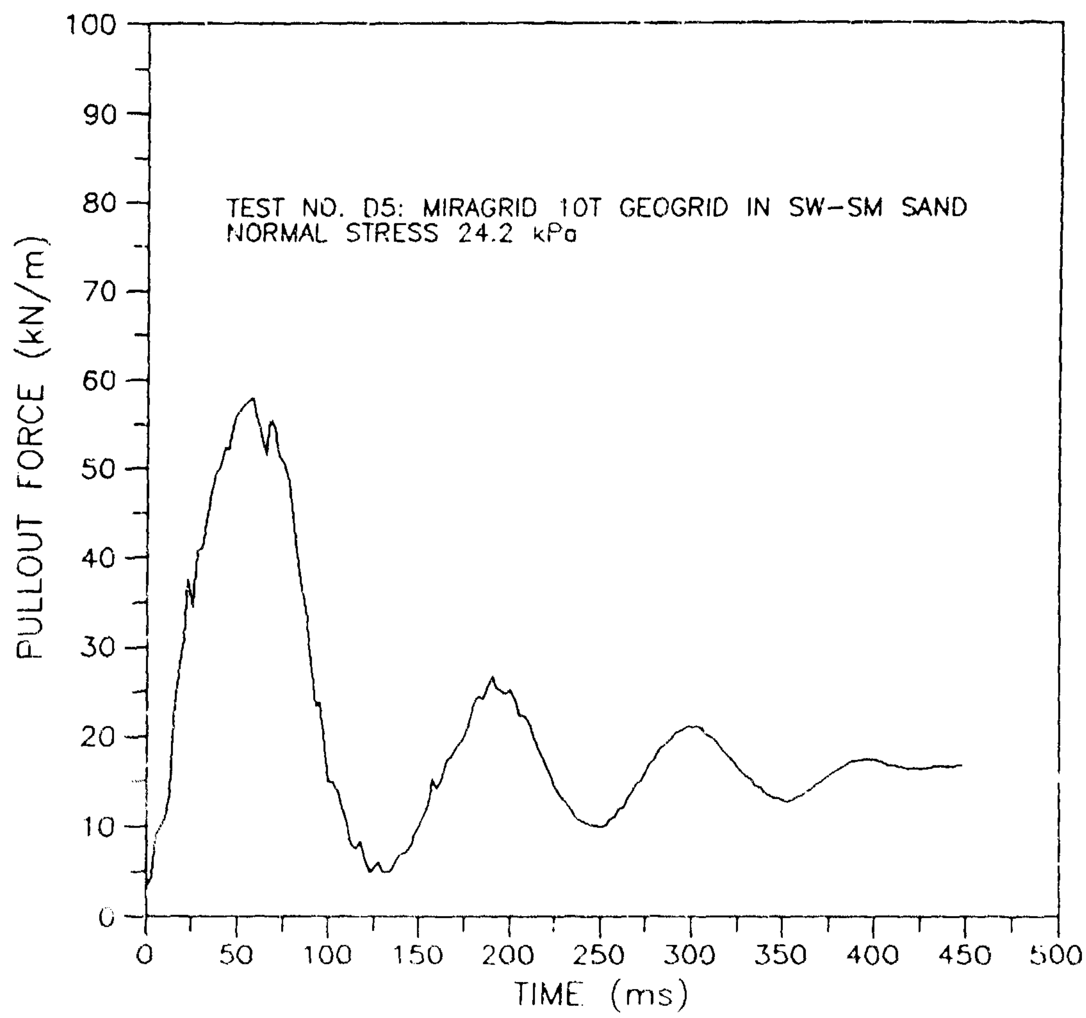

Figure 84. Measured Force at Pulling End of Miragrid 10T Geogrid for Test D5.

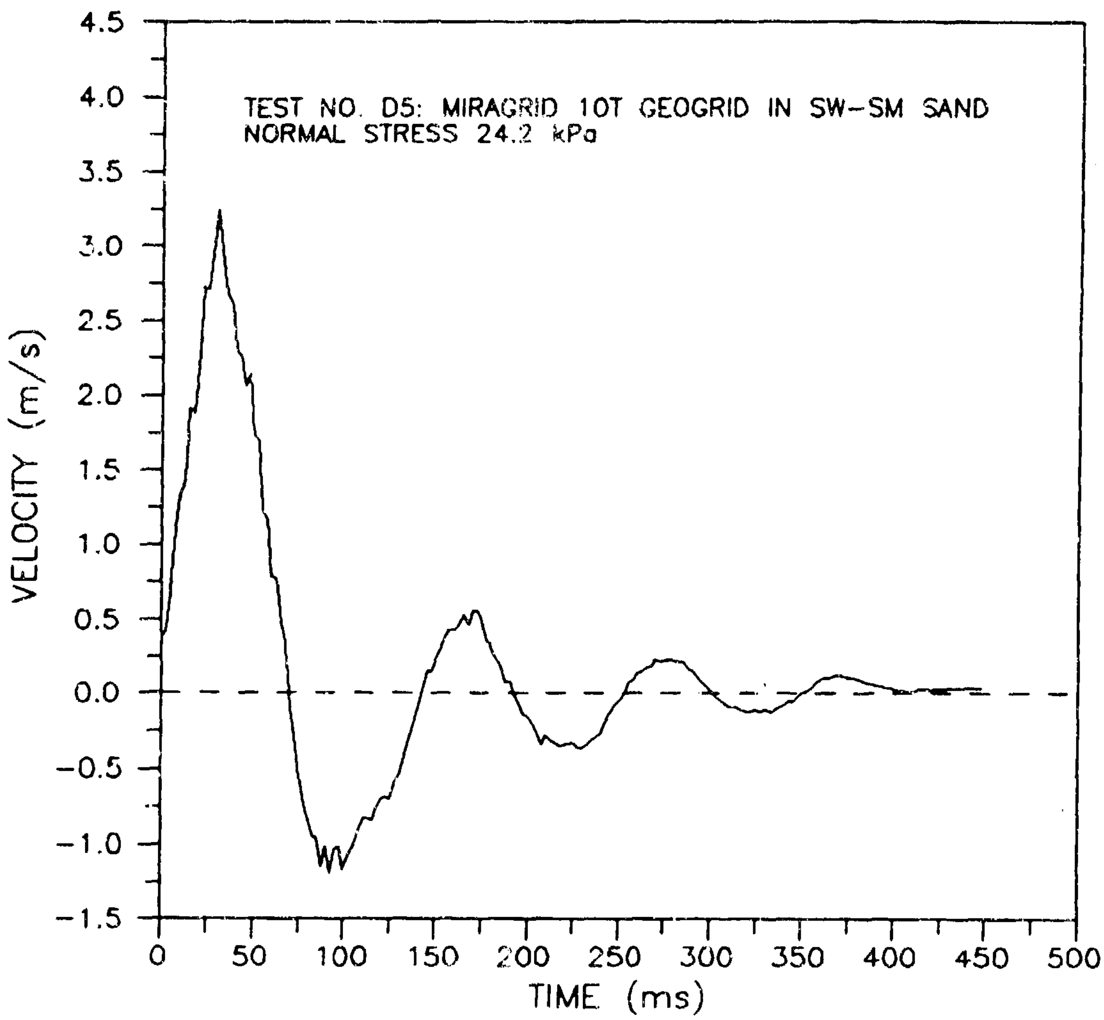

Figure 85. Velocity Time History at Pulling End of Miragrid 10T Geogrid for Test D5.

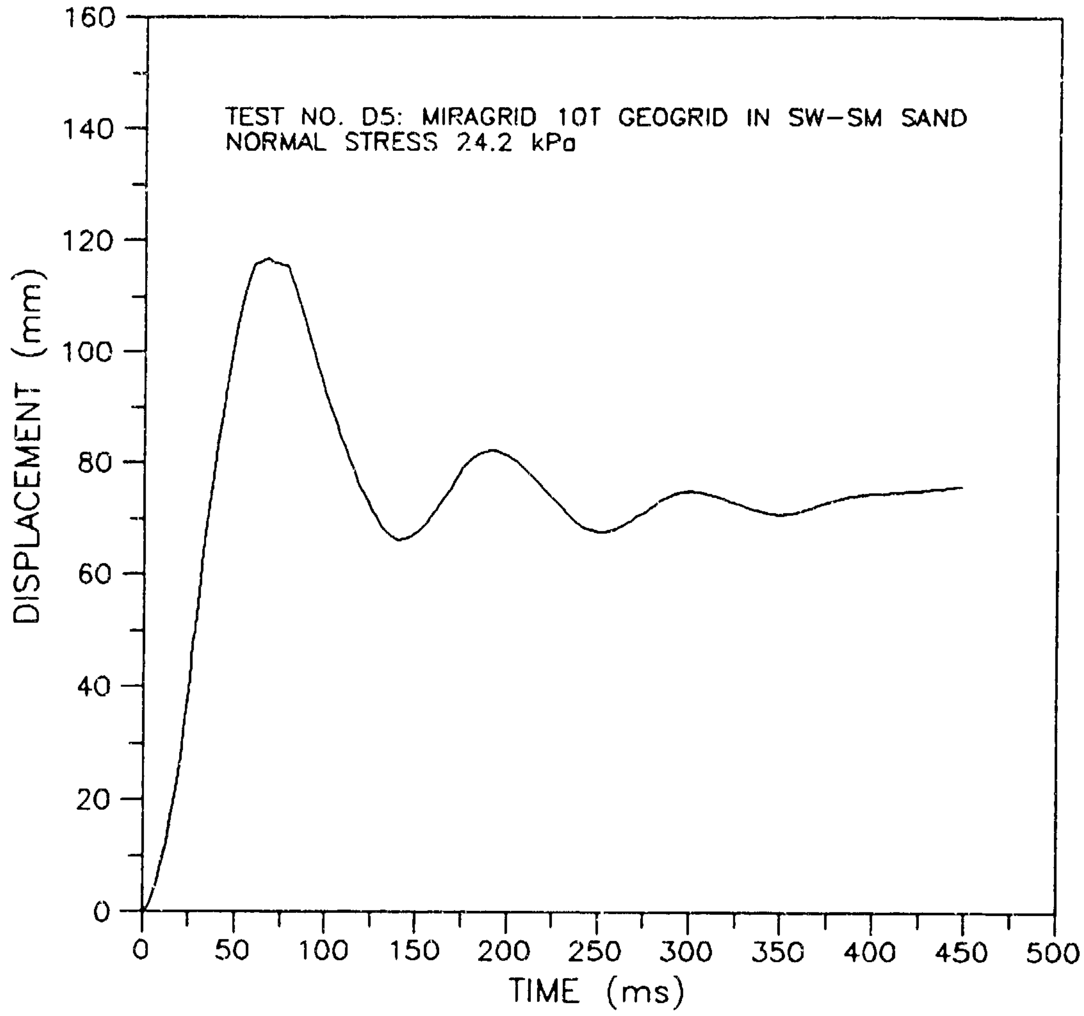

Figure 86. Displacement Time History at Pulling End of Miragrid 10T Geogrid for Test D5.

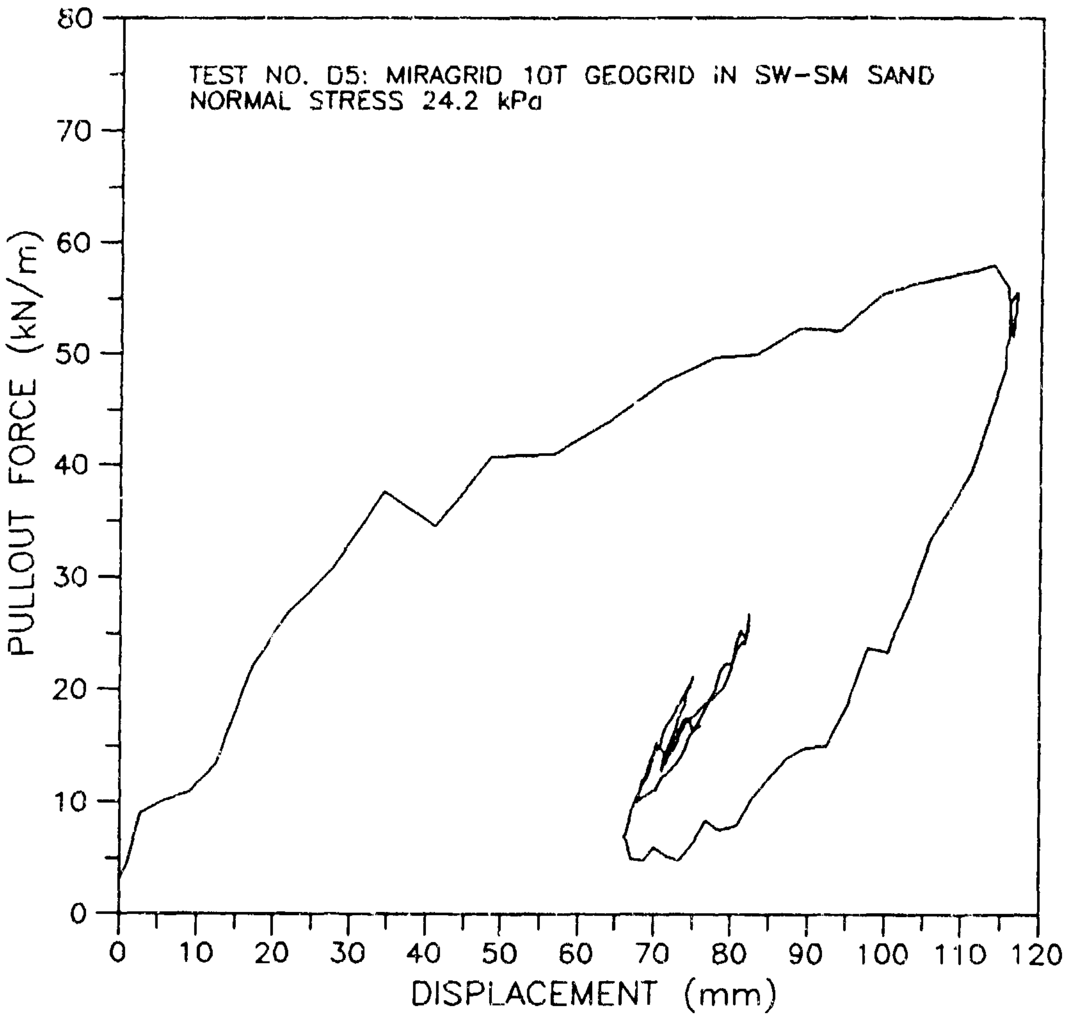

Figure 87. Dynamic Pullout Response of Miragrid 10T Geogrid for Test D5.

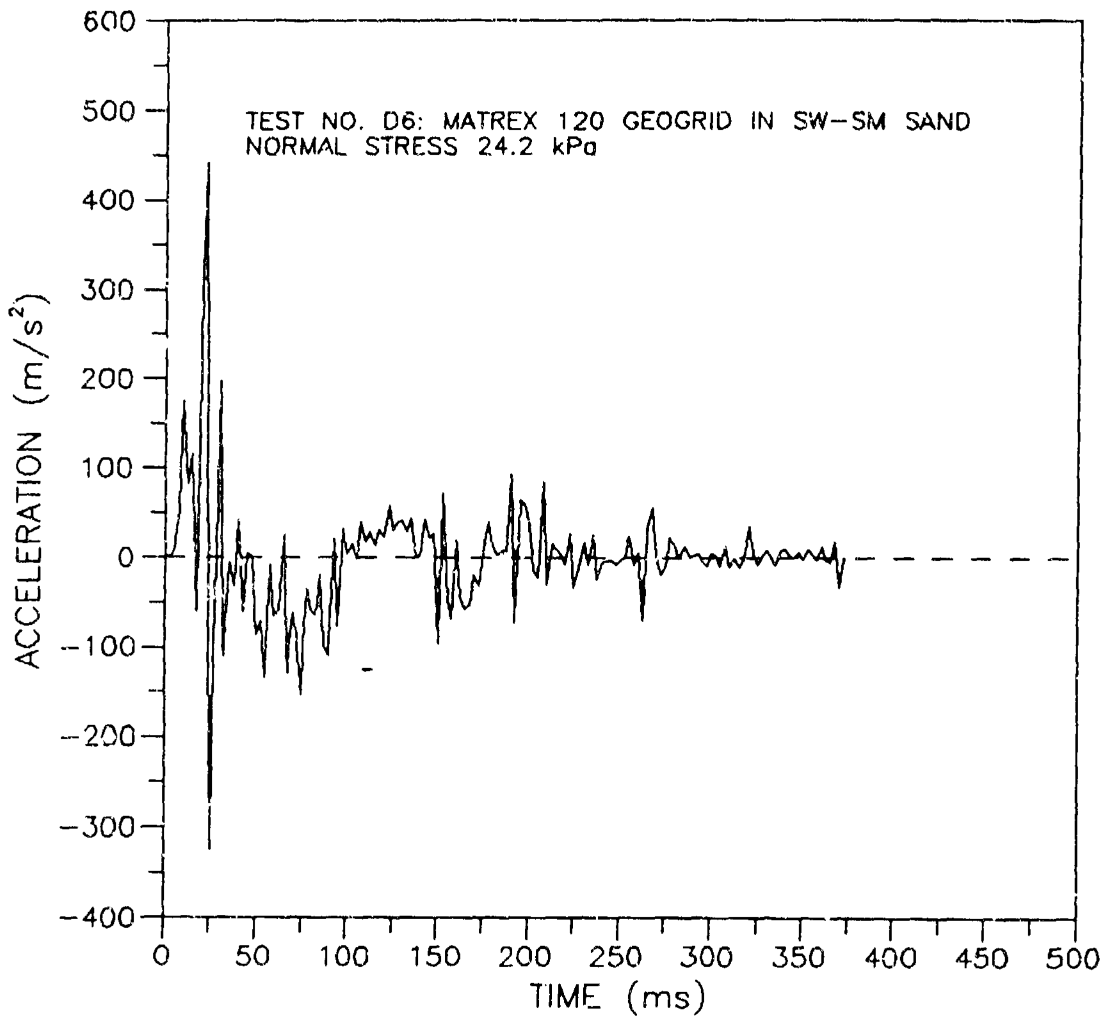

Figure 88. Measured Acceleration at Pulling End of Matrex 120 Geogrid for Test D6.

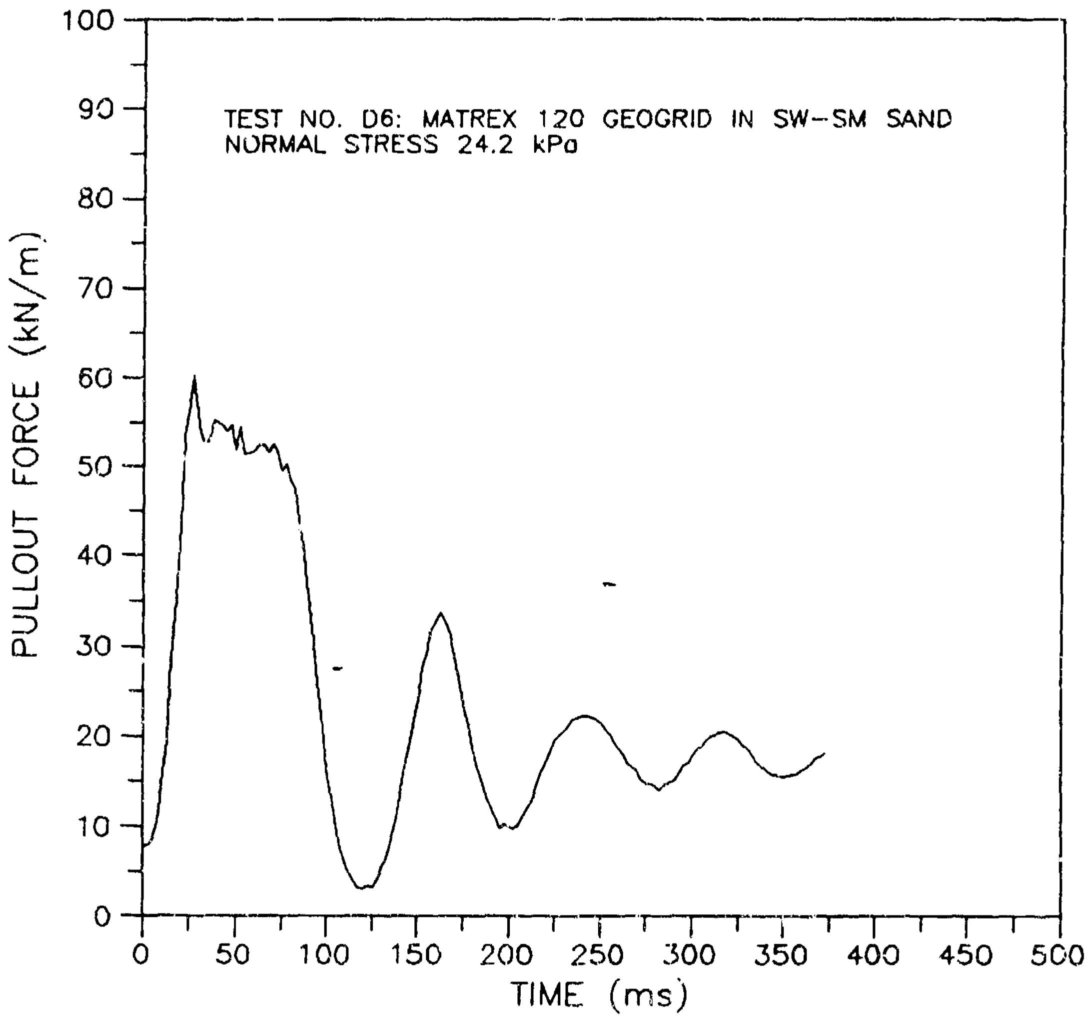

Figure 89. Measured Force at Pulling End of Matrex 120 Geogrid for Test D6.

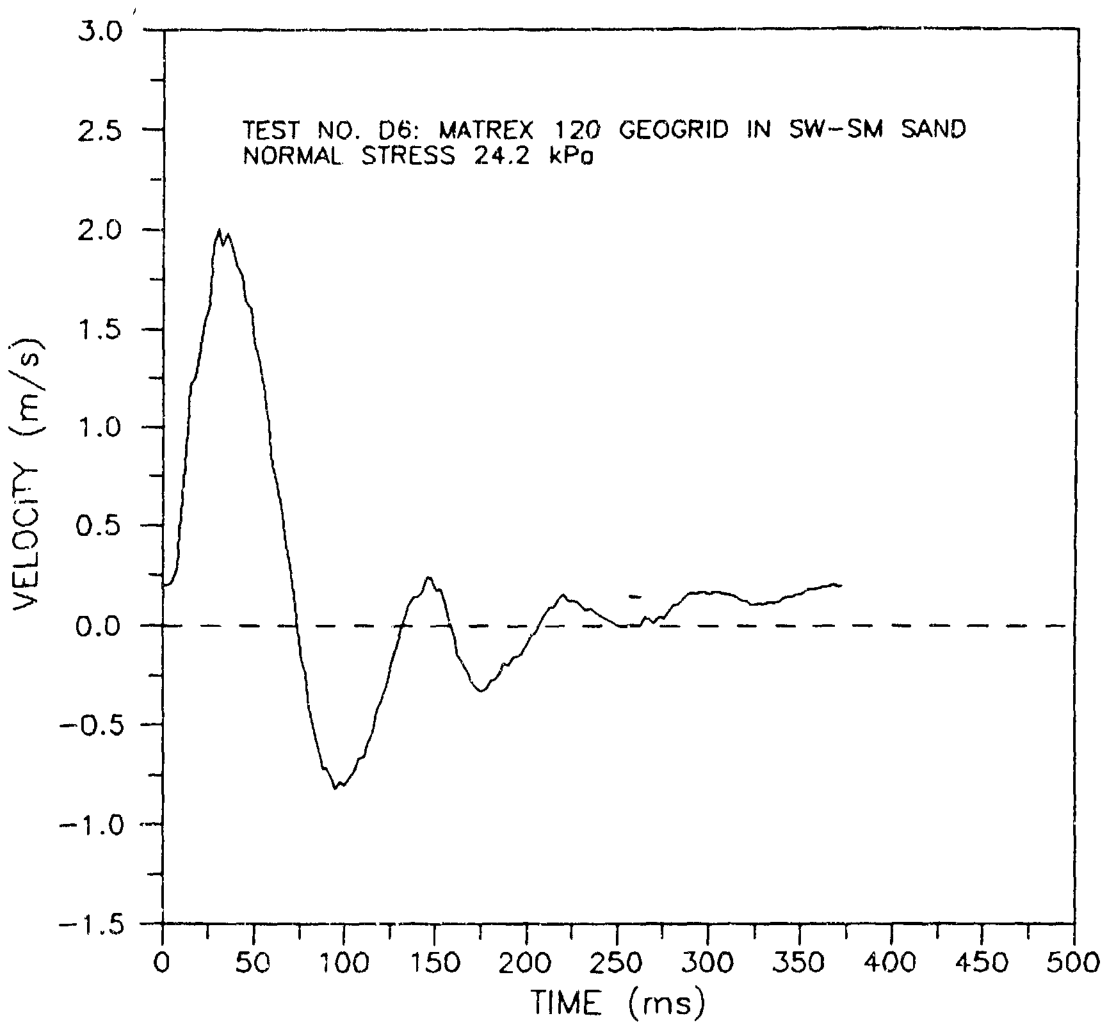

Figure 90. Velocity Time History at Pulling End of Matrex 120 Geogrid for Test D6.

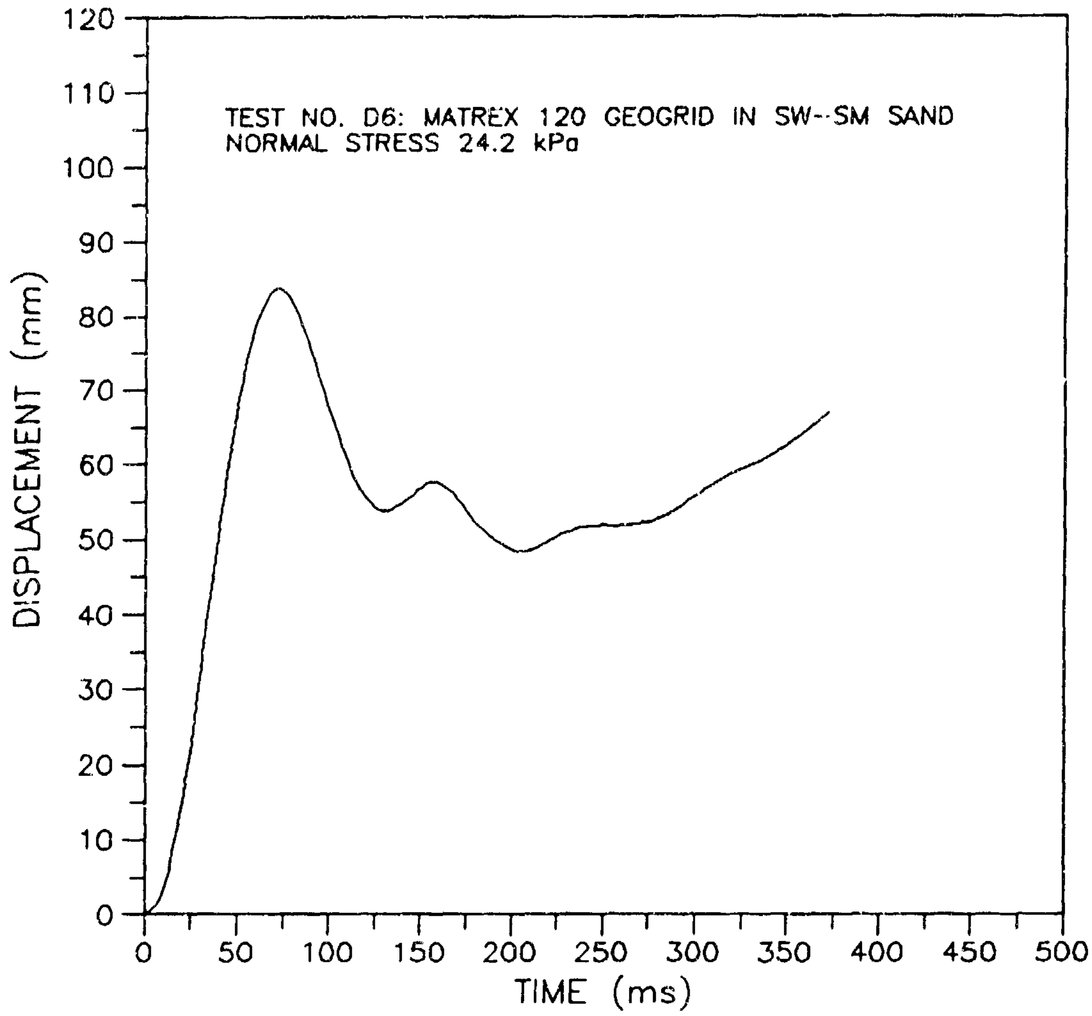

Figure 91. Displacement Time History at Pulling End of Matrex 120 Geogrid for Test D6.

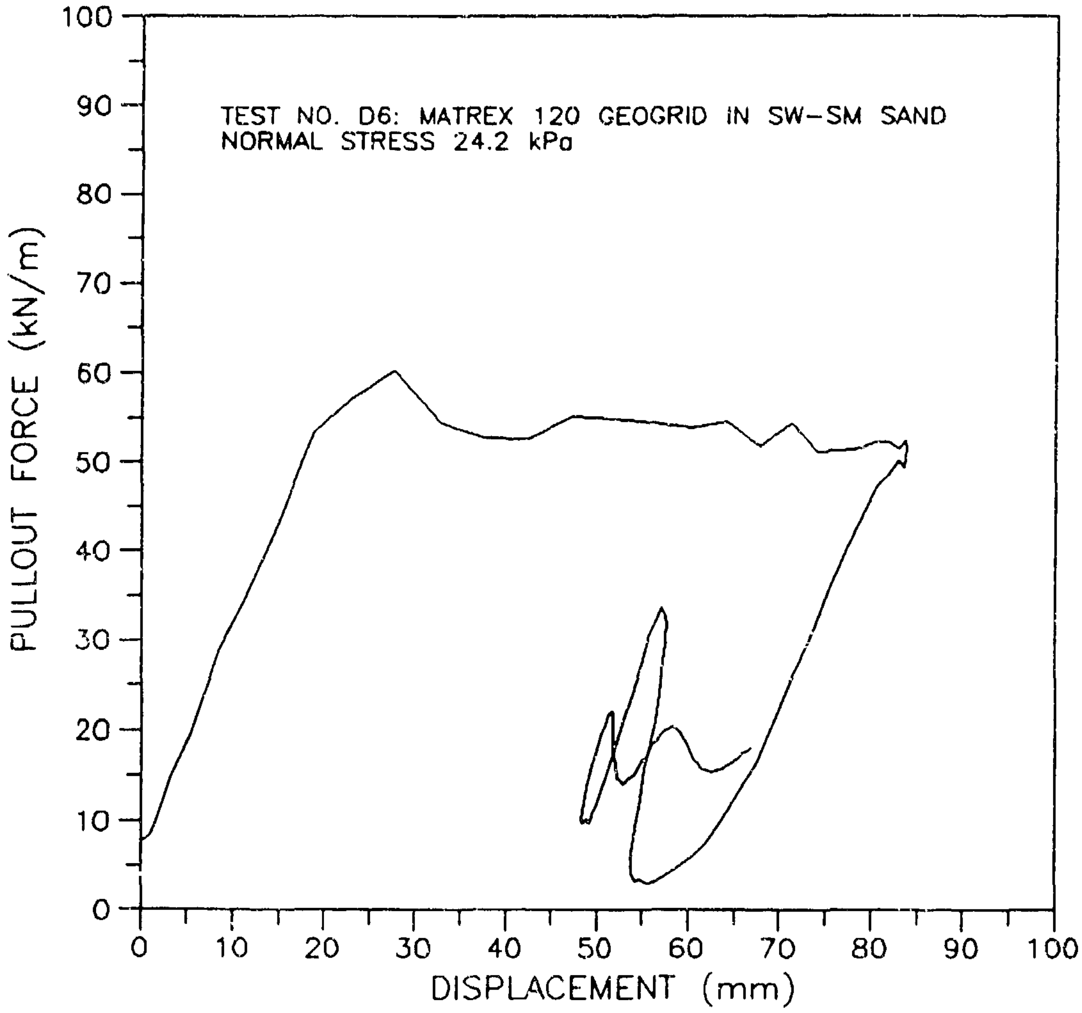

Figure 92. Dynamic Pullout Response of Matrex 120 Geogrid for Test D6.

APPENDIX B

NUMERICAL MODELING

A. INTRODUCTION

This appendix contains example input files for the computer codes INGRID (the pre-processor for DYNA3D) and DYNA3D, as well as figures showing deformed meshes from each analysis.

The example input file for INGRID, presented below in Part B, is annotated and contains the input data for the base analysis, PS1. The units used are meters, kilograms and seconds. The output file produced by INGRID is the DYNA3D input file presented in Section C. This file is also annotated with comments produced by INGRID and additional comments added by the authors. The portions of the DYNA3D input file needed for analysis PS1, but not produced by INGRID, are clearly marked out by comments. To reduce the length of the listing, only a few lines of node and element data are shown. Section D presents figures showing the deformed mesh shape at the end of each analysis described in Volume 1.

B. EXAMPLE OF INGRID INPUT FILE

The following listing is an example of an INGRID input file. All lines beginning with a "c" are comments. Lower case letters are used for all INGRID input except comments. INGRID files should not begin with a comment; the first line listed below is the title to be used for the DYNA3D input file that INGRID will generate.

```
parametric study - base input file (plane strain)
c
c ... identify computer code for which data are being prepared
c
dn3d
c
c ... termination time for the DYNA analysis
c
term 0.08
c
c ...  time interval between writes of state plot data
c
plti 0.040
c
c ...  time interval between writes of time history plot data
c
prti 0.040
c
c  .. gravity acceleration vector
c
grav 0. 0. 9.81
c
c ... for mass proportional damping add alpha-x directly into card 8 of
c     DYNA3D input file since INGRID can't generate rayleigh damping data.
c
c ... define type of sliding interface, static and dynamic friction coeff.
c     NOTE: the 10/17/89 version of INGRID will perform this
c     command correctly; the 6/27/91 version only puts the dynamic
c     friction coeff into the DYNA input file, the static coeff must be input
c     by hand
c
si 1  sv fric 0.9 kfric 0.9;
si 2  sv fric 0.9 kfric 0.9;
si 3  sv fric 0.9 kfric 0.9;
si 4  sv fric 0.9 kfric 0.9;
si 5  sv fric 0.9 kfric 0.9;
si 6  sv fric 0.9 kfric 0.9;
si 7  sv fric 0.9 kfric 0.9;
```

```
si 8  sv fric 0.9 kfric 0.9;
si 9  sv fric 0.9 kfric 0.9;
si 10 sv fric 0.9 kfric 0.9;
si 11 sv fric 0.9 kfric 0.9;
si 12 sv fric 0.9 kfric 0.9;
si 13    tied;
si 14 sv fric 1.5 kfric 1.5;
si 15 sv fric 1.5 kfric 1.5;
si 16 sv fric 1.5 kfric 1.5;
si 17 sv fric 1.5 kfric 1.5;
si 18 sv fric 1.5 kfric 1.5;
si 19    tied;
si 20    tied;
si 21    tied;
si 22    tied;
si 23    tied;
si 24    tied;
si 25 sv fric 0.7 kfric 0.7;
si 26 sv fric 0.7 kfric 0.7;
si 27 sv fric 0.7 kfric 0.7;
si 28 sv fric 0.7 kfric 0.7;
si 29 sv fric 0.7 kfric 0.7;
si 30 sv fric 0.7 kfric 0.7;
si 31 sv fric 0.0 kfric 0.0;
si 32 sv fric 1.5 kfric 1.5;
si 33 sv fric 1.5 kfric 1.5;
c
c ... define two planes of symmetry
c
plane 2   0. 0.0 0.   0. -1. 0.   0.005 symm
          0. 0.1 0.   0.  1. 0.   0.005 symm
c
c ... define gravity loading time history
c
lcd   1  5
0.0   0.0
0.02  0.1
0.06  0.9
0.08  1.0
10.00 1.0
c
c ... define velocity time history for blast simulation, one for each node
c
lcd   2 11
 0.000E+00  0.000E+00
 0.839E-01  0.000E+00
 0.849E-01  0.100E+01
 0.889E-01  0.886E+00
 0.939E-01  0.781E+00
 0.104E+00  0.599E+00
 0.134E+00  0.221E+00
 0.184E+00 -0.059E+00
 0.284E+00 -0.127E+00
 0.500E+00  0 000E+00
```

0.200E+01	0.000E+00
lcd 3 11	
0.000E+00	0.000E+00
0.830E-01	0.000E+00
0.839E-01	0.100E+01
0.880E-01	0.874E+00
0.930E-01	0.760E+00
0.103E+00	0.564E+00
0.133E+00	0.174E+00
0.183E+00	-0.865E-01
0.283E+00	-1.165E-01
0.500E+00	0.000E+00
0.200E+01	0.000E+00
lcd 4 11	
0.000E+00	0.000E+00
0.821E-01	0.000E+00
0.829E-01	0.100E+01
0.871E-01	0.860E+00
0.921E-01	0.736E+00
0.102E+00	0.525E+00
0.132E+00	0.126E+00
0.182E+00	-1.086E-01
0.282E+00	-1.021E-01
0.500E+00	0.000E+00
0.200E+01	0.000E+00
lcd 5 11	
0.000E+00	0.000E+00
0.817E-01	0.000E+00
0.824E-01	0.100E+01
0.867E-01	0.853E+00
0.917E-01	0.723E+00
0.102E+00	0.505E+00
0.132E+00	0.121E+00
0.182E+00	-1.171E-01
0.282E+00	-9.420E-02
0.500E+00	0.000E+00
0.200E+01	0.000E+00
lcd 6 11	
0.000E+00	0.000E+00
0.814E-01	0.000E+00
0.821E-01	0.100E+01
0.864E-01	0.848E+00
0.914E-01	0.714E+00
0.101E+00	0.491E+00
0.131E+00	0.870E-01
0.181E+00	-1.220E-01
0.281E+00	-8.860E-02
0.500E+00	0.000E+00
0.200E+01	0.000E+00
lcd 7 11	
0.000E+00	0.000E+00
0.813E-01	0.000E+00
0.820E-01	0.100E+01
0.863E-01	0.846E+00

```
 0.913E-01  0.710E+00
 0.101E+00  0.484E+00
 0.131E+00  0.798E-01
 0.181E+00 -1.240E-01
 0.281E+00 -8.600E-02
 0.500E+00  0.000E+00
 0.200E+01  0.000E+00
lcd   8 11
 0.000E+00  0.000E+00
 0.811E-01  0.000E+00
 0.818E-01  0.100E+01
 0.861E-01  0.843E+00
 0.911E-01  0.704E+00
 0.101E+00  0.476E+00
 0.131E+00  0.707E-01
 0.181E+00 -1.263E-01
 0.281E+00 -8.260E-02
 0.500E+00  0.000E+00
 0.200E+01  0.000E+00
lcd   9 11
 0.000E+00  0.000E+00
 0.810E-01  0.000E+00
 0.817E-01  0.100E+01
 0.860E-01  0.840E+00
 0.910E-01  0.700E+00
 0.101E+00  0.470E+00
 0.131E+00  0.640E-01
 0.181E+00 -1.279E-01
 0.281E+00 -8.010E-02
 0.500E+00  0.000E+00
 0.200E+01  0.000E+00
lcd  10 11
 0.000E+00  0.000E+00
 0.808E-01  0.000E+00
 0.815E-01  0.100E+01
 0.858E-01  0.836E+00
 0.908E-01  0.692E+00
 0.101E+00  0.457E+00
 0.131E+00  0.507E-01
 0.181E+00 -1.306E-01
 0.281E+00 -7.490E-02
 0.500E+00  0.000E+00
 0.200E+01  0.000E+00
lcd  11 11
 0.000E+00  0.000E+00
 0.806E-01  0.000E+00
 0.813E-01  0.100E+01
 0.856E-01  0.831E+00
 0.906E-01  0.683E+00
 0.101E+00  0.444E+00
 0.131E+00  0.386E-01
 0.181E+00 -1.325E-01
 0.281E+00 -7.020E-02
 0.500E+00  0.000E+00
```

```
 0.200E+01  0.000E+00
lcd  12 11
 0.000E+00  0.000E+00
 0.805E-01  0.000E+00
 0.812E-01  0.100E+01
 0.855E-01  0.829E+00
 0.905E-01  0.680E+00
 0.101E+00  0.439E+00
 0.131E+00  0.334E-01
 0.181E+00 -1.332E-01
 0.281E+00 -6.820E-02
 0.500E+00  0.000E+00
 0.200E+01  0.000E+00
lcd  13 11
 0.000E+00  0.000E+00
 0.804E-01  0.000E+00
 0.810E-01  0.100E+01
 0.854E-01  0.826E+00
 0.904E-01  0.675E+00
 0.100E+00  0.432E+00
 0.130E+00  0.271E-01
 0.180E+00 -1.339E-01
 0.280E+00 -6.570E-02
 0.500E+00  0.000E+00
 0.200E+01  0.000E+00
lcd  14 11
 0.000E+00  0.000E+00
 0.803E-01  0.000E+00
 0.810E-01  0.100E+01
 0.853E-01  0.824E+00
 0.903E-01  0.672E+00
 0.100E+00  0.428E+00
 0.130E+00  0.226E-01
 0.180E+00 -1.343E-01
 0.280E+00 -6.390E-02
 0.500E+00  0.000E+00
 0.200E+01  0.000E+00
lcd  15 11
 0.000E+00  0.000E+00
 0.802E-01  0.000E+00
 0.808E-01  0.100E+01
 0.852E-01  0.821E+00
 0.902E-01  0.666E+00
 0.100E+00  0.419E+00
 0.130E+00  0.146E-01
 0.180E+00 -1.349E-01
 0.280E+00 -6.080E-02
 0.500E+00  0.000E+00
 0.200E+01  0.000E+00
lcd  16 11
 0.000E+00  0.000E+00
 0.801E-01  0.000E+00
 0.807E-01  0.100E+01
 0.851E-01  0.818E+00
```

```
 0.901E-01  0.662E+00
 0.100E+00  0.412E+00
 0.130E+00  0.840E-02
 0.180E+00 -1.352E-01
 0.280E+00 -5.830E-02
 0.500E+00  0.000E+00
 0.200E+01  0.000E+00
lcd  17 11
 0.000E+00  0.000E+00
 0.801E-01  0.000E+00
 0.807E-01  0.100E+01
 0.851E-01  0.817E+00
 0.901E-01  0.660E+00
 0.100E+00  0.409E+00
 0.130E+00  0.620E-02
 0.180E+00 -1.353E-01
 0.280E+00 -5.740E-02
 0.500E+00  0.000E+00
 0.200E+01  0.000E+00
lcd  18 11
 0.000E+00  0.000E+00
 0.800E-01  0.000E+00
 0.806E-01  0.100E+01
 0.850E-01  0.816E+00
 0.900E-01  0.658E+00
 0.100E+00  0.407E+00
 0.130E+00  0.390E-02
 0.180E+00 -1.353E-01
 0.280E+00 -5.650E-02
 0.500E+00  0.000E+00
 0.200E+01  0.000E+00
lcd  19 11
 0.000E+00  0.000E+00
 0.800E-01  0.000E+00
 0.806E-01  0.100E+01
 0.850E-01  0.816E+00
 0.900E-01  0.657E+00
 0.100E+00  0.405E+00
 0.130E+00  0.270E-02
 0.180E+00 -1.353E-01
 0.280E+00 -5.600E-02
 0.500E+00  0.000E+00
 0.200E+01  0.000E+00
lcd  20 11
 0.000E+00  0.000E+00
 0.800E-01  0.000E+00
 0.806E-01  0.100E+01
 0.850E-01  0.815E+00
 0.900E-01  0.656E+00
 0.100E+00  0.404E+00
 0.130E+00  0.160E-02
 0.180E+00 -1.353E-01
 0.280E+00 -5.560E-02
 0.500E+00  0.000E+00
```

```
 0.200E+01  0.000E+00
lcd  21 11
 0.000E+00  0.000E+00
 0.800E-01  0.000E+00
 0.806E-01  0.100E+01
 0.850E-01  0.816E+00
 0.900E-01  0.657E+00
 0.100E+00  0.405E+00
 0.130E+00  0.270E-02
 0.180E+00 -1.353E-01
 0.280E+00 -5.600E-02
 0.500E+00  0.000E+00
 0.200E+01  0.000E+00
lcd  22 11
 0.000E+00  0.000E+00
 0.800E-01  0.000E+00
 0.806E-01  0.100E+01
 0.850E-01  0.816E+00
 0.900E-01  0.658E+00
 0.100E+00  0.407E+00
 0.130E+00  0.390E-02
 0.180E+00 -1.353E-01
 0.280E+00 -5.650E-02
 0.500E+00  0.000E+00
 0.200E+01  0.000E+00
lcd  23 11
 0.000E+00  0.000E+00
 0.801E-01  0.000E+00
 0.807E-01  0.100E+01
 0.851E-01  0.817E+00
 0.901E-01  0.660E+00
 0.100E+00  0.409E+00
 0.130E+00  0.620E-02
 0.180E+00 -1.353E-01
 0.280E+00 -5.740E-02
 0.500E+00  0.000E+00
 0.200E+01  0.000E+00
lcd  24 11
 0.000E+00  0.000E+00
 0.801E-01  0.000E+00
 0.807E-01  0.100E+01
 0.851E-01  0.818E+00
 0.901E-01  0.662E+00
 0.100E+00  0.412E+00
 0.130E+00  0.840E-02
 0.180E+00 -1.352E-01
 0.280E+00 -5.830E-02
 0.500E+00  0.000E+00
 0.200E+01  0.000E+00
lcd  25 11
 0.000E+00  0.000E+00
 0.802E-01  0.000E+00
 0.808E-01  0.100E+01
 0.852E-01  0.821E+00
```

```
 0.902E-01   0.666E+00
 0.100E+00   0.419E+00
 0.130E+00   0.146E-01
 0.180E+00  -1.349E-01
 0.280E+00  -6.080E-02
 0.500E+00   0.000E+00
 0.200E+01   0.000E+00
lcd  26 11
 0.000E+00   0.000E+00
 0.803E-01   0.000E+00
 0.810E-01   0.100E+01
 0.853E-01   0.824E+00
 0.903E-01   0.672E+00
 0.100E+00   0.428E+00
 0.130E+00   0.226E-01
 0.180E+00  -1.343E-01
 0.280E+00  -6.390E-02
 0.500E+00   0.000E+00
 0.200E+01   0.000E+00
lcd  27 11
 0.000E+00   0.000E+00
 0.804E-01   0.000E+00
 0.810E-01   0.100E+01
 0.854E-01   0.826E+00
 0.904E-01   0.675E+00
 0.100E+00   0.432E+00
 0.130E+00   0.271E-01
 0.180E+00  -1.339E-01
 0.280E+00  -6.570E-02
 0.500E+00   0.000E+00
 0.200E+01   0.000E+00
lcd  28 11
 0.000E+00   0.000E+00
 0.805E-01   0.000E+00
 0.812E-01   0.100E+01
 0.855E-01   0.829E+00
 0.905E-01   0.680E+00
 0.101E+00   0.439E+00
 0.131E+00   0.334E-01
 0.181E+00  -1.332E-01
 0.281E+00  -6.820E-02
 0.500E+00   0.000E+00
 0.200E+01   0.000E+00
lcd  29 11
 0.000E+00   0.000E+00
 0.806E-01   0.000E+00
 0.813E-01   0.100E+01
 0.856E-01   0.831E+00
 0.906E-01   0.683E+00
 0.101E+00   0.444E+00
 0.131E+00   0.386E-01
 0.181E+00  -1.325E-01
 0.281E+00   7.020E-02
 0.500E+00   0.000E+00
```

```
 0.200E+01  0.000E+00
lcd  30 11
 0.000E+00  0.000E+00
 0.808E-01  0.000E+00
 0.815E-01  0.100E+01
 0.858E-01  0.836E+00
 0.908E-01  0.692E+00
 0.101E+00  0.457E+00
 0.131E+00  0.507E-01
 0.181E+00 -1.306E-01
 0.281E+00 -7.490E-02
 0.500E+00  0.000E+00
 0.200E+01  0.000E+00
lcd  31 11
 0.000E+00  0.000E+00
 0.810E-01  0.000E+00
 0.817E-01  0.100E+01
 0.860E-01  0.840E+00
 0.910E-01  0.700E+00
 0.101E+00  0.470E+00
 0.131E+00  0.640E-01
 0.181E+00 -1.279E-01
 0.281E+00 -8.010E-02
 0.500E+00  0.000E+00
 0.200E+01  0.000E+00
lcd  32 11
 0.000E+00  0.000E+00
 0.811E-01  0.000E+00
 0.818E-01  0.100E+01
 0.861E-01  0.843E+00
 0.911E-01  0.704E+00
 0.101E+00  0.476E+00
 0.131E+00  0.707E-01
 0.181E+00 -1.263E-01
 0.281E+00 -8.260E-02
 0.500E+00  0.000E+00
 0.200E+01  0.000E+00
lcd  33 11
 0.000E+00  0.000E+00
 0.813E-01  0.000E+00
 0.820E-01  0.100E+01
 0.863E-01  0.846E+00
 0.913E-01  0.710E+00
 0.101E+00  0.484E+00
 0.131E+00  0.798E-01
 0.181E+00 -1.240E-01
 0.281E+00 -8.600E-02
 0.500E+00  0.000E+00
 0.200E+01  0.000E+00
lcd  34 11
 0.000E+00  0.000E+00
 0.814E-01  0.000E+00
 0.821E-01  0.100E+01
 0.864E-01  0.848E+00
```

```
 0.914E-01  0.714E+00
 0.101E+00  0.491E+00
 0.131E+00  0.870E-01
 0.181E+00 -1.220E-01
 0.282E+00 -8.860E-02
 0.500E+00  0.000E+00
 0.200E+01  0.000E+00
lcd  35 11
 0.000E+00  0 000E+00
 0.817E-01  0.000E+00
 0.824E-01  0.100E+01
 0.867E-01  0.853E+00
 0.917E-01  0.723E+00
 0.102E+00  0.505E+00
 0.132E+00  0.121E+00
 0.182E+00 -1.171E-01
 0.282E+00 -9.420E-02
 0.500E+00  0.000E+00
 0.200E+01  0.000E+00
c
c  .. Information for part 1
c
start
c
c ... Define index space for base soil
c
1  10 11 12 27; 1 2; 1 2 3 4 5;
0. 2.7 2.85 3.0 7.5
0. 0.10
0. 0.6 1.2 1.80 2.10
c
c ... define boundary conditions on bottom
c
b  1 1 1   5 2 1   101000
c
c ... place nonreflecting boundary at left hand side
c
nri -1; 1 2; 1 5;
c
c ... define master surface between base and bottom facing element
c
sii-  1 5; 1 2; -5; 32 m 8. 0. 0.
c
c ... define material used in part 1
c
mate 1
c
c ... end definition of part 1
c
end
c
c ... Information for part 2
c
start
```

```
c
c ... define index space for reinforced soil above and below reinforcement
c
1 16; 1 2; 1 2 3 4 0 6 7 8 9 10 11 12 0 14 15 16 17 18 19 20 0
22 23 24 25 26 27 28 0 30 31 32 33 34 35 36 0 38 39 40 41 42 43 44 0 46
47 48 49;
3.0 7.5
0. 0.1
2.10   2.31   2.41   2.4625 2.4625 2.4875 2.54   2.64   2.85   3.06
3.16   3.2125 3.2125 3.2375 3.29   3.39   3.6    3.81   3.91   3.9625
3.9625 3.9875 4.04   4.14   4.35   4.56   4.66   4.7125 4.7125 4.7375
4.79   4.89   5.1    5.31   5.41   5.4625 5.4625 5.4875 5.54   5.64 5.85
6.06   6.16   6.2125 6.2125 6.2375 6.29   6.39   6.6
c
c ... define slave surface for sliding between soil and wall
c
sii- -1; 1 2; 1 9; 25 s 8. 0.05 4.
sii- -1; 1 2; 9 17; 26 s 8. 0.05 4.
sii- -1; 1 2; 17 25; 27 s 8. 0.05 4.
sii- -1; 1 2; 25 33; 28 s 8. 0.05 4.
sii- -1; 1 2; 33 41; 29 s 8. 0.05 4.
sii- -1; 1 2; 41 49; 30 s 8. 0.05 4.
c
c ... define master surface  between soil and reinforcement
c
sii- 1 2; 1 2;  -4;  1 m 5. 0.05 0.
sii- 1 2; 1 2;  -6;  2 m 5. 0.05 10.
sii- 1 2; 1 2; -12;  3 m 5. 0.05 0.
sii- 1 2; 1 2; -14;  4 m 5. 0.05 10.
sii- 1 2; 1 2; -20;  5 m 5. 0.05 0.
sii- 1 2; 1 2; -22;  6 m 5. 0.05 10.
sii- 1 2; 1 2; -28;  7 m 5. 0.05 0.
sii- 1 2; 1 2; -30;  8 m 5. 0.05 10
sii- 1 2; 1 2; -36;  9 m 5. 0.05 0.
sii- 1 2; 1 2; -38; 10 m 5. 0.05 10.
sii- 1 2; 1 2; -44; 11 m 5. 0.05 0.
sii- 1 2; 1 2; -46; 12 m 5. 0.05 10.
c
c define slave interface tied with soil to right
c
sii+ -2; 1 2; 1 49; 13 s 10. 0.05 4.
c
c ... define sliding interface with roof
c
sii- 1 2; 1 2; -49; 33 s 5. 0.05 0.
c
c ... define material used in part 2
c
mate 1
c
c ... end definition of part 2
c
end
c
```

```
c ... Information for part 3
c
start
c
c ... define index space for reinforcement
c
1 31; 1 2; 1 4 0 6 9 0 11 14 0 16 19 0 21 24 0 26 29;
3.0 7.5
0. 0.1
2.4625 2.4875 2.4875 3.2125 3.2375 3.2375 3.9625 3.9875 3.9875
4.7125 4.7375 4.7375 5.4625 5.4875 5.4875 6.2125 6.2375
c
c ... define slave surface between reinforcement and soil
c
sii- 1 2; 1 2;  -1;  1 s 5. 0.05 10.
sii- 1 2; 1 2;  -2;  2 s 5. 0.05 0.
sii- 1 2; 1 2;  -4;  3 s 5. 0.05 10.
sii- 1 2; 1 2;  -5;  4 s 5. 0.05 0.
sii- 1 2; 1 2;  -7;  5 s 5. 0.05 10.
sii- 1 2; 1 2;  -8;  6 s 5. 0.05 0.
sii- 1 2; 1 2; -10;  7 s 5. 0.05 10.
sii- 1 2; 1 2; -11;  8 s 5. 0.05 0
sii- 1 2; 1 2; -13;  9 s 5. 0.05 10.
sii- 1 2; 1 2; -14; 10 s 5. 0.05 0.
sii- 1 2; 1 2; -16; 11 s 5. 0.05 10.
sii- 1 2; 1 2; -17; 12 s 5. 0.05 0.
c
c ... define slave surface tied between reinforcement and wall
c
sii+ -1; 1 2;  1  2; 19 s 0. 0.05 4.
sii+ -1; 1 2;  4  5; 20 s 0. 0.05 4.
sii+ -1; 1 2;  7  8; 21 s 0. 0.05 4.
sii+ -1; 1 2; 10 11; 22 s 0. 0.05 4.
sii+ -1; 1 2; 13 14; 23 s 0. 0.05 4.
sii+ -1; 1 2; 16 17; 24 s 0. 0.05 4.
c
c ... define material used in part 3
c
mate 2
c
c ... end definition of part 3
c
end
c
c ... Information for part 4
c
start
c
c ... define index space for soil to right of reinforcment
c
1 6; 1 2; 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35;
7.5  8.0
0.  0.1
```

```
0. 0.6  1.2  1.80 2.10 2.31 2.41 2.54 2.64 2.85 3.06 3.16
3.29 3.39 3.60 3.81 3.91 4.04 4.14 4.35 4.56 4.66 4.79 4.89
5.10 5.31 5.41 5.54 5.64 5.85 6.06 6.16 6.29 6.39 6.6
c
c ... define boundary condition at bottom
c
b 1 1 1  2 2 1   101000
c
c ... define master surfaces with soil to left
c
sii+ -1; 1 2; 5 35; 13 m 0. 0.05 4.
c
c ... define slave surface with rigid body to right
c
sii- -2; 1 2; 1 35; 31 s 0. 0. 4.
c
c ... define velocity loading
c
fv  2 1 2    2 2 2     2   2.270e+00  -1.00  0.00 0.
fv  2 1 3    2 2 3     3   3.226e+00  -1.00  0.00 0.
fv  2 1 4    2 2 4     4   4.591e+00  -1.00  0.00 0.
fv  2 1 5    2 2 5     5   5.453e+00  -1.00  0.00 0.
fv  2 1 6    2 2 6     6   6.128e+00  -1.00  0.00 0.
fv  2 1 7    2 2 7     7   6.468e+00  -1.00  0.00 0.
fv  2 1 8    2 2 8     8   6.927e+00  -1.00  0.00 0.
fv  2 1 9    2 2 9     9   7.290e+00  -1.00  0.00 0.
fv  2 1 10   2 2 10   10   8.075e+00  -1.00  0.00 0.
fv  2 1 11   2 2 11   11   8.869e+00  -1.00  0.00 0.
fv  2 1 12   2 2 12   12   9.242e+00  -1.00  0.00 0.
fv  2 1 13   2 2 13   13   9.715e+00  -1.00  0.00 0.
fv  2 1 14   2 2 14   14   1.006e+01  -1.00  0.00 0.
fv  2 1 15   2 2 15   15   1.073e+01  -1.00  0.00 0.
fv  2 1 16   2 2 16   16   1.129e+01  -1.00  0.00 0.
fv  2 1 17   2 2 17   17   1.150e+01  -1.00  0.00 0.
fv  2 1 18   2 2 18   18   1.171e+01  -1.00  0.00 0.
fv  2 1 19   2 2 19   19   1.183e+01  -1.00  0.00 0.
fv  2 1 20   2 2 20   20   1.193e+01  -1.00  0.00 0.
fv  2 1 21   2 2 21   21   1.183e+01  -1.00  0.00 0.
fv  2 1 22   2 2 22   22   1.171e+01  -1.00  0.00 0.
fv  2 1 23   2 2 23   23   1.150e+01  -1.00  0.00 0.
fv  2 1 24   2 2 24   24   1.129e+01  -1.00  0.00 0.
fv  2 1 25   2 2 25   25   1.073e+01  -1.00  0.00 0.
fv  2 1 26   2 2 26   26   1.006e+01  -1.00  0.00 0.
fv  2 1 27   2 2 27   27   9.715e+00  -1.00  0.00 0.
fv  2 1 28   2 2 28   28   9.242e+00  -1.00  0.00 0.
fv  2 1 29   2 2 29   29   8.869e+00  -1.00  0.00 0.
fv  2 1 30   2 2 30   30   8.075e+00  -1.00  0.00 0.
fv  2 1 31   2 2 31   31   7.290e+00  -1.00  0.00 0.
fv  2 1 32   2 2 32   32   6.927e+00  -1.00  0.00 0.
fv  2 1 33   2 2 33   33   6.468e+00  -1.00  0.00 0.
fv  2 1 34   2 2 34   34   6.128e+00  -1.00  0.00 0.
fv  2 1 35   2 2 35   35   5.453e+00  -1.00  0.00 0.
c
c ... define material used for part 4
```

```
c
mate 1
c
c ... end definition of part 4
c
end
c
c ... Information for part 5a
c
start
c
c define index space for concrete facing - bottom element (block)
c
1 3; 1 2; 1 4;
2.85 3.0
0. 0.1
2.10 2.85
c
c ... define slave surface under concrete wall
c
sii- 1 2; 1 2; -1; 1 s 3. 0.05 10.
c
c define master surface at top of element
c
sii- 1 2; 1 2; -2; 14 m 3. 0.05 0.
c
c ... define master surface with reinforcement
c
sii+ -2; 1 2; 1 2; 19 m 10. 0.05 4.
c
c ... define slave surface under concrete wall
c
sii- 1 2; 1 2; -1; 32 s 3. 0.05 10.
c
c ... define master surface between wall and soil elements
c
sii- -2; 1 2; 1 2; 25 m 0. 0.05 4.
c
c ... define material used for part 5a
c
mate 3
c
c ... end definition of part 5a
c
end
c
c ... Information for part 5b
c
start
c
c ... define index space for concrete facing - bottom element + 1
c
1 3; 1 2; 1 4;
2.85 3.0
```

```
0. 0.1
2.85 3.60
c
c ... define slave surface at bottom of element
c
sii- 1 2; 1 2; -1; 14 s 3. 0.05 10.
c
c ... define master surface at top of element
c
sii- 1 2; 1 2: -2; 15 m 3. 0.05 0.
c
c ... define master surface with reinforcement
c
sii+ -2; 1 2; 1 2; 20 m 10. 0.05 4.
c
c ... define master surface between wall and soil elements
c
sii- -2; 1 2; 1 2; 26 m 0. 0.05 4.
c
c ... define material used for part 5b
c
mate 3
c
c ... end definition of part 5b
c
end
c
c ... Information for part 5c
c
start
c
c define index space for concrete facing - bottom element + 2
c
1 3; 1 2; 1 4:
2.85 3.0
0. 0.1
3.60 4.35
c
c ... define slave surface at bottom of element
c
sii- 1 2; 1 2; -1; 15 s 3. 0.05 10.
c
c ... define master surface at top of element
c
sii- 1 2; 1 2; -2; 16 m 3. 0.05 0.
c
c ... define master surface with reinforcement
c
sii+ -2; 1 2; 1 2; 21 m 10. 0.05 4.
c
c ... define master surface between wall and soil elements
c
sii- -2; 1 2; 1 2; 27 m 0. 0.05 4.
c
```

```
c ... define material used for part 5c
c
mate 3
c
c ... end definition of part 5c
c
end
c
c ... Information for part 5d
c
start
c
c ... define index space for concrete facing - bottom element + 3
c
1 3; 1 2; 1 4;
2.85 3.0
0. 0.1
4.35 5.10
c
c ... define slave surface at bottom of element
c
sii- 1 2; 1 2; -1; 16 s 3. 0.05 10.
c
c ... define master surface at top of element
c
sii- 1 2; 1 2; -2; 17 m 3. 0.05 0.
c
c ... define master surface with reinforcement
c
sii+ -2; 1 2; 1 2; 22 m 10. 0.05 4.
c
c ... define master surface between wall and soil elements
c
sii- -2; 1 2; 1 2; 28 m 0. 0.05 4.
c
c ... define material used for part 5d
c
mate 3
c
c ... end definition of part 5d
c
end
c
c ... Information for part 5e
c
start
c
c ... define index space for concrete facing - bottom element + 4
c
1 3; 1 2; 1 4;
2.85 3.0
0. 0.1
5.10 5.85
c
```

```
c ... define slave surface at bottom of element
c
sii- 1 2; 1 2; -1; 17 s 3. 0.05 10.
c
c ... define master surface at top of element
c
sii- 1 2; 1 2; -2; 18 m 3. 0.05 0.
c
c ... define master surface with reinforcement
c
sii+ -2; 1 2; 1 2; 23 m 10. 0.05 4.
c
c ... define master surface between wall and soil elements
c
sii- -2; 1 2; 1 2; 29 m 0. 0.05 4.
c
c ... define material used for part 5e
c
mate 3
c
c ... end definition of part 5e
c
end
c
c ... Information for part 5f
c
start
c
c ... define index space for concrete facing - top element
c
1 3; 1 2; 1 4;
2.85 3.0
0. 0.1
5.85 6.60
c
c ... define slave surface at top with roof
c
sii- 1 2; 1 2; -2; 33 s 3. 0.05 0.
c
c ... define slave surface at bottom of element
c
sii- 1 2; 1 2; -1; 18 s 3. 0.05 10.
c
c ... define master surface with reinforcement
c
sii+ -2; 1 2; 1 2; 24 m 10. 0.05 4.
c
c ... define master surface between wall and soil elements
c
sii- -2; 1 2; 1 2; 30 m 0. 0.05 4.
c
c ... fix top of this facing element in x-direction
c
b 1 1 2 1 2 2 100000
```

```
c
c ... define material used in part 5f
c
mate 3
c
c ... end definition of part 5f
c
end
c
c ... Information for part 6
c
start
c
c ... define index space for elastic elements to right of mesh
c
1 3; 1 2; 1 11;
8.0 8.5
0. 0.1
0. 6.6
c
c ... define master surface between soil and rigid rhs
c
sii- -1; 1 2; 1 2; 31 m 10. 0. 4.
c
c ... define boundary conditions for rigid rhs
c
b  1 1 1  2 2  2  111111
c
c ... define material used for part 6
c
mate 3
c
c ... end definition of part 6
c
end
c
c ... Information for part 7
c
start
c
c define index space for roof
c
1 2; 1 2; 1 2;
2.0 3.15
0. 0.1
6.6 7.0
c
c ... fix roof in all directions
c
b 1 1 1   2 2 2  111111
c
c ... define master surface between roof and upper facing
c
sii- 1 2; 1 2- -1; 33 m  3. 0.05 10.
```

```
c
c ... define material used for part 7
c
mate 3
c
c ... end definition of part 7
c
end
c
c ... define material properties for soil (material #1)
c
mat 1  25
k      4.6e8
g      2.758e8
c  alpha  0.
alpha 8.0e3
gamma  0.
c theta  0.2729
theta  0.263
beta   9.718e-8
r      2.5
d      9.718e-8
w      0.066
x0     1.3e6
nplot  3
ltype  1
t      -6.895e3
ro     2000.
c
c ... end definition of material properties for soil
c
endmat
c
c ... define material properties for reinforcing (material #2)
c
mat 2  3
e      3.7e7
pr     0.4
sigy   3.6e6
etan   3.7e5
beta   0.
ro     1000.
c
c ... end definition of material properties for reinforcing
c
endmat
c
c ... define material properties for facing, roof and right hand side
c     (Material #3)
c
mat 3   1
e      2.07e10
pr     0.25
ro     2720.
```

```
c
c ... end definition of material properties for facing roof and rhs
c
endmat
c
c ... end ingrid
c
end
```

```
c
c
c  ... interactive commands necessary for generation of DYNA input deck
c
c
c
c  ... remove redundant nodes between parts
c
tp 0.001
c
c  ... additional interactive commands may be used to check the mesh
c
c
c  ... generate DYNA input file
c
cont
```

C. EXAMPLE OF DYNA3D INPUT FILE

The following is an example of a DYNA3D input file. Lines beginning with "*comment* were added by the authors. Lines beginning with just a "*" are comments generated by INGRID. Input data not generated by INGRID are clearly marked by *comment* lines.

```
parametric study - base input file (plane strain)                      88 large
*                                                                      88 large
*
*----------------- ANALYSIS INPUT DATA FOR DYNA3D 88 -----------------*
* Generated with INGRID  version  10/17/89 by Robert Rainsberger.
*
*
*------------------------- CONTROL CARD #1 ---------------------------*
*
* number of materials[1] nodal points[2] solid hexahedron elements[3] beam
* elements[4] 4-node shell elements[5] 8-node solid shell elements[6]
    3      3520      1309          0          0          0
*
*------------------------- CONTROL CARD #2 ---------------------------*
*
* number of time history blocks for nodes[1] hexahedron elements[2] beam
* elements[3] shell elements[4] thick shell elements[5] and report interval[6]
    0    0    0    0    0    0
*comment* The number of time history blocks for nodes and elements has been
*comment* added by hand in this study, not generated by INGRID.  The data for
*comment* Analysis PS1 are shown below.
   15   26    0    0    0    0
*comment*
*
*------------------------- CONTROL CARD #3 ---------------------------*
*
* number of nodes in DYNA3D-JOY interface[1] number of sliding boundary
* planes[2] sliding boundary planes w/ failure[3] points in density vs depth
* curve[4] brode function flag[5] number of rigid body merge cards[6]
* nodal coordinate format[7]
    0    0    0    0    0    0e20.9
*
*------------------------- CONTROL CARD #4 ---------------------------*
*
* number of load curves[1] concentrated nodal loads[2] element sides having
* pressure loads applied[3] velocity/acceleration boundary condition cards[4]
```

```
* rigid walls (stonewalls)[5] nodal constraint cards[6] initial condition
* parameter[7] sliding interfaces[8] base acceleration in x[9] y[10] and
* z-direction[11] angular velocity about x[12] y[13] and z-axis[14] number of
* solid hexahedron elements for momentum deposit[15] detonation points[16]
   35    0    0   68    0    0    0   33    0    0    1    0    0    0    0    0
*
*-------------------------- CONTROL CARD #5 --------------------------*
*
* termination time[1] time history dump interval[2] complete dump interval[3]
* time steps between restart dumps[4] time steps between running restart
* dumps[5] initial time step[6] sliding interface penalty factor[7] thermal
* effects option[8] default viscosity flag[9] computed time step factor[10]
 8.000E-02 4.000E-02 4.000E-02    0    0 0.000E+00 0.000E+00    0    0 0.000E+00
*
*-------------------------- CONTROL CARD #6 --------------------------*
*
* number of joint definitions[1] rigid bodies with extra nodes[2] shell-
* solid interfaces[3] tie-breaking shell slidelines[4] tied node sets with
* failure[5] limiting time step load curve number[6] springs-dampers-masses
* flag[7] rigid bodies with inertial properties[8] dump shell strain flag[9]
* shadow burn flag[10] dump hydro variables flag[11] shell update[12]
* thickness[13] and theory options[14] number of nonreflecting
* boundary segments[15]
    0    0    0    0    0    0    0    0    0    0    0    0    0    0    4
*
*-------------------------- CONTROL CARD #7 --------------------------*
*
* number of point constraint nodes[1] coordinate systems for constraint
* nodes[2] minimum step factor[3] number of beam integration rules[4]
* maximum integration points for beams[5] number of shell integration rules[6]
* maximum integration points for shells[7] relaxation iterations between
* checks[8] relaxation tolerance[9] dynamic relaxation factor[10] dynamic
* relaxation time step factor[11] 4-node shell time step option[12]
    0    0 0.000E+00    0    0    0    0  250 1.000E-04 9.950E-01 0.000E+00    0
*
*-------------------------- CONTROL CARD #8 --------------------------*
*
* plane stress plasticity[1] printout flag[2] number of 1D slidelines[3]
    1    0    0
*comment* the mass proportional rayleigh damping term must be input by hand
*comment* in cols 21-30 on the above line since this cannot be done by INGRID.
*comment* the data for analysis PS1 is shown below:
    1    0    0      1.000e+01
*comment*
*
*-------------------------- MATERIAL CARDS --------------------------*
*
    1   252.0000E+03    0    00.0000E+00    00.0000E+000.0000E+00    0    0    0
material type # 25 (invicid two invariant geologic cap model)
 4.600E+08 2.758E+08 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00
 8.000E+03 2.630E-01 0.000E+00 9.718E-08 2.500E+00 0.000E+00 0.000E+00 0.000E+00
 9.718E-08 6.600E-02 1.300E+06 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00
 3.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00
 1.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00
```

```
-6.895E+03 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00
    2    31.0000E+03    0     00.0000E+00     00.0000E+000.0000E+00    0    0    0
material type # 3 (Kinematic/Isotropic elastic-plastic)
 3.700E+07 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00
 4.000E-01 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00
 3.600E+06 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00
 3.700E+05 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00
 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00
 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00
    3    12.7200E+03    0     00.0000E+00     00.0000E+000.0000E+00    0    0    0
material type # 1  (elastic)
 2.070E+10 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00
 2.500E-01 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00
 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00
 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00
 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00
 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00
*
*------------------------- NODE DEFINITIONS -------------------------*
*
      1   7. 0.0000000000000E+00 0.0000000000000E+00 0.0000000000000E+00   7.
      2   2. 0.0000000000000E+00 0.0000000000000E+00 6.0000002384186E-01   7.
      3   7. 0.0000000000000E+00 1.0000000149012E-01 0.0000000000000E+00   7.
      4   2. 0.0000000000000E+00 1.0000000149012E-01 6.0000002384186E-01   7.
*comment*
*comment* data for nodes 5-3516 are omitted so save space
*comment*
   3517   7. 3.1500000953674E+00 0.0000000000000E+00 6.5999999046326E+00   7.
   3518   7. 3.1500000953674E+00 0.0000000000000E+00 7.0000000000000E+00   7.
   3519   7. 3.1500000953674E+00 1.0000000149012E-01 6.5999999046326E+00   7.
   3520   7. 3.1500000953674E+00 1.0000000149012E-01 7.0000000000000E+00   7.
*
*------------------ ELEMENT CARDS FOR SOLID ELEMENTS ------------------*
*
      1    1      1      5      7      3      2      6      8      4
      2    1      5      9     11      7      6     10     12      8
      3    1      9     13     15     11     10     14     16     12
      4    1     13     17     19     15     14     18     20     16
*comment*
*comment* data for elements 5-1305 are omitted so save space
*comment*
   1306    3   3477   3499   3510   3488   3478   3500   3511   3489
   1307    3   3456   3478   3489   3467   3457   3479   3490   3468
   1308    3   3478   3500   3511   3489   3479   3501   3512   3490
   1309    3   3513   3517   3519   3515   3514   3518   3520   3516
*comment*
*comment*
*comment* Node time history blocks and element time history blocks were entered by
*comment* hand in this study.  The data for analysis PS1 are shown below:
*comment*
*comment**
*-----------------------NODE TIME HISTORY BLOCKS----------------------*
*
    109    109   3303   3303   3306   3306   3327   3327   3330   3330
```

```
    3351      3351      3354      3354      3375      3375      3378      3378      3399      3399
    3402      3402      3423      3423      3426      3426       911       911       879       879
*
*----------------- SOLID ELEMENT TIME HISTORY BOCKS -----------------*
*
     360       374      1203      1203      1237      1237       645       645       675       675
     705       705       735       735       765       765       795       795       825       825
     855       855       885       885       915       915       945       945       975       975
    1005      1005      1035      1035      1065      1065      1095      1095      1125      1125
    1155      1155       285       285       300       300       315       315       330       330
     345       345
*comment*
*comment* load curve definitions are generated by INGRID
*comment*
*
*----------------------- LOAD CURVE DEFINITIONS ---------------------*
*
    1    5
 0.000E+00 0.000E+00
 0.200E-01 0.100E+00
 0.600E-01 0.900E+00
 0.800E-01 0.100E+01
 0.100E+02 0.100E+01
    2   11
 0.000E+00 0.000E+00
 0.839E-01 0.000E+00
 0.849E-01 0.100E+01
 0.889E-01 0.886E+00
 0.939E-01 0.781E+00
 0.104E+00 0.599E+00
 0.134E+00 0.221E+00
 0.184E+00-0.590E-01
 0.284E+00-0.127E+00
 0.500E+00 0.000E+00
 0.200E+01 0.000E+00
    3   11
 0.000E+00 0.000E+00
 0.830E-01 0.000E+00
 0.839E-01 0.100E+01
 0.880E-01 0.874E+00
 0.930E-01 0.760E+00
 0.103E+00 0.564E+00
 0.133E+00 0.174E+00
 0.183E+00-0.865E-01
 0.283E+00-0.116E+00
 0.500E+00 0.000E+00
 0.200E+01 0.000E+00
    4   11
 0.000E+00 0.000E+00
 0.821E-01 0.000E+00
 0.829E-01 0.100E+01
 0.871E-01 0.860E+00
 0.921E-01 0.736E+00
 0.102E+00 0.525E+00
```

```
 0.132E+00 0.126E+00
 0.182E+00-0.109E+00
 0.282E+00-0.102E+00
 0.500E+00 0.000E+00
 0.200E+01 0.000E+00
    5    11
 0.000E+00 0.000E+00
 0.817E-01 0.000E+00
 0.824E-01 0.100E+01
 0.867E-01 0.853E+00
 0.917E-01 0.723E+00
 0.102E+00 0.505E+00
 0.132E+00 0.121E+00
 0.182E+00-0.117E+00
 0.282E+00-0.942E-01
 0.500E+00 0.000E+00
 0.200E+01 0.000E+00
    6    11
 0.000E+00 0.000E+00
 0.814E-01 0.000E+00
 0.821E-01 0.100E+01
 0.864E-01 0.848E+00
 0.914E-01 0.714E+00
 0.101E+00 0.491E+00
 0.131E+00 0.870E-01
 0.181E+00-0.122E+00
 0.281E+00-0.886E-01
 0.500E+00 0.000E+00
 0.200E+01 0.000E+00
    7    11
 0.000E+00 0.000E+00
 0.813E-01 0.000E+00
 0.820E-01 0.100E+01
 0.863E-01 0.846E+00
 0.913E-01 0.710E+00
 0.101E+00 0.484E+00
 0.131E+00 0.798E-01
 0.181E+00-0.124E+00
 0.281E+00-0.860E-01
 0.500E+00 0.000E+00
 0.200E+01 0.000E+00
    8    11
 0.000E+00 0.000E+00
 0.811E-01 0.000E+00
 0.818E-01 0.100E+01
 0.861E-01 0.843E+00
 0.911E-01 0.704E+00
 0.101E+00 0.476E+00
 0.131E+00 0.707E-01
 0.181E+00-0.126E+00
 0.281E+00-0.826E-01
 0.500E+00 0.000E+00
 0.200E+01 0.000E+00
    9    11
```

0.000E+00	0.000E+00
0.810E-01	0.000E+00
0.817E-01	0.100E+01
0.860E-01	0.840E+00
0.910E-01	0.700E+00
0.101E+00	0.470E+00
0.131E+00	0.640E-01
0.181E+00	-0.128E+00
0.281E+00	-0.801E-01
0.500E+00	0.000E+00
0.200E+01	0.000E+00
10	11
0.000E+00	0.000E+00
0.808E-01	0.000E+00
0.815E-01	0.100E+01
0.858E-01	0.836E+00
0.908E-01	0.692E+00
0.101E+00	0.457E+00
0.131E+00	0.507E-01
0.181E+00	-0.131E+00
0.281E+00	-0.749E-01
0.500E+00	0.000E+00
0.200E+01	0.000E+00
11	11
0.000E+00	0.000E+00
0.806E-01	0.000E+00
0.813E-01	0.100E+01
0.856E-01	0.831E+00
0.906E-01	0.683E+00
0.101E+00	0.444E+00
0.131E+00	0.386E-01
0.181E+00	-0.132E+00
0.281E+00	-0.702E-01
0.500E+00	0.000E+00
0.200E+01	0.000E+00
12	11
0.000E+00	0.000E+00
0.805E-01	0.000E+00
0.812E-01	0.100E+01
0.855E-01	0.829E+00
0.905E-01	0.680E+00
0.101E+00	0.439E+00
0.131E+00	0.334E-01
0.181E+00	-0.133E+00
0.281E+00	-0.682E-01
0.500E+00	0.000E+00
0.200E+01	0.000E+00
13	11
0.000E+00	0.000E+00
0.804E-01	0.000E+00
0.810E-01	0.100E+01
0.854E-01	0.826E+00
0.904E-01	0.675E+00
0.100E+00	0.432E+00

```
0.130E+00 0.271E-01
0.180E+00-0.134E+00
0.280E+00-0.657E-01
0.500E+00 0.000E+00
0.200E+01 0.000E+00
  14    11
0.000E+00 0.000E+00
0.803E-01 0.000E+00
0.810E-01 0.100E+01
0.853E-01 0.824E+00
0.903E-01 0.672E+00
0.100E+00 0.428E+00
0.130E+00 0.226E-01
0.180E+00-0.134E+00
0.280E+00-0.639E-01
0.500E+00 0.000E+00
0.200E+01 0.000E+00
  15    11
0.000E+00 0.000E+00
0.802E-01 0.000E+00
0.808E-01 0.100E+01
0.852E-01 0.821E+00
0.902E-01 0.666E+00
0.100E+00 0.419E+00
0.130E+00 0.146E-01
0.180E+00-0.135E+00
0.280E+00-0.608E-01
0.500E+00 0.000E+00
0.200E+01 0.000E+00
  16    11
0.000E+00 0.000E+00
0.801E-01 0.000E+00
0.807E-01 0.100E+01
0.851E-01 0.818E+00
0.901E-01 0.662E+00
0.100E+00 0.412E+00
0.130E+00 0.840E-02
0.180E+00-0.135E+00
0.280E+00-0.583E-01
0.500E+00 0.000E+00
0.200E+01 0.000E+00
  17    11
0.000E+00 0.000E+00
0.801E-01 0.000E+00
0.807E-01 0.100E+01
0.851E-01 0.817E+00
0.901E-01 0.660E+00
0.100E+00 0.409E+00
0.130E+00 0.620E-02
0.180E+00-0.135E+00
0.280E+00-0.574E-01
0.500E+00 0.000E+00
0.200E+01 0.000E+00
  18    11
```

```
 0.000E+00  0.000E+00
 0.800E-01  0.000E+00
 0.806E-01  0.100E+01
 0.850E-01  0.816E+00
 0.900E-01  0.658E+00
 0.100E+00  0.407E+00
 0.130E+00  0.390E-02
 0.180E+00 -0.135E+00
 0.280E+00 -0.565E-01
 0.500E+00  0.000E+00
 0.200E+01  0.000E+00
   19    11
 0.000E+00  0.000E+00
 0.800E-01  0.000E+00
 0.806E-01  0.100E+01
 0.850E-01  0.816E+00
 0.900E-01  0.657E+00
 0.100E+00  0.405E+00
 0.130E+00  0.270E-02
 0.180E+00 -0.135E+00
 0.280E+00 -0.560E-01
 0.500E+00  0.000E+00
 0.200E+01  0.000E+00
   20    11
 0.000E+00  0.000E+00
 0.800E-01  0.000E+00
 0.806E-01  0.100E+01
 0.850E-01  0.815E+00
 0.900E-01  0.656E+00
 0.100E+00  0.404E+00
 0.130E+00  0.160E-02
 0.180E+00 -0.135E+00
 0.280E+00 -0.556E-01
 0.500E+00  0.000E+00
 0.200E+01  0.000E+00
   21    11
 0.000E+00  0.000E+00
 0.800E-01  0.000E+00
 0.806E-01  0.100E+01
 0.850E-01  0.816E+00
 0.900E-01  0.657E+00
 0.100E+00  0.405E+00
 0.130E+00  0.270E-02
 0.180E+00 -0.135E+00
 0.280E+00 -0.560E-01
 0.500E+00  0.000E+00
 0.200E+01  0.000E+00
   22    11
 0.000E+00  0.000E+00
 0.800E-01  0.000E+00
 0.806E-01  0.100E+01
 0.850E-01  0.816E+00
 0.900E-01  0.658E+00
 0.100E+00  0.407E+00
```

```
0.130E+00 0.390E-02
0.180E+00-0.135E+00
0.280E+00-0.565E-01
0.500E+00 0.000E+00
0.200E+01 0.000E+00
  23    11
0.000E+00 0.000E+00
0.801E-01 0.000E+00
0.807E-01 0.100E+01
0.851E-01 0.817E+00
0.901E-01 0.660E+00
0.100E+00 0.409E+00
0.130E+00 0.620E-02
0.180E+00-0.135E+00
0.280E+00-0.574E-01
0.500E+00 0.000E+00
0.200E+01 0.000E+00
  24    11
0.000E+00 0.000E+00
0.801E-01 0.000E+00
0.807E-01 0.100E+01
0.851E-01 0.818E+00
0.901E-01 0.662E+00
0.100E+00 0.412E+00
0.130E+00 0.840E-02
0.180E+00-0.135E+00
0.280E+00-0.583E-01
0.500E+00 0.000E+00
0.200E+01 0.000E+00
  25    11
0.000E+00 0.000E+00
0.802E-01 0.000E+00
0.808E-01 0.100E+01
0.852E-01 0.821E+00
0.902E-01 0.666E+00
0.100E+00 0.419E+00
0.130E+00 0.146E-01
0.180E+00-0.135E+00
0.280E+00-0.608E-01
0.500E+00 0.000E+00
0.200E+01 0.000E+00
  26    11
0.000E+00 0.000E+00
0.803E-01 0.000E+00
0.810E-01 0.100E+01
0.853E-01 0.824E+00
0.903E-01 0.672E+00
0.100E+00 0.428E+00
0.130E+00 0.226E-01
0.180E+00-0.134E+00
0.280E+00-0.639E-01
0.500E+00 0.000E+00
0.200E+01 0.000E+00
  27    11
```

```
0.000E+00 0.000E+00
0.804E-01 0.000E+00
0.810E-01 0.100E+01
0.854E-01 0.826E+00
0.904E-01 0.675E+00
0.100E+00 0.432E+00
0.130E+00 0.271E-01
0.180E+00-0.134E+00
0.280E+00-0.657E-01
0.500E+00 0.000E+00
0.200E+01 0.000E+00
  28    11
0.000E+00 0.000E+00
0.805E-01 0.000E+00
0.812E-01 0.100E+01
0.855E-01 0.829E+00
0.905E-01 0.680E+00
0.101E+00 0.439E+00
0.131E+00 0.334E-01
0.181E+00-0.133E+00
0.281E+00-0.682E-01
0.500E+00 0.000E+00
0.200E+01 0.000E+00
  29    11
0.000E+00 0.000E+00
0.806E-01 0.000E+00
0.813E-01 0.100E+01
0.856E-01 0.831E+00
0.906E-01 0.683E+00
0.101E+00 0.444E+00
0.131E+00 0.386E-01
0.181E+00-0.132E+00
0.281E+00-0.702E-01
0.500E+00 0.000E+00
0.200E+01 0.000E+00
  30    11
0.000E+00 0.000E+00
0.808E-01 0.000E+00
0.815E-01 0.100E+01
0.858E-01 0.836E+00
0.908E-01 0.692E+00
0.101E+00 0.457E+00
0.131E+00 0.507E-01
0.181E+00-0.131E+00
0.281E+00-0.749E-01
0.500E+00 0.000E+00
0.200E+01 0.000E+00
  31    11
0.000E+00 0.000E+00
0.810E-01 0.000E+00
0.817E-01 0.100E+01
0.860E-01 0.840E+00
0.910E-01 0.700E+00
0.101E+00 0.470E+00
```

```
0.131E+00 0.640E-01
0.181E+00-0.128E+00
0.281E+00-0.801E-01
0.500E+00 0.000E+00
0.200E+01 0.000E+00
  32    11
0.000E+00 0.000E+00
0.811E-01 0.000E+00
0.818E-01 0.100E+01
0.861E-01 0.843E+00
0.911E-01 0.704E+00
0.101E+00 0.476E+00
0.131E+00 0.707E-01
0.181E+00-0.126E+00
0.281E+00-0.826E-01
0.500E+00 0.000E+00
0.200E+01 0.000E+00
  33    11
0.000E+00 0.000E+00
0.813E-01 0.000E+00
0.820E-01 0.100E+01
0.863E-01 0.846E+00
0.913E-01 0.710E+00
0.101E+00 0.484E+00
0.131E+00 0.798E-01
0.181E+00-0.124E+00
0.281E+00-0.860E-01
0.500E+00 0.000E+00
0.200E+01 0.000E+00
  34    11
0.000E+00 0.000E+00
0.814E-01 0.000E+00
0.821E-01 0.100E+01
0.864E-01 0.848E+00
0.914E-01 0.714E+00
0.101E+00 0.491E+00
0.131E+00 0.870E-01
0.181E+00-0.122E+00
0.282E+00-0.886E-01
0.500E+00 0.000E+00
0.200E+01 0.000E+00
  35    11
0.000E+00 0.000E+00
0.817E-01 0.000E+00
0.824E-01 0.100E+01
0.867E-01 0.853E+00
0.917E-01 0.723E+00
0.102E+00 0.505E+00
0.132E+00 0.121E+00
0.182E+00-0.117E+00
0.282E+00-0.942E-01
0.500E+00 0.000E+00
0.200E+01 0.000E+00
*
```

--------- VELOCITY SPECIFICATION FOR NODES AND RIGID BODIES ---------
*

3234	2	4	2.270E+00	-1.000E+00	0.000E+00	0.000E+00	0
3236	2	4	2.270E+00	-1.000E+00	0.000E+00	0.000E+00	0
3237	3	4	3.226E+00	-1.000E+00	0.000E+00	0.000E+00	0
3238	3	4	3.226E+00	-1.000E+00	0.000E+00	0.000E+00	0
3239	4	4	4.591E+00	-1.000E+00	0.000E+00	0.000E+00	0
3240	4	4	4.591E+00	-1.000E+00	0.000E+00	0.000E+00	0
3241	5	4	5.453E+00	-1.000E+00	0.000E+00	0.000E+00	0
3242	5	4	5.453E+00	-1.000E+00	0.000E+00	0.000E+00	0
3243	6	4	6.128E+00	-1.000E+00	0.000E+00	0.000E+00	0
3244	6	4	6.128E+00	-1.000E+00	0.000E+00	0.000E+00	0
3245	7	4	6.468E+00	-1.000E+00	0.000E+00	0.000E+00	0
3246	7	4	6.468E+00	-1.000E+00	0.000E+00	0.000E+00	0
3247	8	4	6.927E+00	-1.000E+00	0.000E+00	0.000E+00	0
3248	8	4	6.927E+00	-1.000E+00	0.000E+00	0.000E+00	0
3249	9	4	7.290E+00	-1.000E+00	0.000E+00	0.000E+00	0
3250	9	4	7.290E+00	-1.000E+00	0.000E+00	0.000E+00	0
3251	10	4	8.075E+00	-1.000E+00	0.000E+00	0.000E+00	0
3252	10	4	8.075E+00	-1.000E+00	0.000E+00	0.000E+00	0
3253	11	4	8.869E+00	-1.000E+00	0.000E+00	0.000E+00	0
3254	11	4	8.869E+00	-1.000E+00	0.000E+00	0.000E+00	0
3255	12	4	9.242E+00	-1.000E+00	0.000E+00	0.000E+00	0
3256	12	4	9.242E+00	-1.000E+00	0.000E+00	0.000E+00	0
3257	13	4	9.715E+00	-1.000E+00	0.000E+00	0.000E+00	0
3258	13	4	9.715E+00	-1.000E+00	0.000E+00	0.000E+00	0
3259	14	4	1.006E+01	-1.000E+00	0.000E+00	0.000E+00	0
3260	14	4	1.006E+01	-1.000E+00	0.000E+00	0.000E+00	0
3261	15	4	1.073E+01	-1.000E+00	0.000E+00	0.000E+00	0
3262	15	4	1.073E+01	-1.000E+00	0.000E+00	0.000E+00	0
3263	16	4	1.129E+01	-1.000E+00	0.000E+00	0.000E+00	0
3264	16	4	1.129E+01	-1.000E+00	0.000E+00	0.000E+00	0
3265	17	4	1.150E+01	-1.000E+00	0.000E+00	0.000E+00	0
3266	17	4	1.150E+01	-1.000E+00	0.000E+00	0.000E+00	0
3267	18	4	1.171E+01	-1.000E+00	0.000E+00	0.000E+00	0
3268	18	4	1.171E+01	-1.000E+00	0.000E+00	0.000E+00	0
3269	19	4	1.183E+01	-1.000E+00	0.000E+00	0.000E+00	0
3270	19	4	1.183E+01	-1.000E+00	0.000E+00	0.000E+00	0
3271	20	4	1.193E+01	-1.000E+00	0.000E+00	0.000E+00	0
3272	20	4	1.193E+01	-1.000E+00	0.000E+00	0.000E+00	0
3273	21	4	1.183E+01	-1.000E+00	0.000E+00	0.000E+00	0
3274	21	4	1.183E+01	-1.000E+00	0.000E+00	0.000E+00	0
3275	22	4	1.171E+01	-1.000E+00	0.000E+00	0.000E+00	0
3276	22	4	1.171E+01	-1.000E+00	0.000E+00	0.000E+00	0
3277	23	4	1.150E+01	-1.000E+00	0.000E+00	0.000E+00	0
3278	23	4	1.150E+01	-1.000E+00	0.000E+00	0.000E+00	0
3279	24	4	1.129E+01	-1.000E+00	0.000E+00	0.000E+00	0
3280	24	4	1.129E+01	-1.000E+00	0.000E+00	0.000E+00	0
3281	25	4	1.073E+01	-1.000E+00	0.000E+00	0.000E+00	0
3282	25	4	1.073E+01	-1.000E+00	0.000E+00	0.000E+00	0
3283	26	4	1.006E+01	-1.000E+00	0.000E+00	0.000E+00	0
3284	26	4	1.006E+01	-1.000E+00	0.000E+00	0.000E+00	0
3285	27	4	9.715E+00	-1.000E+00	0.000E+00	0.000E+00	0
3286	27	4	9.715E+00	-1.000E+00	0.000E+00	0.000E+00	0

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3287    28     4 9.242E+00-1.000E+00 0.000E+00 0.000E+00     0
3288    28     4 9.242E+00-1.000E+00 0.000E+00 0.000E+00     0
3289    29     4 8.869E+00-1.000E+00 0.000E+00 0.000E+00     0
3290    29     4 8.869E+00-1.000E+00 0.000E+00 0.000E+00     0
3291    30     4 8.075E+00-1.000E+00 0.000E+00 0.000E+00     0
3292    30     4 8.075E+00-1.000E+00 0.000E+00 0.000E+00     0
3293    31     4 7.290E+00-1.000E+00 0.000E+00 0.000E+00     0
3294    31     4 7.290E+00-1.000E+00 0.000E+00 0.000E+00     0
3295    32     4 6.927E+00-1.000E+00 0.000E+00 0.000E+00     0
3296    32     4 6.927E+00-1.000E+00 0.000E+00 0.000E+00     0
3297    33     4 6.468E+00-1.000E+00 0.000E+00 0.000E+00     0
3298    33     4 6.468E+00-1.000E+00 0.000E+00 0.000E+00     0
3299    34     4 6.128E+00-1.000E+00 0.000E+00 0.000E+00     0
3300    34     4 6.128E+00-1.000E+00 0.000E+00 0.000E+00     0
3301    35     4 5.[illegible]53E+00-1.000E+00 0.000E+00 0.000E+00     0
3302    35     4 5.[illegible]53E+00-1.000E+00 0.000E+00 0.000E+00     0
*
*-------------------------- SLIDING INTERFACE DEFINITIONS --------------------*
*
   32       15     3 9.000E-01 9.000E-01 0.000E+00     0     0     00.0E+000.0E+00
   30       15     3 9.000E-01 9.000E-01 0.000E+00     0     0     00.0E+000.0E+00
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29	3079	3083	3091	3087
30	3087	3091	3099	3095
1	1455	1457	1458	1456
2	1457	1459	1460	1458
3	1459	1461	1462	1460
4	1461	1463	1464	1462
5	1463	1465	1466	1464
6	1465	1467	1468	1466

7	1467	1469	1470	1468
8	1469	1471	1472	1470
9	1471	1473	1474	1472
10	1473	1475	1476	1474
11	1475	1477	1478	1476
12	1477	1479	1480	1478
13	1479	1481	1482	1480
14	1481	1483	1484	1482
15	1483	1485	1486	1484
1	2858	2866	2870	2862
2	2866	2874	2878	2870
3	2874	2882	2886	2878
4	2882	2890	2894	2886
5	2890	2898	2902	2894
6	2898	2906	2910	2902
7	2906	2914	2918	2910
8	2914	2922	2926	2918
9	2922	2930	2934	2926
10	2930	2938	2942	2934
11	2938	2946	2950	2942
12	2946	2954	2958	2950
13	2954	2962	2966	2958
14	2962	2970	2974	2966
15	2970	2978	2982	2974
16	2978	2986	2990	2982
17	2986	2994	2998	2990
18	2994	3002	3006	2998
19	3002	3010	3014	3006
20	3010	3018	3022	3014
21	3018	3026	3030	3022
22	3026	3034	3038	3030
23	3034	3042	3046	3038
24	3042	3050	3054	3046
25	3050	3058	3062	3054
26	3058	3066	3070	3062
27	3066	3074	3078	3070
28	3074	3082	3086	3078
29	3082	3090	3094	3086
30	3090	3098	3102	3094
1	1487	1489	1493	1491
2	1491	1493	1497	1495
3	1495	1497	1501	1499
4	1499	1501	1505	1503
5	1503	1505	1509	1507
6	1507	1509	1513	1511
7	1511	1513	1517	1515
8	1515	1517	1521	1519
9	1519	1521	1525	1523
10	1523	1525	1529	1527
11	1527	1529	1533	1531
12	1531	1533	1537	1535
13	1535	1537	1541	1539
14	1539	1541	1545	1543
15	1543	1545	1549	1547

1	269	270	302	301
2	301	302	334	333
3	333	334	366	365
4	427	429	430	428
5	428	430	462	461
6	461	462	494	493
7	493	494	526	525
8	525	526	558	557
9	557	558	590	589
10	651	653	654	652
11	652	654	686	685
12	685	686	718	717
13	717	718	750	749
14	749	750	782	781
15	781	782	814	813
16	875	877	878	876
17	876	878	910	909
18	909	910	942	941
19	941	942	974	973
20	973	974	1006	1005
21	1005	1006	1038	1037
22	1099	1101	1102	1100
23	1100	1102	1134	1133
24	1133	1134	1166	1165
25	1165	1166	1198	1197
26	1197	1198	1230	1229
27	1229	1230	1252	1261
28	1323	1325	1326	1324
29	1324	1326	1358	1357
30	1357	1358	1390	1389
31	1389	1390	1422	1421
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34	1547	1549	1550	1548
35	1548	1550	1582	1581
36	1581	1582	1614	1613
1	269	3113	3114	270
2	3113	3117	3118	3114
3	3117	3121	3122	3118
4	3121	3125	3126	3122
5	3125	3129	3130	3126
6	3129	3133	3134	3130
7	3133	3137	3138	3134
8	3137	3141	3142	3138
9	3141	3145	3146	3142
10	3145	3149	3150	3146
11	3149	3153	3154	3150
12	3153	3157	3158	3154
13	3157	3161	3162	3158
14	3161	3165	3166	3162
15	3165	3169	3170	3166
16	3169	3173	3174	3170
17	3173	3177	3178	3174
18	3177	3181	3182	3178

19	3181	3185	3186	3182
20	3185	3189	3190	3186
21	3189	3193	3194	3190
22	3193	3197	3198	3194
23	3197	3201	3202	3198
24	3201	3205	3206	3202
25	3205	3209	3210	3206
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2	3314	3322	3326	3318
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2	3359	3363	3371	3367
1	3330	3338	3342	3334
2	3338	3346	3350	3342
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2	3383	3387	3395	3391
1	3354	3362	3366	3358
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1	3399	3403	3411	3407
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1	3378	3386	3390	3382
2	3386	3394	3398	3390
1	3423	3427	3435	3431
2	3431	3435	3443	3439
1	3402	3410	3414	3406
2	3410	3418	3422	3414
1	1615	1616	1620	1619
2	1616	1617	1621	1620
3	1617	1618	1622	1621
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2	3320	3324	3325	3321
3	3321	3325	3326	3322
1	1963	1864	1868	1867
2	1864	1865	1869	1868
3	1865	1866	1870	1869
1	3343	3347	3348	3344
2	3344	3348	3349	3345
3	3345	3349	3350	3346
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2	2112	2113	2117	2116
3	2113	2114	2118	2117
1	3367	3371	3372	3368
2	3368	3372	3373	3369
3	3369	3373	3374	3370
1	2359	2360	2364	2363
2	2360	2361	2365	2364
3	2361	2362	2366	2365
1	3391	3395	3396	3392

2	3392	3396	3397	3393
3	3393	3397	3398	3394
1	2607	2608	2612	2611
2	2608	2609	2613	2612
3	2609	2610	2614	2613
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2	2856	2857	2861	2860
3	2857	2858	2862	2861
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2	3440	3444	3445	3441
3	3441	3445	3446	3442
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2	271	303	304	272
3	303	335	336	304
4	367	368	370	369
5	368	431	432	370
6	431	463	464	432
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2	3320	3324	3325	3321
3	3321	3325	3326	3322
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2	495	527	528	496
3	527	559	560	528
4	591	592	594	593
5	592	655	656	594
6	655	687	688	656
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2	3344	3348	3349	3345
3	3345	3349	3350	3346
1	687	719	- 720	638
2	719	751	752	720
3	751	783	784	752
4	815	816	818	817
5	816	879	880	818
6	879	911	912	880
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2	3368	3372	3373	3369
3	3369	3373	3374	3370
1	911	943	944	912
2	943	975	976	944
3	975	1007	1008	976
4	1039	1040	1042	1041
5	1040	1103	1104	1042
6	1103	1135	1136	1104
1	3391	3395	3396	3392
2	3392	3396	3397	3393
3	3393	3397	3398	3394
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2	1167	1199	1200	1168
3	1199	1231	1232	1200
4	1263	1264	1266	1265

5	1264	1327	1328	1266
6	1327	1359	1360	1328
1	3415	3419	3420	3416
2	3416	3420	3421	3417
3	3417	3421	3422	3418
1	1359	1391	1392	1360
2	1391	1423	1424	1392
3	1423	1455	1456	1424
4	1487	1488	1490	1489
5	1488	1551	1552	1490
6	1551	1583	1584	1552
1	3439	3443	3444	3440
2	3440	3444	3445	3441
3	3441	3445	3446	3442
1	3233	3235	3236	3234
2	3234	3236	3238	3237
3	3237	3238	3240	3239
4	3239	3240	3242	3241
5	3241	3242	3244	3243
6	3243	3244	3246	3245
7	3245	3246	3248	3247
8	3247	3248	3250	3249
9	3249	3250	3252	3251
10	3251	3252	3254	3253
11	3253	3254	3256	3255
12	3255	3256	3258	3257
13	3257	3258	3260	3259
14	3259	3260	3262	3261
15	3261	3262	3264	3263
16	3263	3264	3266	3265
17	3265	3266	3268	3267
18	3267	3268	3270	3269
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22	3275	3276	3278	3277
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25	3281	3282	3284	3283
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29	3289	3290	3292	3291
30	3291	3292	3294	3293
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32	3295	3296	3298	3297
33	3297	3298	3300	3299
34	3299	3300	3302	3301
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2	3448	3449	3460	3459
3	3449	3450	3461	3460
4	3450	3451	3462	3461
5	3451	3452	3463	3462
6	3452	3453	3464	3463

7	3453	3454	3465	3464
8	3454	3455	3466	3465
9	3455	3456	3467	3466
10	3456	3457	3468	3467
1	3303	3307	3315	3311
2	3311	3315	3323	3319
1	81	83	84	82
2	83	85	86	84
3	85	87	88	86
4	87	89	90	88
5	89	91	92	90
6	91	93	94	92
7	93	95	96	94
8	95	97	98	96
9	97	99	100	98
10	99	109	110	100
11	109	119	120	110
12	119	241	242	120
13	241	243	244	242
14	243	245	246	244
15	245	247	248	246
16	247	249	250	248
17	249	251	252	250
18	251	253	254	252
19	253	255	256	254
20	255	257	258	256
21	257	259	260	258
22	259	261	262	260
23	261	263	264	262
24	263	265	266	264
25	265	267	268	266
26	267	269	270	268
1	1583	1585	1586	1584
2	1585	1587	1588	1586
3	1587	1589	1590	1588
4	1589	1591	1592	1590
5	1591	1593	1594	1592
6	1593	1595	1596	1594
7	1595	1597	1598	1596
8	1597	1599	1600	1598
9	1599	1601	1602	1600
10	1601	1603	1604	1602
11	1603	1605	1606	1604
12	1605	1607	1608	1606
13	1607	1609	1610	1608
14	1609	1611	1612	1610
15	1611	1613	1614	1612
16	3426	3434	3438	3430
17	3434	3442	3446	3438
1	3513	3515	3519	3517

*
------------------- BASE ACCELERATION IN z-DIRECTION -------------------
*

1 9.810E+00

```
*
*------------------- NONREFLECTING BOUNDARY SEGMENTS -------------------*
*
    1       1       2       4       3
    2       2      41      42       4
    3      41      61      62      42
    4      61      81      82      62
```

D. DEFORMED WALL GEOMETRIES

The deformed shape of each wall analyzed in the numerical study (except for PS1 which is shown in Volume 1, page 137) is presented in Figures 93-106. The time at which the deformed mesh is shown varies from 0.41 to 1.03 seconds due to differences in the length of time it took for each wall to stop moving.

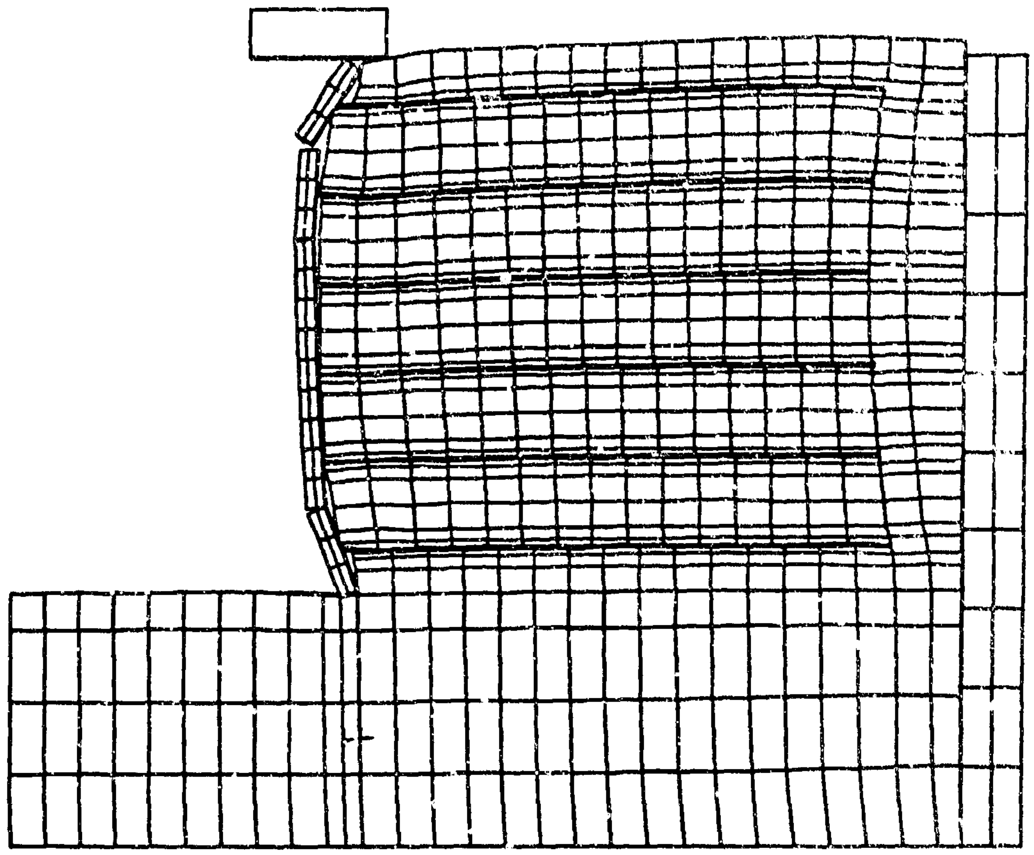


Figure 93. Deformed Shape of Mesh at 0.46 Seconds - Analysis PS2 (week reinforcement).

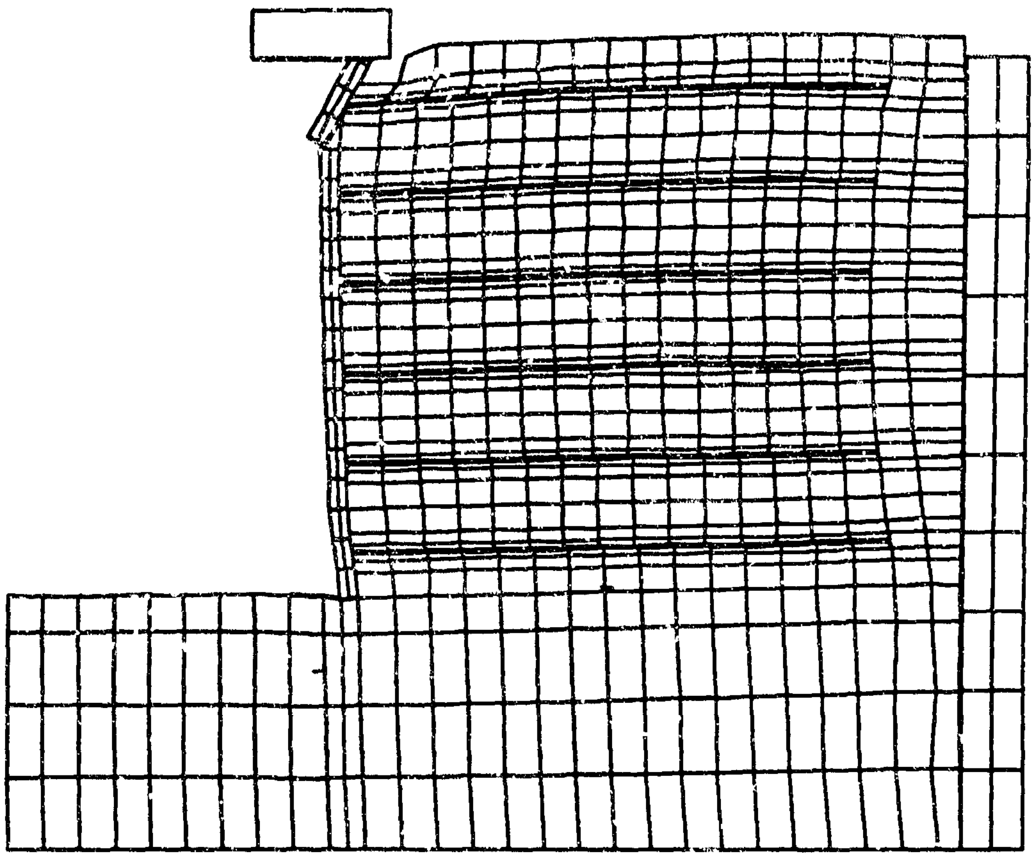


Figure 94. Deformed Shape of Mesh at 0.41 Seconds-
Analysis PS3 (strong reinforcement).

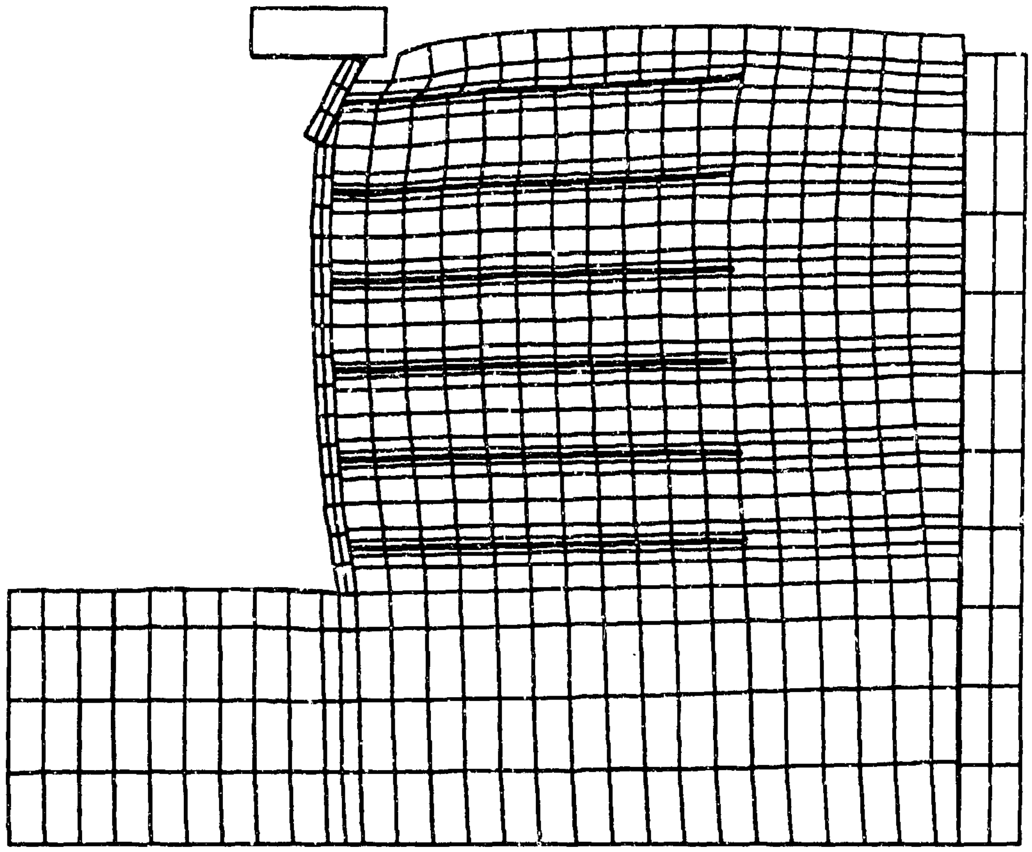


Figure 95. Deformed Shape of Mesh at 0.41 Seconds-Analysis PS4 (short reinforcement).

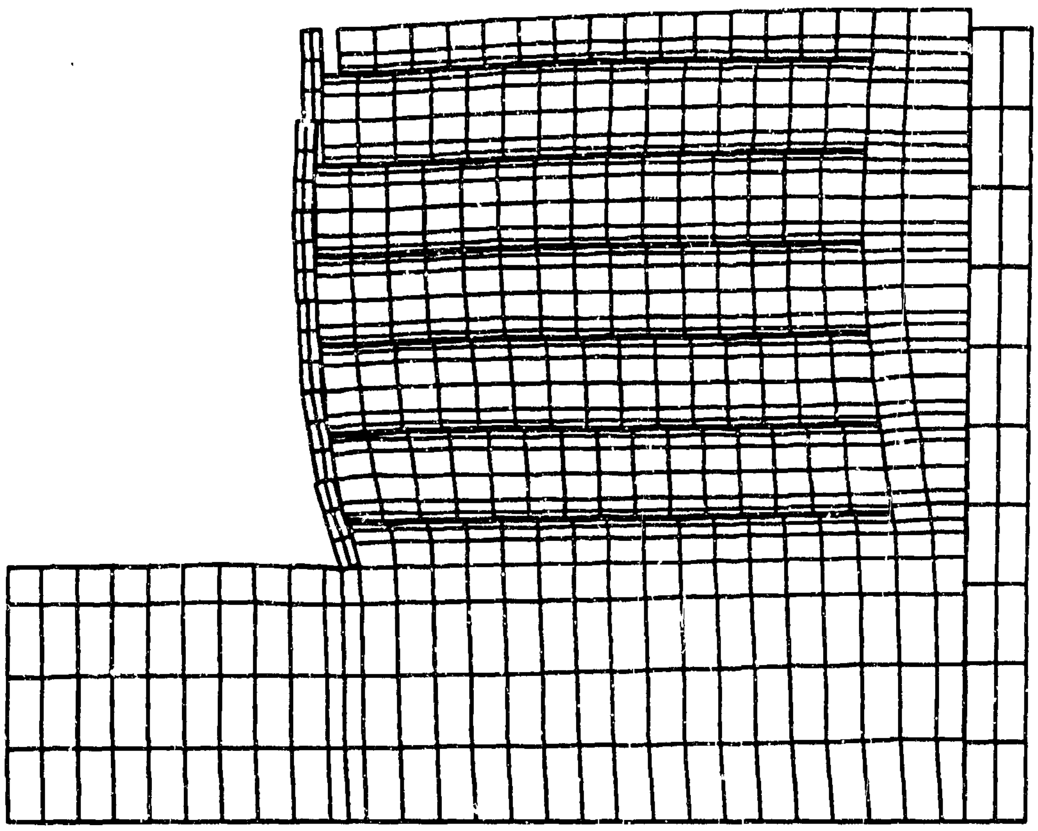


Figure 96. Deformed Shape of Mesh at 0.43 Seconds-
Analysis PS5 (no roof).

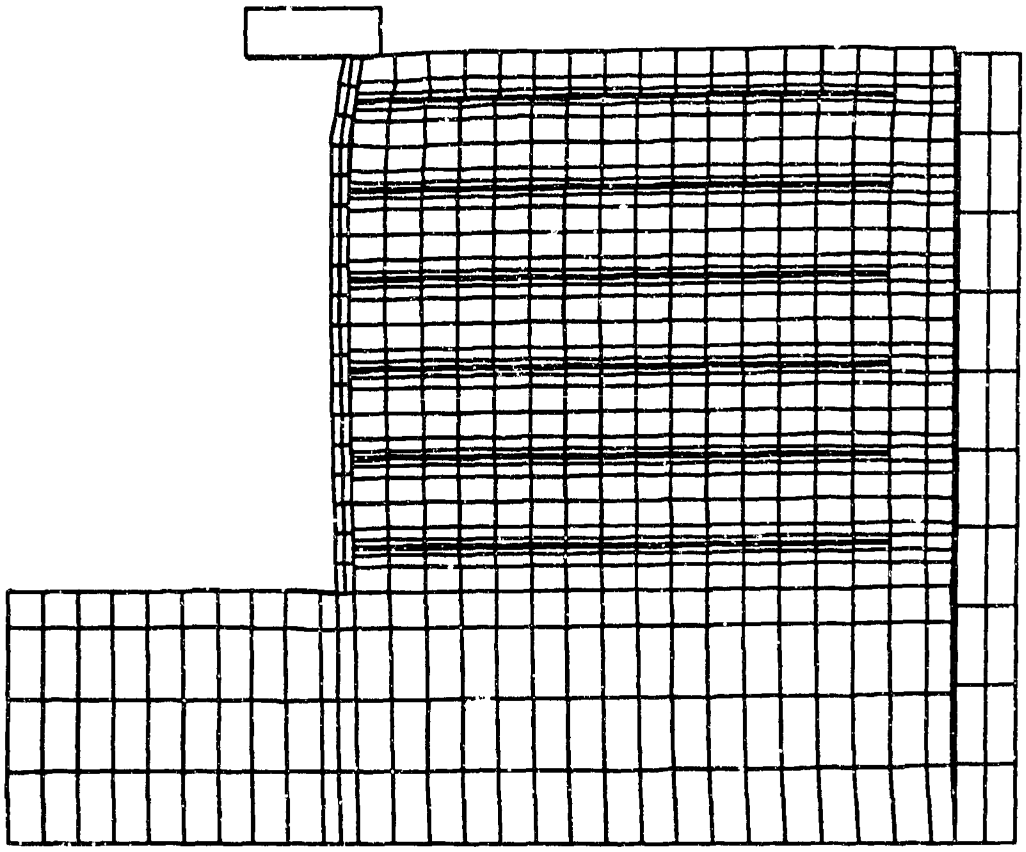


Figure 97. Deformed Shape of Mesh at 0.41 Seconds-
Analysis PS6 (197 lb @ 20 ft).

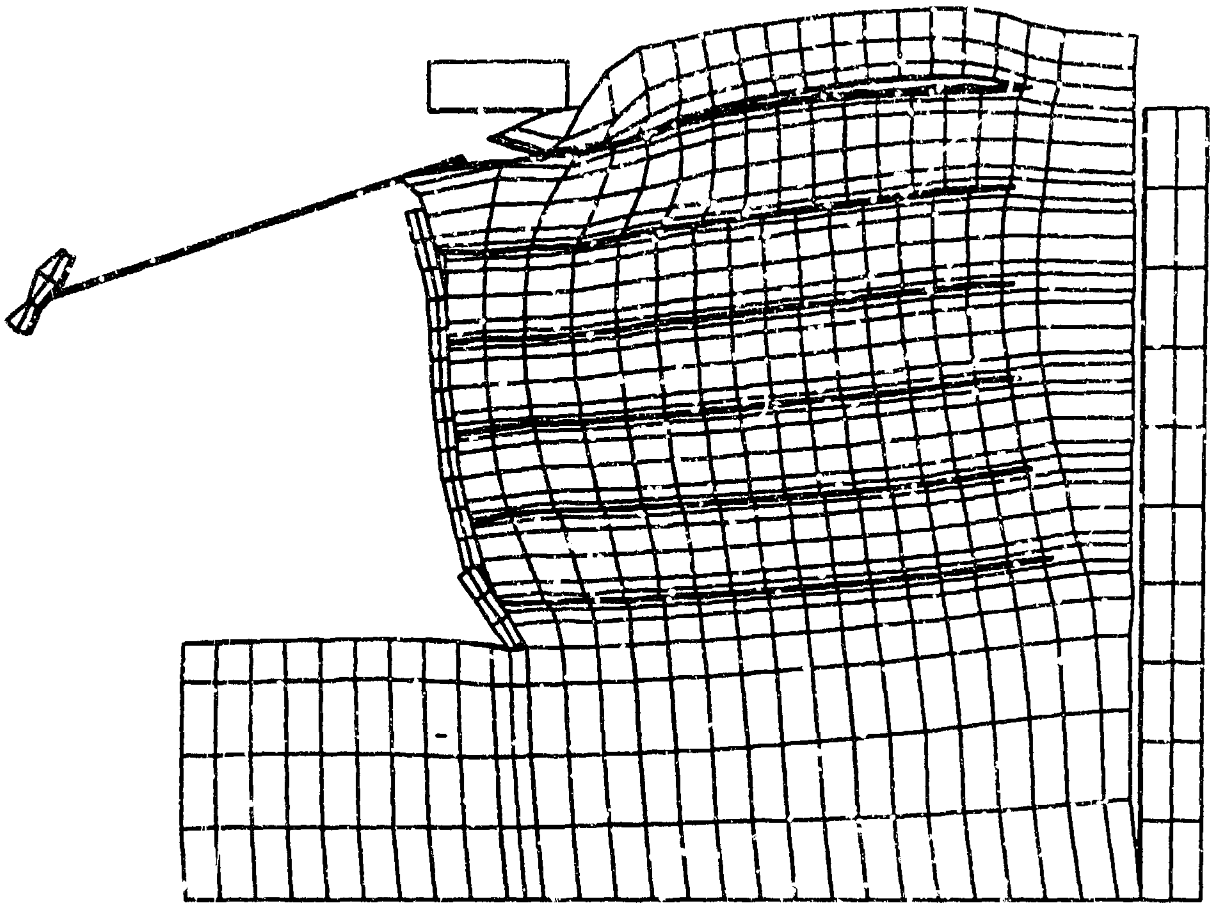


Figure 98. Deformed Shape of Mesh at 0.31 Seconds-Analysis PS7 (500 lb @ 10 ft).

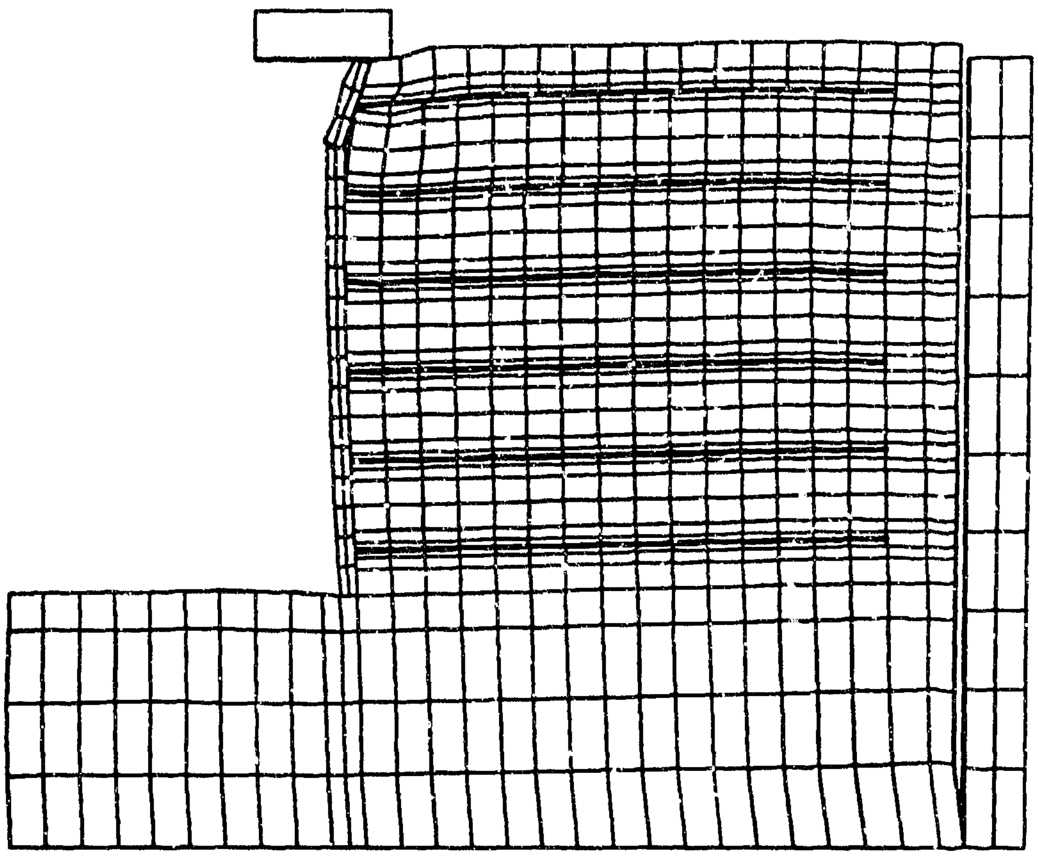


Figure 99. Deformed Shape of Mesh at 0.41 Seconds-
Analysis PS8 (500 lb @ 20 ft).

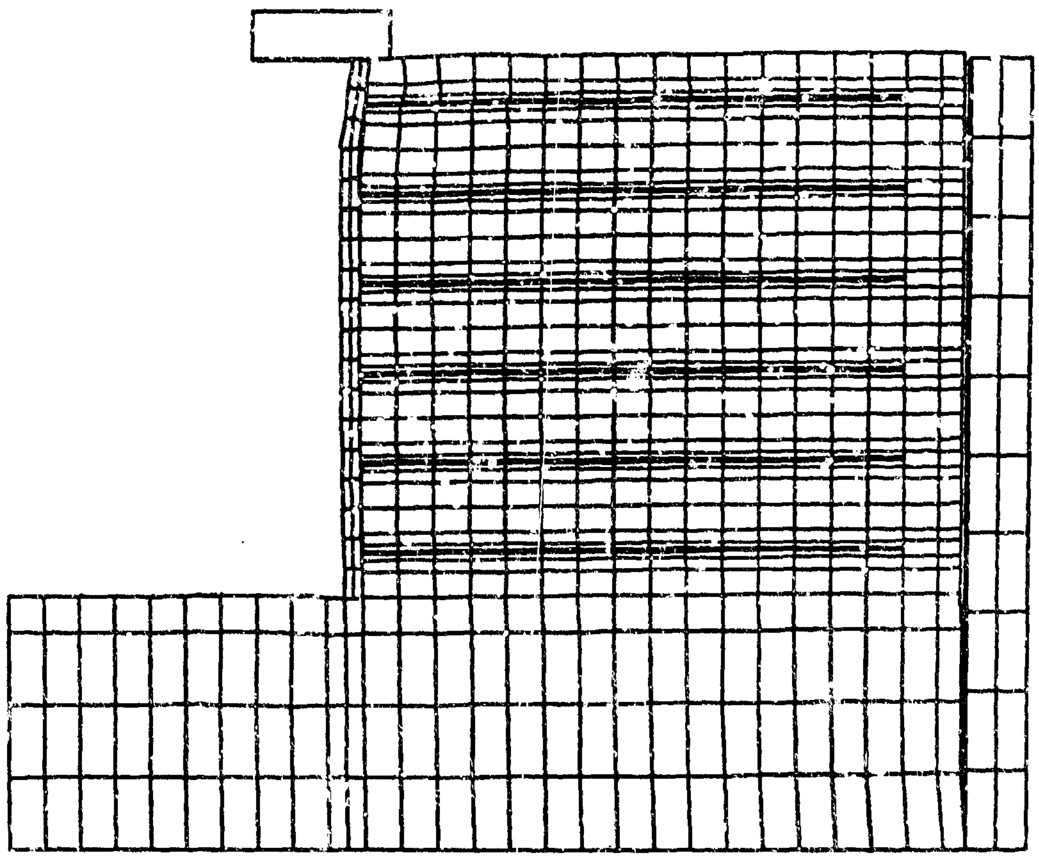


Figure 100. Deformed Shape of Mesh at 0.41 Seconds-
Analysis PS9 (500 15 @ 40 ft).

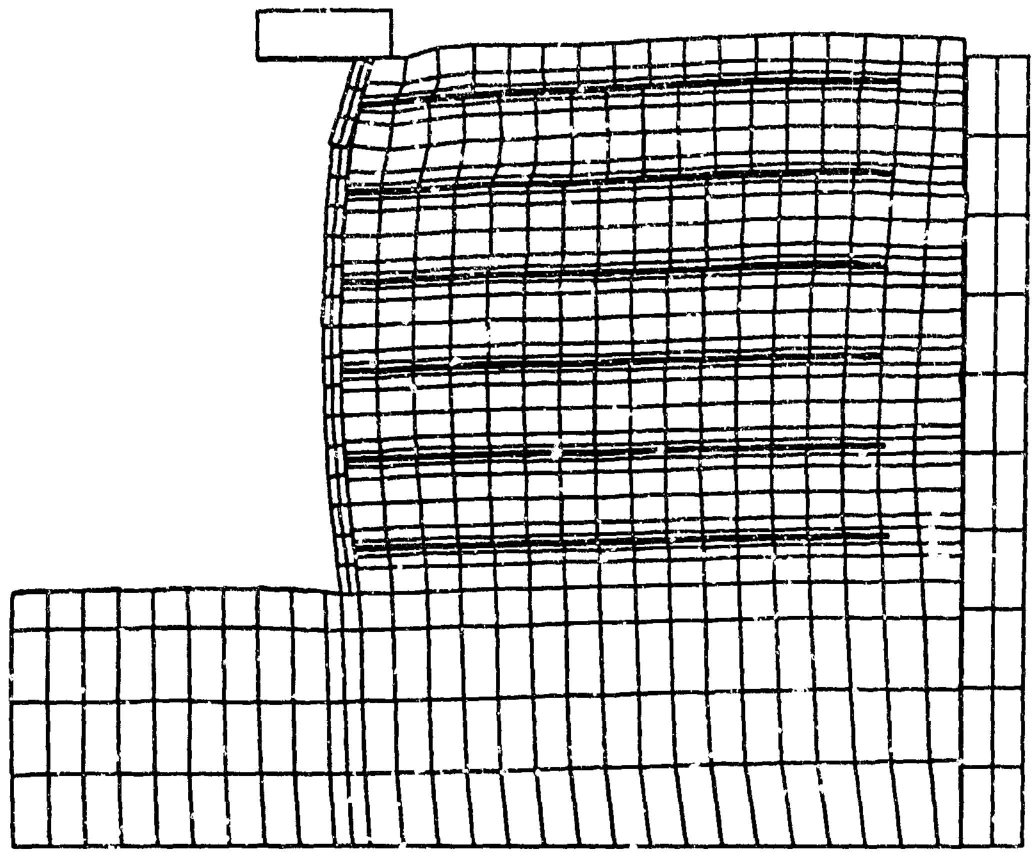


Figure 101. Deformed Shape of Mesh at 0.41 Seconds-
Analysis PS1B (weapon @ base).

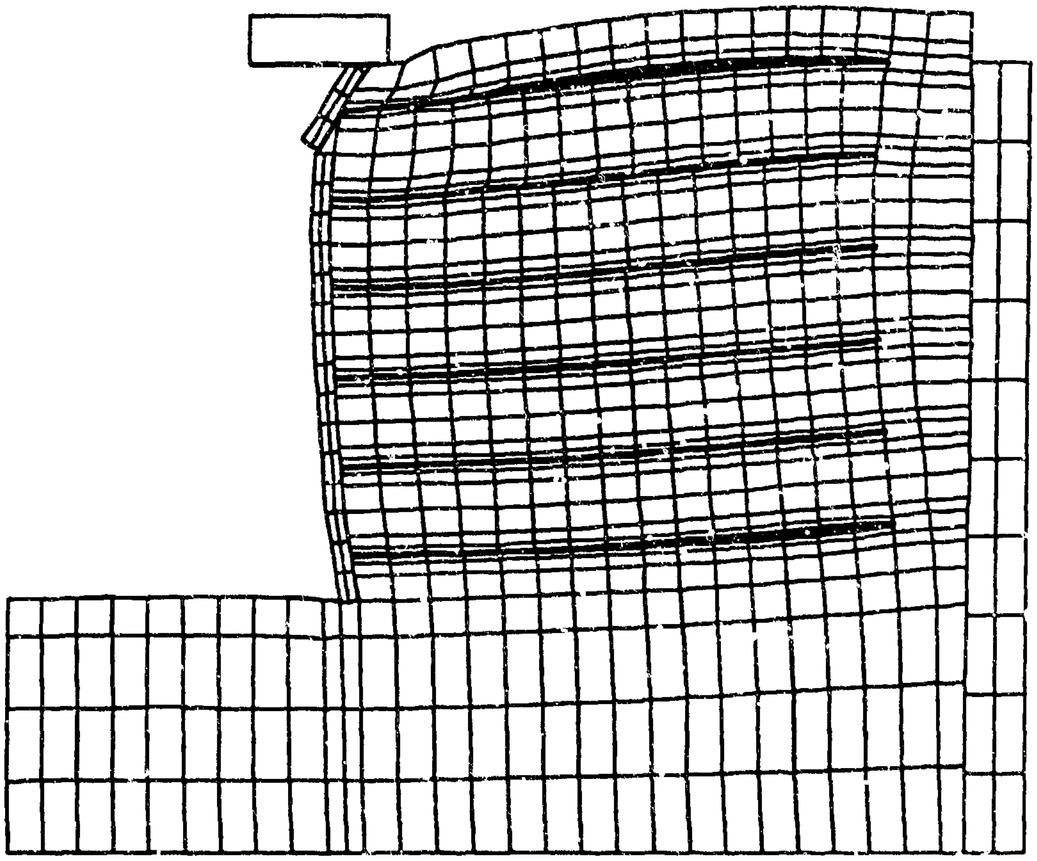


Figure 102. Deformed Shape of Mesh at 1.03 Seconds-Analysis PSIN (no gravity).

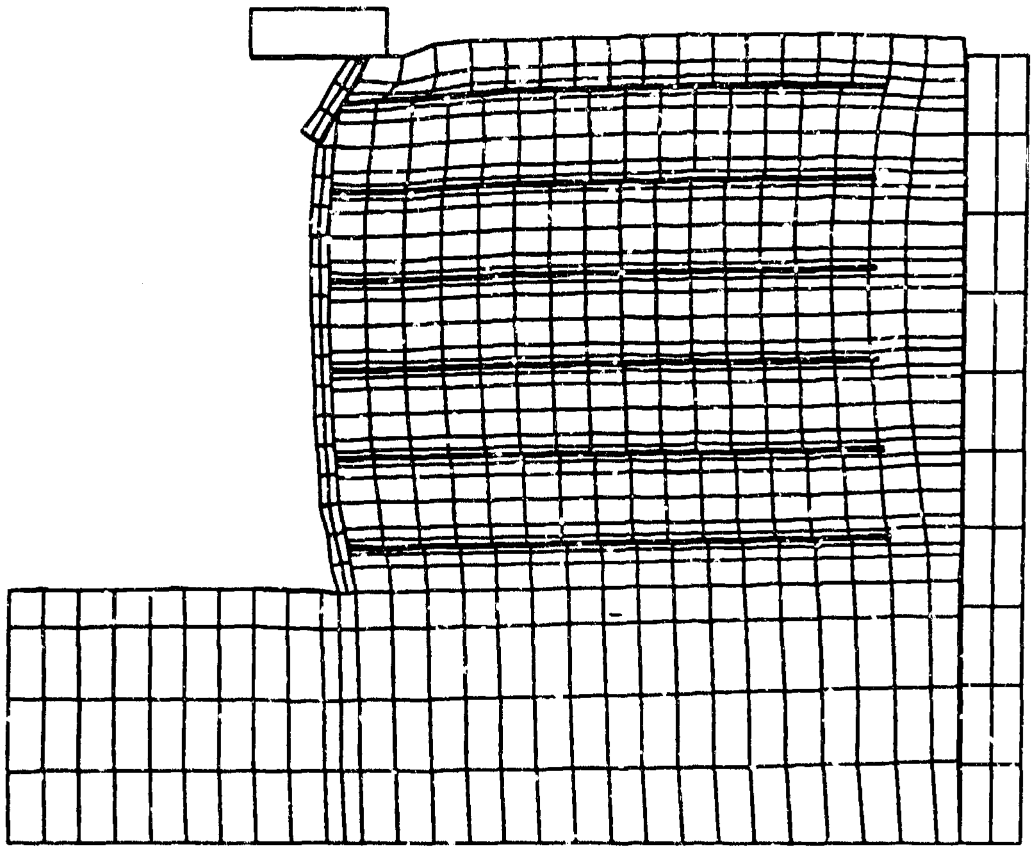


Figure 103. Deformed Shape of Mesh at 0.41 Seconds-Analysis PS1S (low interface friction).

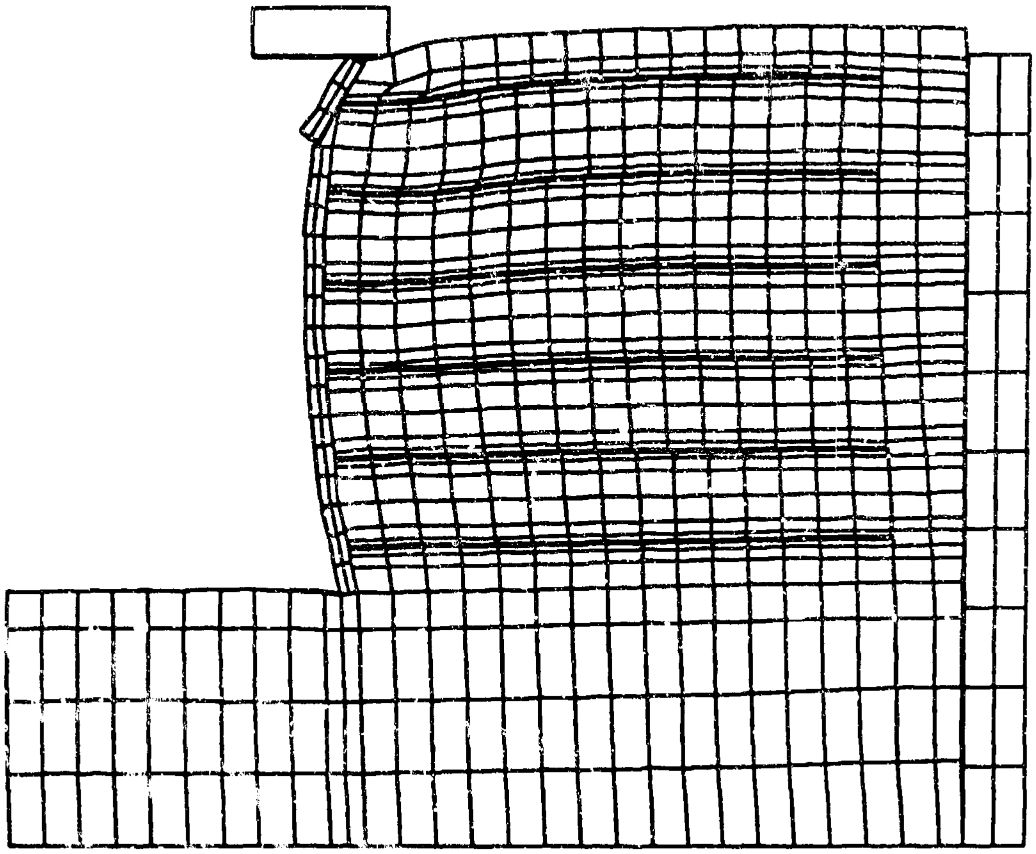


Figure 104. Deformed Shape of Mesh at 0.41 Seconds-
Analysis PS1W (low soil stiffness).

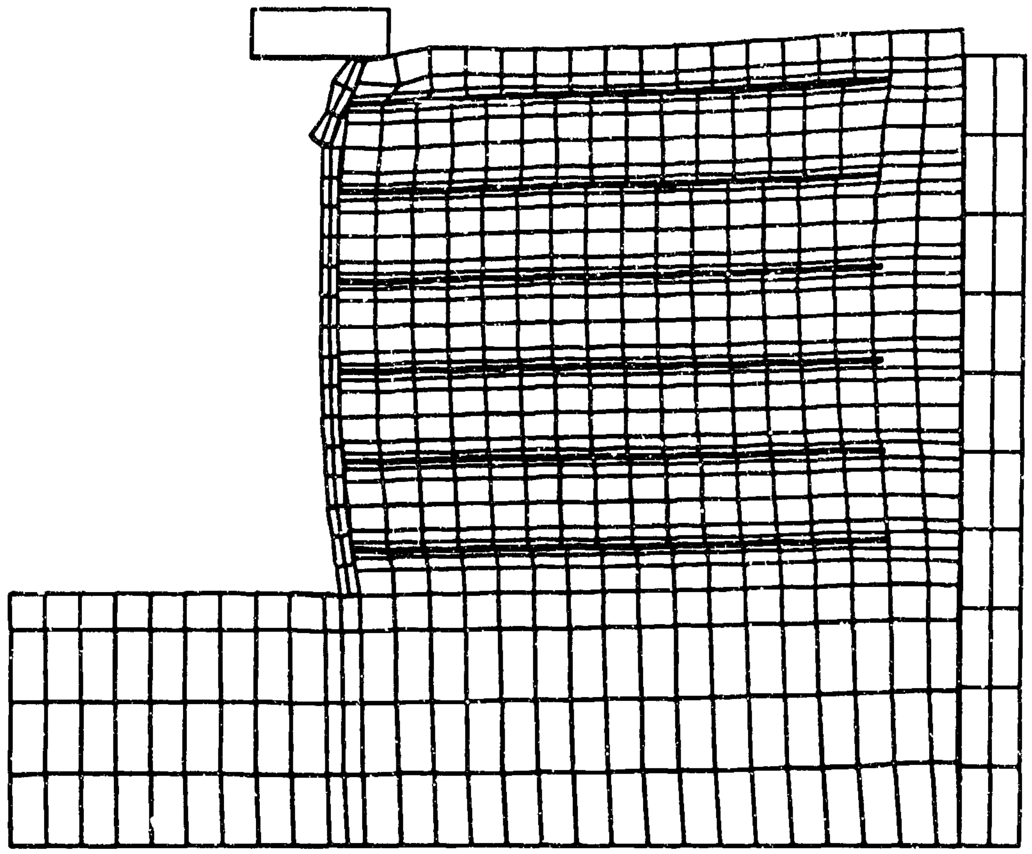


Figure 105. Deformed Shape of Mesh at 0.41 Seconds-
Analysis P1PHI (high soil friction angle).

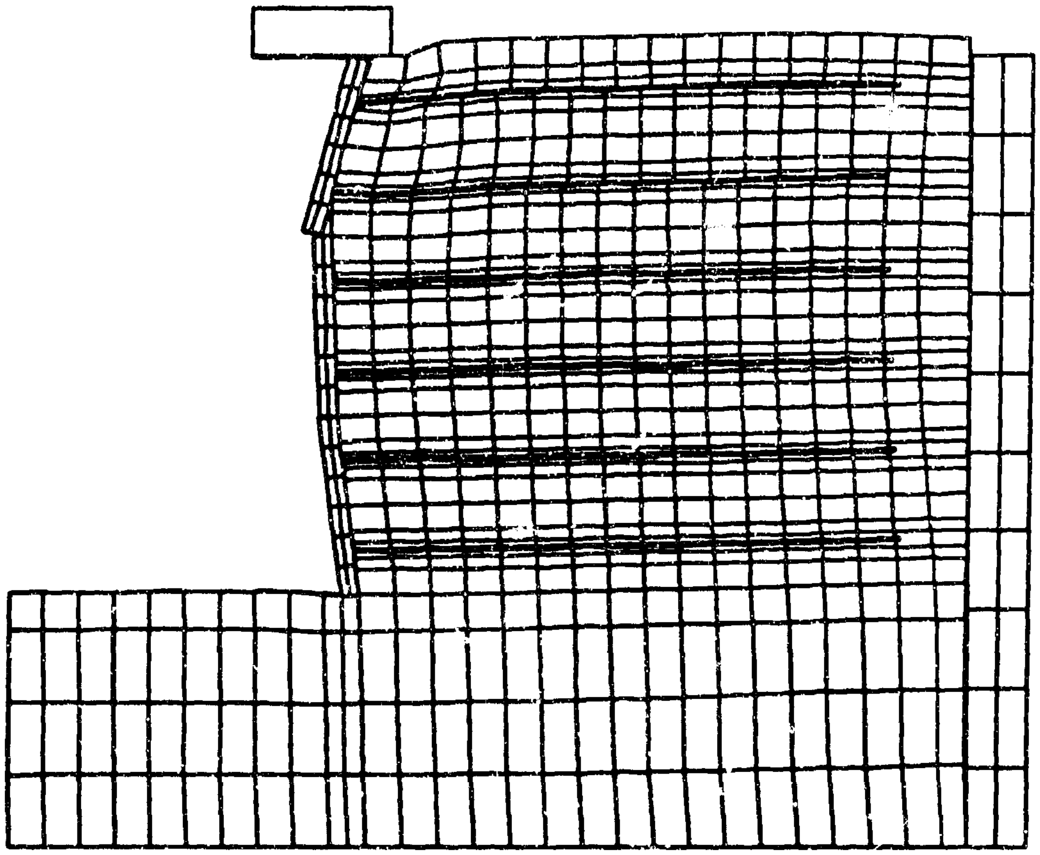


Figure 106. Deformed Shape of Mesh at 0.41 Seconds-Analysis PS1P (3 facing panels).

APPENDIX C

PHYSICAL MODELING

A. INTRODUCTION

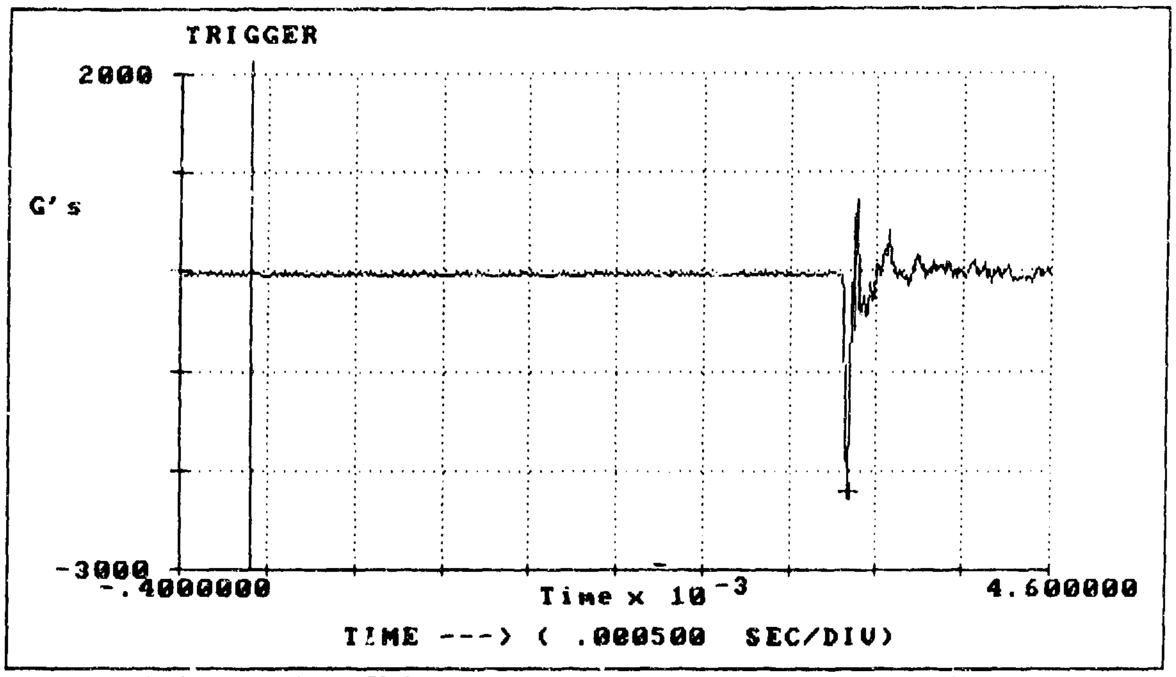
Appendix C contains a compilation of resistor, pressure gage, and accelerometer data collected and photographs taken throughout the centrifuge testing program. Appendix C is organized as follows:

- acceleration- , voltage-, and pressure-time histories for the centrifuge testing program are presented in Section B.

- model construction sequence, pre-shot and post-shot photographs of the reinforced soil walls for selected tests are presented in Section C.

B. INSTRUMENT DATA

Acceleration-time histories for panels T6, M6, and B6 are presented below for all production tests. Peak panel accelerations were read directly and blast wave velocities were calculated from these plots. Voltage-time histories for the replicate testing are presented. Peak pressures and blast wave velocities were calculated from these plots. Pressure-time histories for the two pressure gages used in the replicate tests are presented. Peak pressures were read directly and blast wave velocities were calculated from these plots.



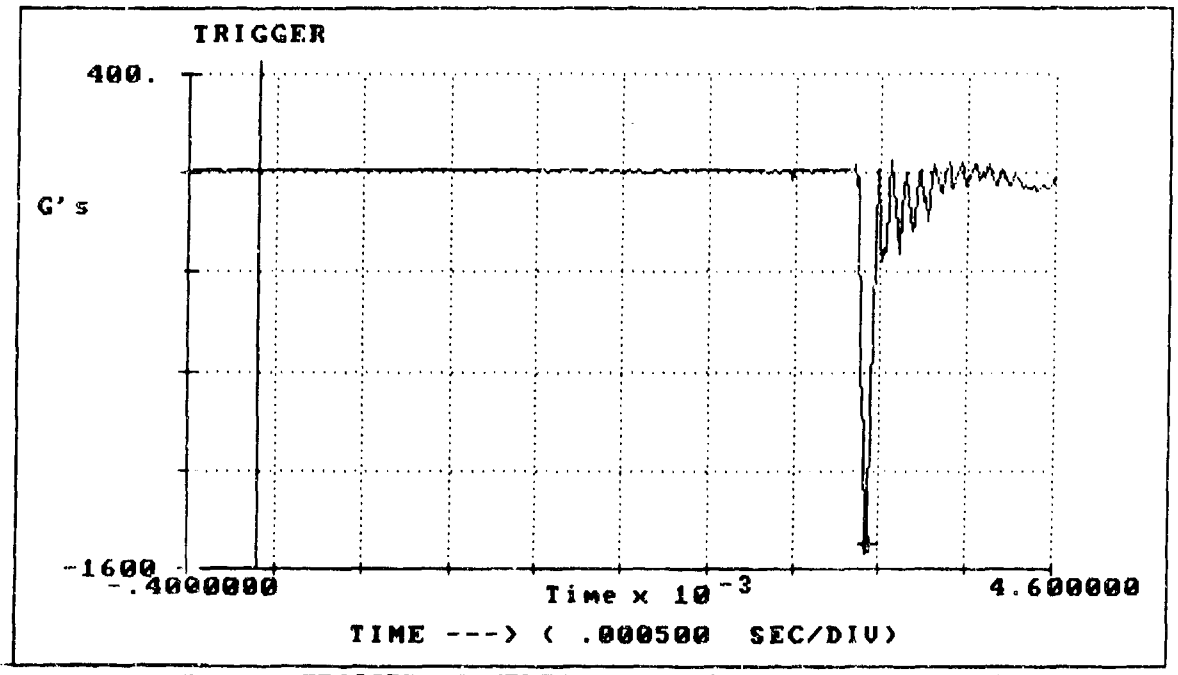
A-1 TRIGGER OCCURRED 14.561820 SECONDS AFTER START

LEGEND: 24 APR 92

A-1

Time= .003432 G's =-2209.012939

Figure 107. Acceleration-Time History: Test 1, Panel T6.



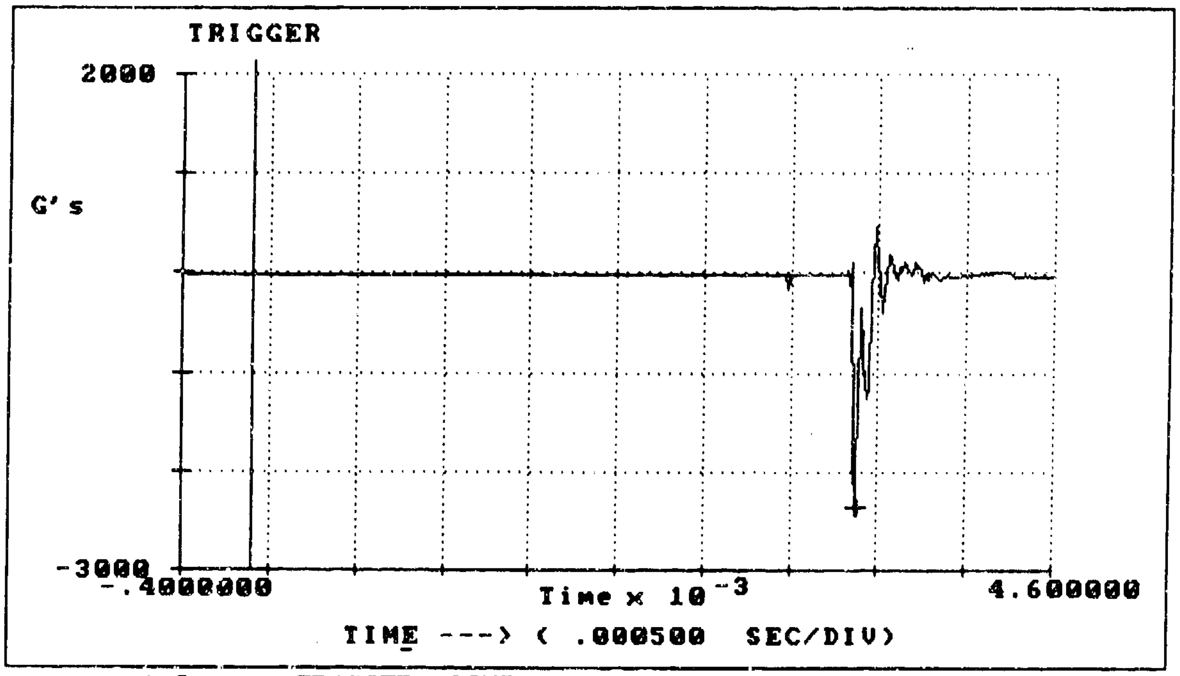
A-2 TRIGGER OCCURRED 14.561820 SECONDS AFTER START

LEGEND: 24 APR 92

A-2

Time= .003540 G's =-1504.262085

Figure 108. Acceleration-Time History: Test 1, Panel M6.



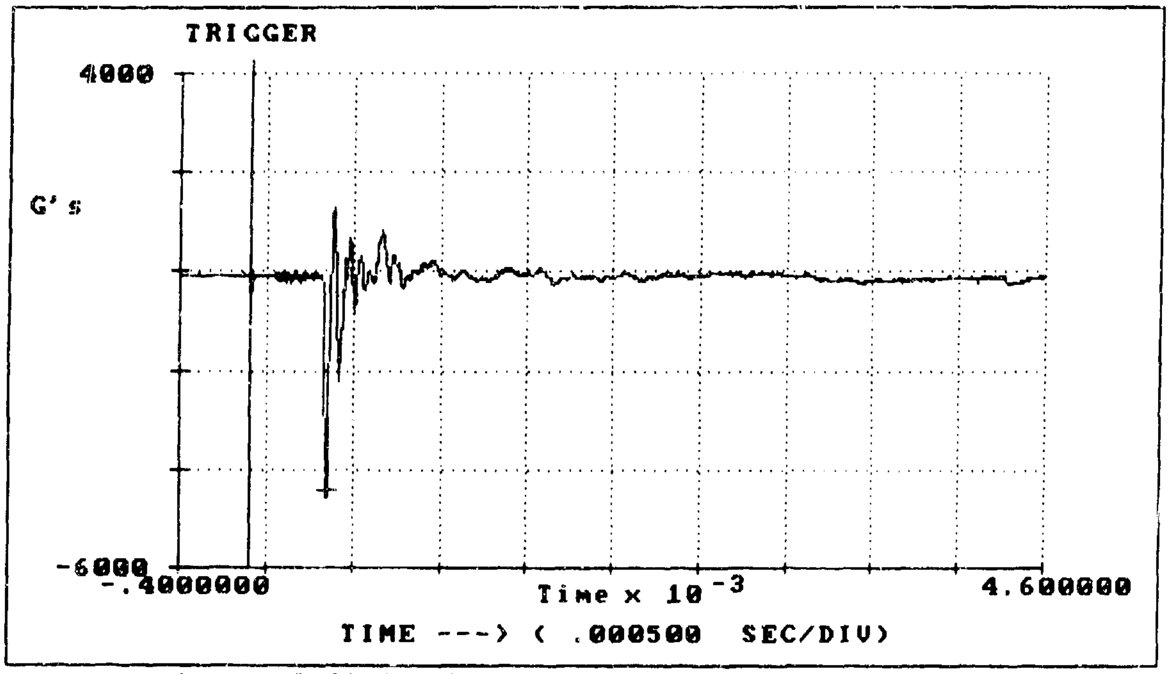
A-3 TRIGGER OCCURRED 14.561820 SECONDS AFTER START

LEGEND: 24 APR 92

A-3

Time= .003460 G's =-2377.840088

Figure 109. Acceleration-Time History: Test 1, Panel B6.



A-1 TRIGGER OCCURRED 18.123056 SECONDS AFTER START

LEGEND: 27 APR 92

A-1

Time= .000446 G's =-4405.256836

Figure 110. Acceleration-Time History: Test 2, Panel T6.

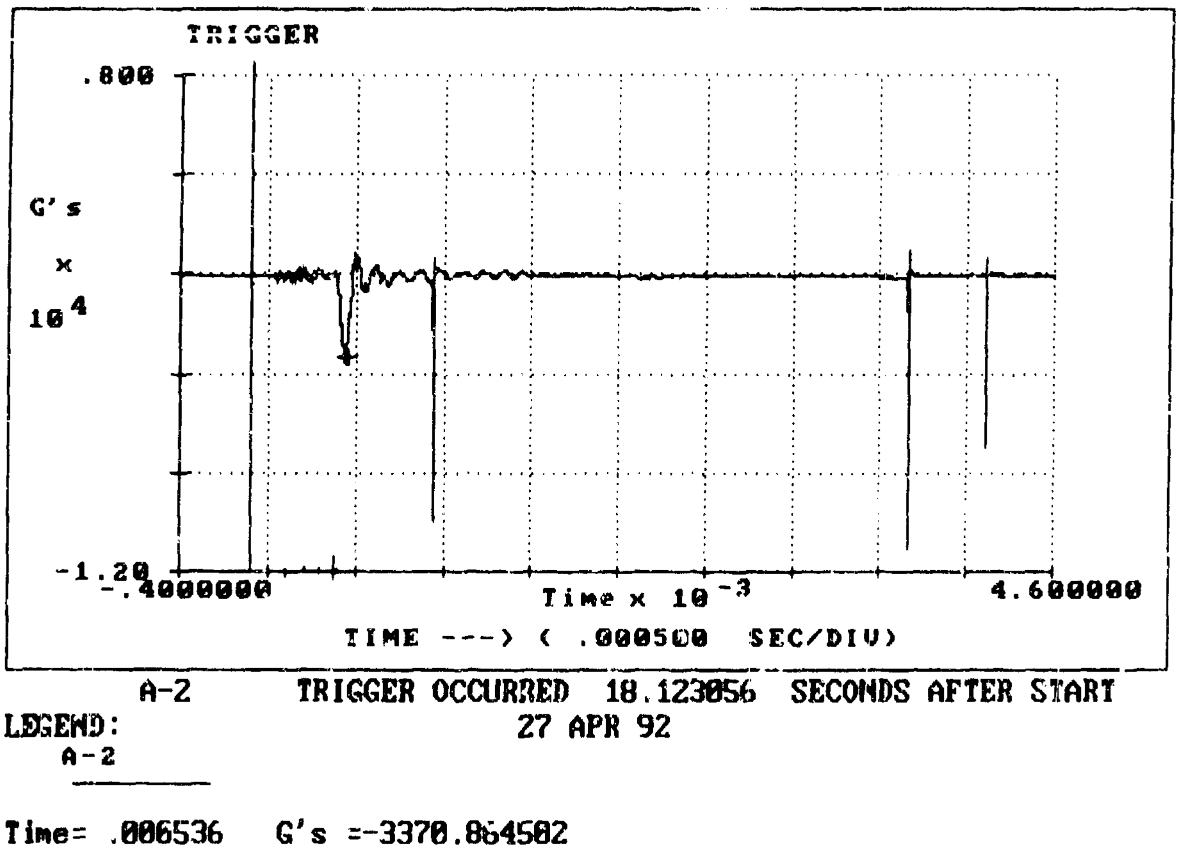
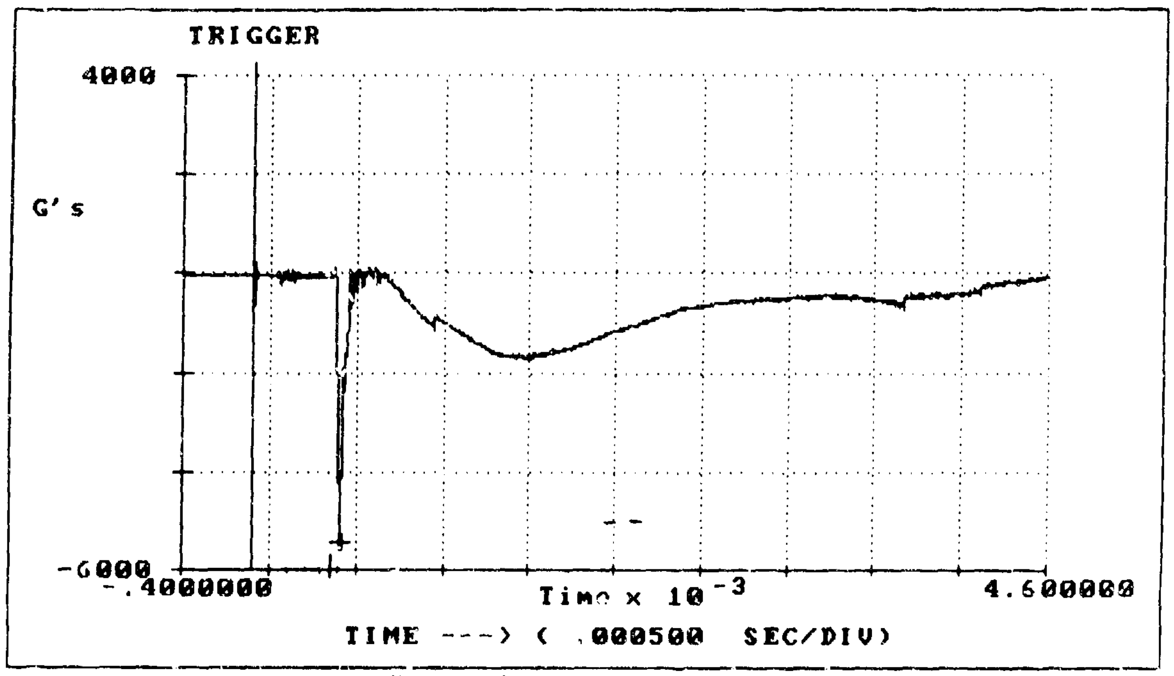


Figure 111. Acceleration-Time History: Test 2, Panel M6.



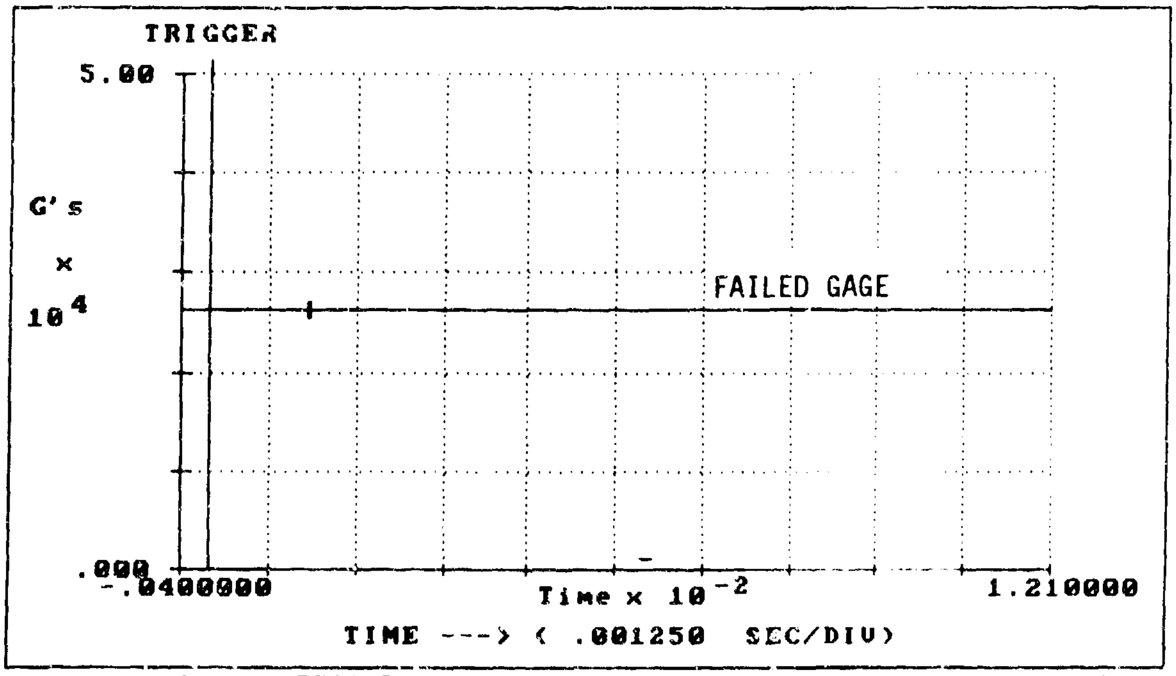
A 3 TRIGGER OCCURRED 13.123056 SECONDS AFTER START

LEGEND: 27 APR 92

A-3

Time= .000502 G's =-5450.197754

Figure 112. Acceleration-Time History: Test 2, Panel B6.



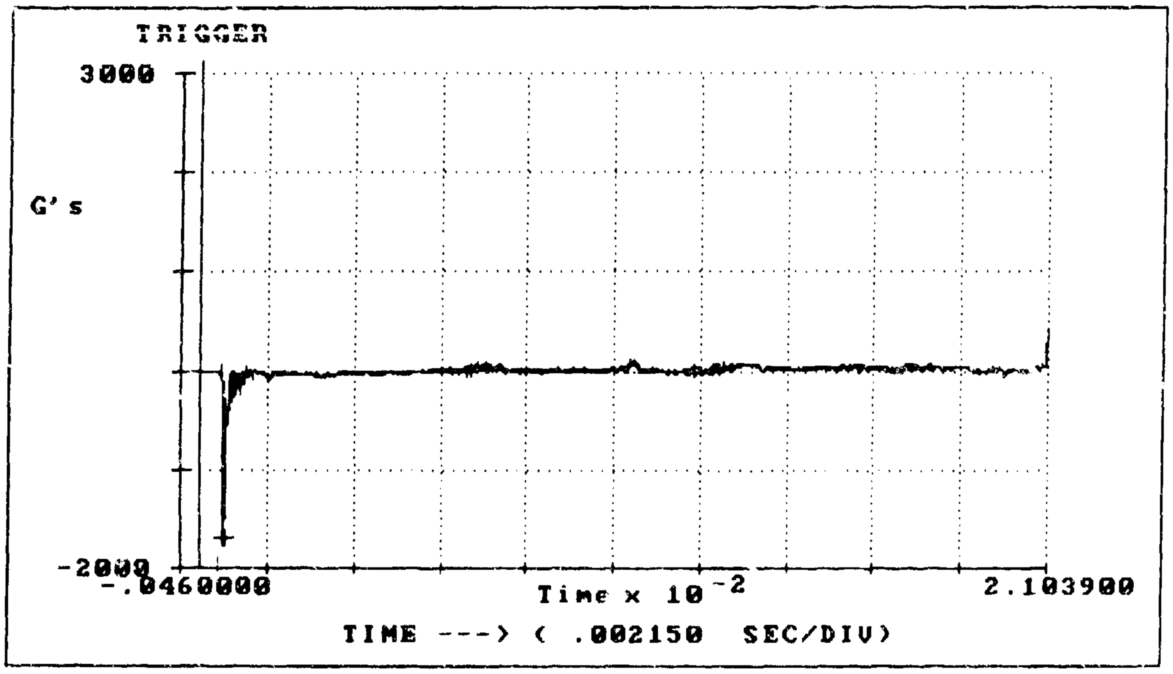
A-1 TRIGGER OCCURRED 15.520102 SECONDS AFTER START

LEGEND: 29 APR 92

A-1

Time= .001382 G's = 26150.626953

Figure 113. Acceleration-Time History: Test 3, Panel T6.



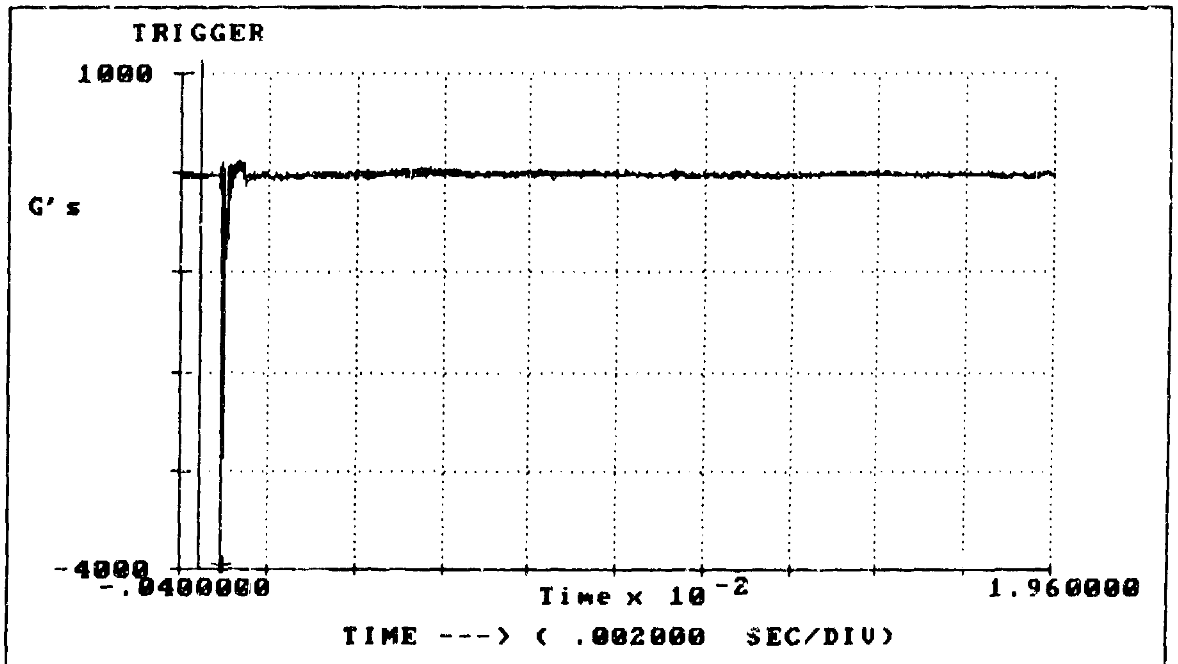
A-2 TRIGGER OCCURRED 15.520102 SECONDS AFTER START

LEGEND: 29 APR 92

A-2

Time= .000580 G's =-1690.922241

Figure 114. Acceleration-Time History: Test 3, Panel M6.



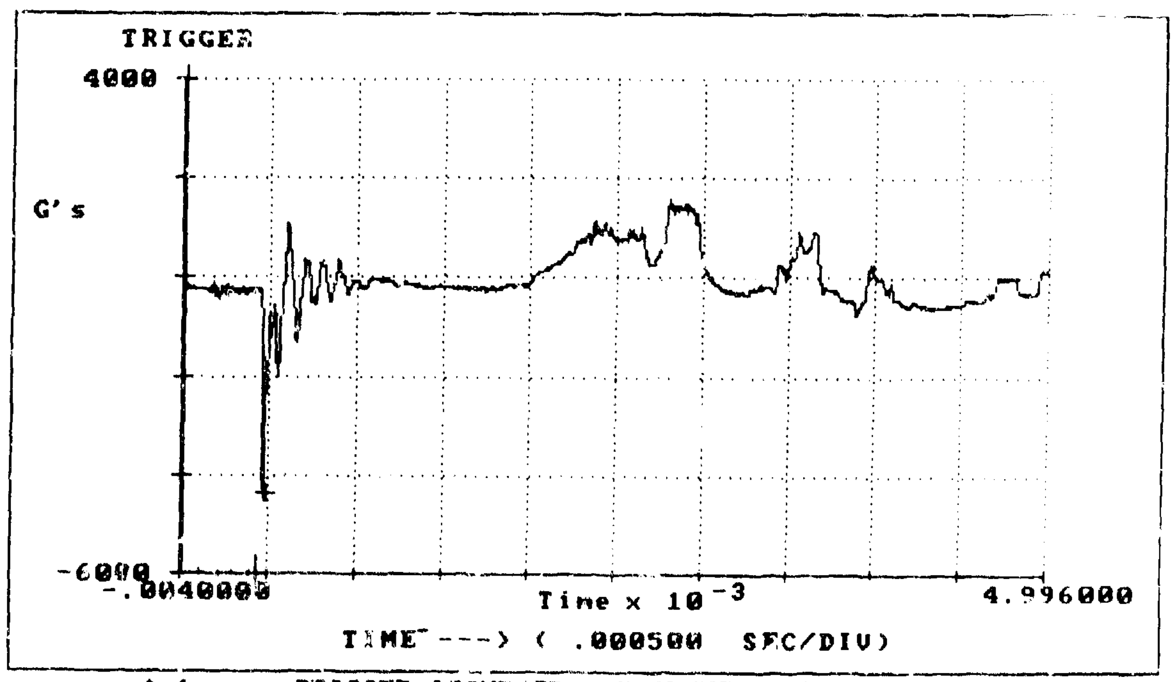
A-3 TRIGGER OCCURRED 15.520102 SECONDS AFTER START

LEGEND: 29 APR 91

A-3

Time= .000510 G's =-3955.219238

Figure 115. Acceleration-Time History: Test 3, Panel B6.



A-1 TRIGGER OCCURRED 10.174528 SECONDS AFTER START

LEGEND: 1 MAY 92

A-1

Time= .000464 G's =-4392.488281

Figure 116. Acceleration-Time History: Test 4, Panel T6.

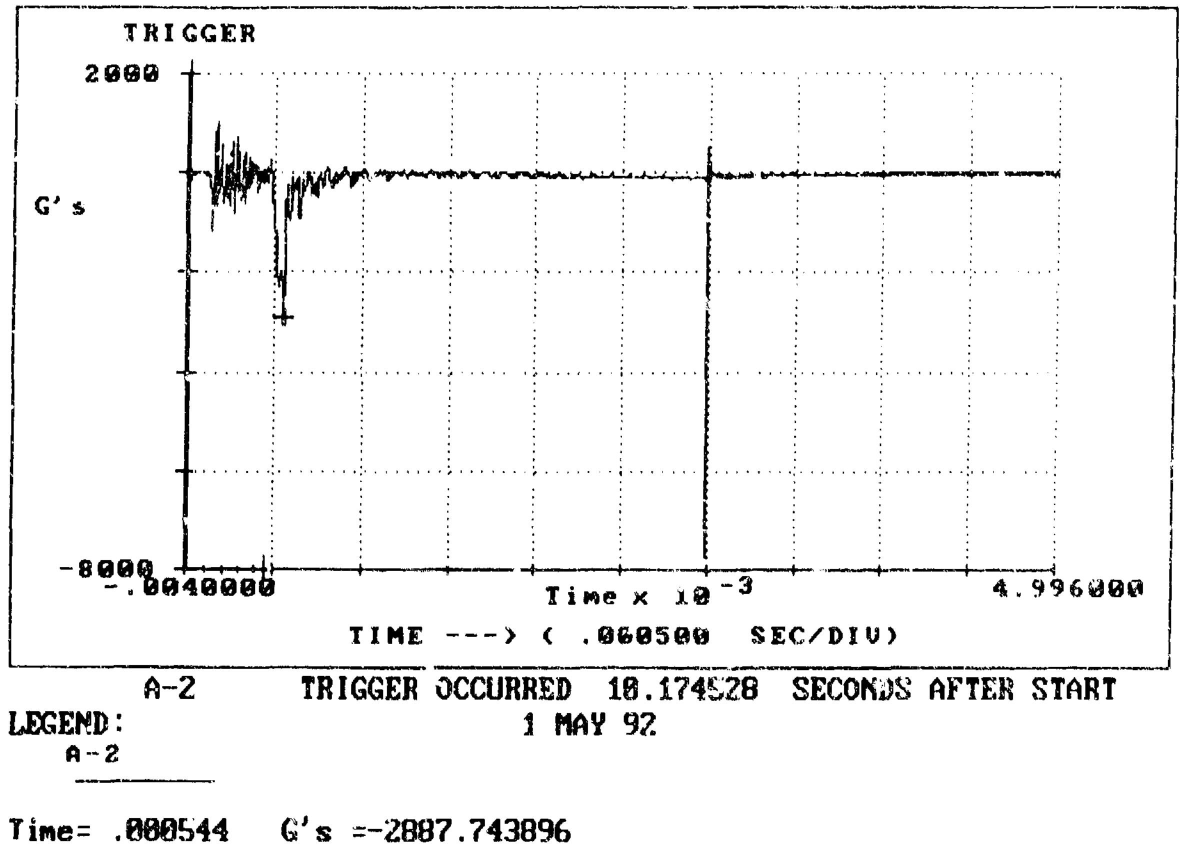
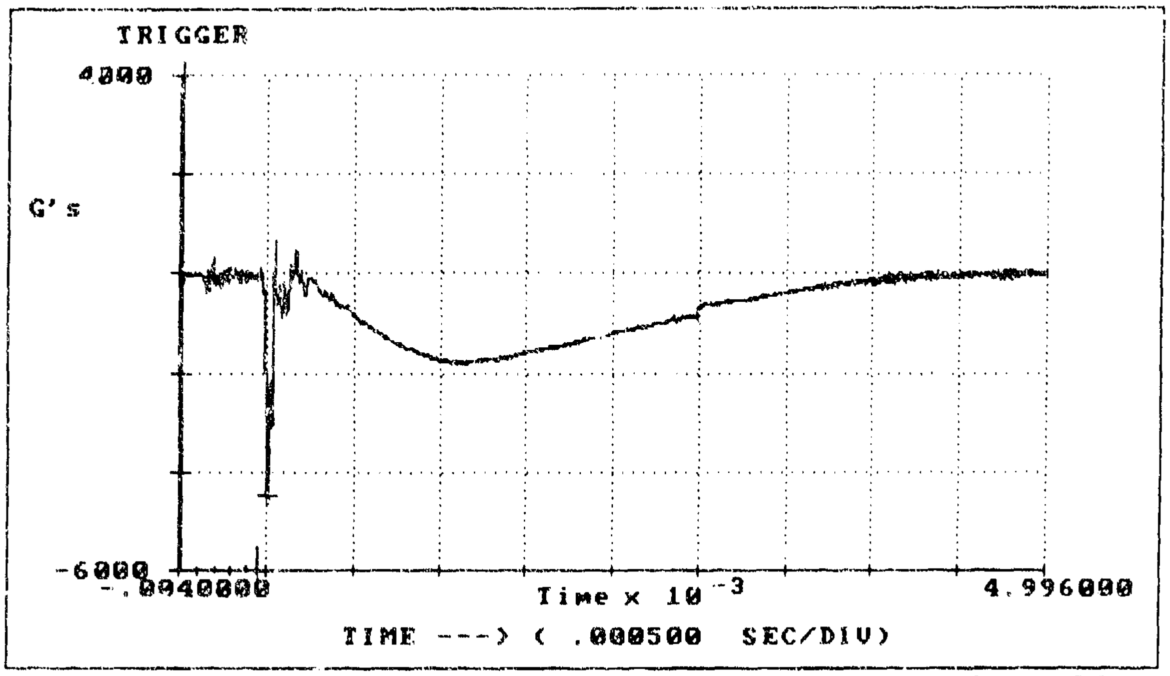


Figure 117. Acceleration-Time History: Test 4, Panel M5.



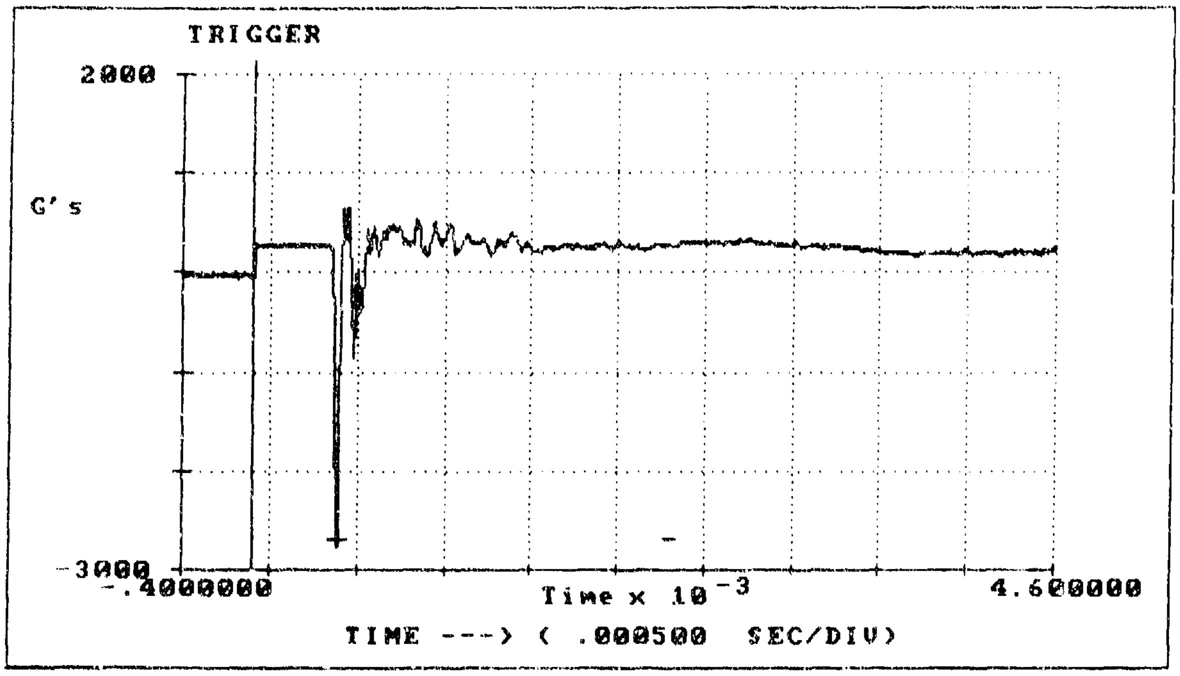
A-3 TRIGGER OCCURRED 10.174528 SECONDS AFTER START

LEGEND: 1 MAY 92

A-3

Time= .000498 G's =-4484.936035

Figure 118. Acceleration-Time History: Test 4, Panel B6.



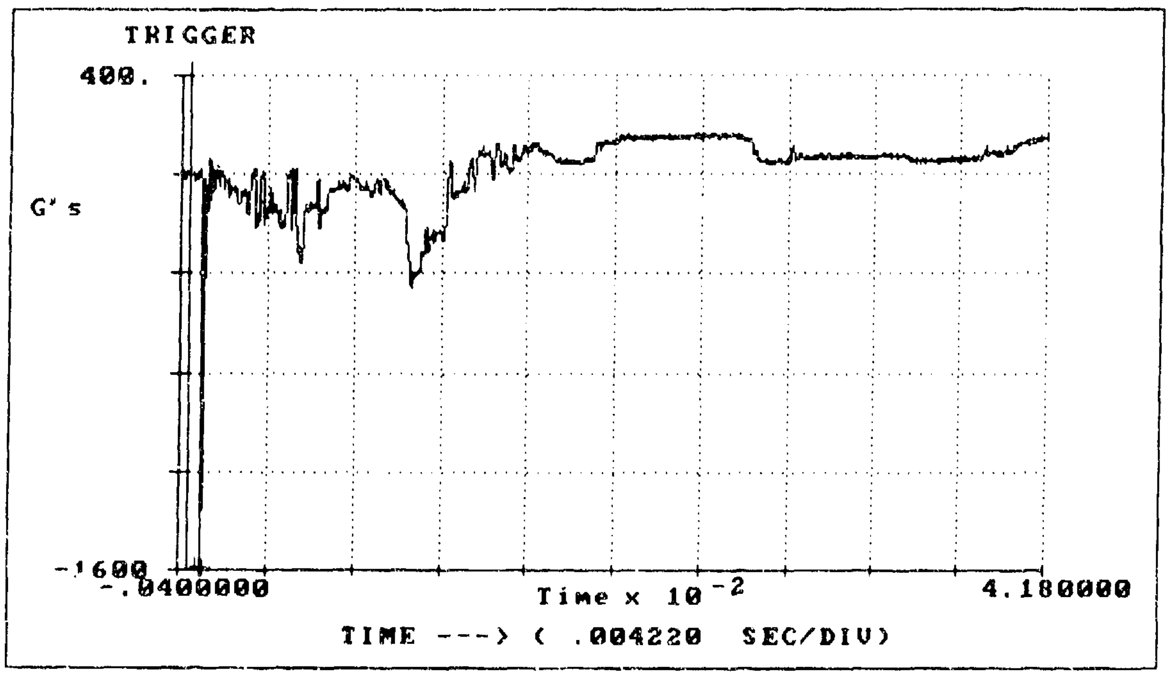
A-1 TRIGGER OCCURRED 15.773801 SECONDS AFTER START

LEGEND: 5 MAY 92

A-1

Time= .000482 G's =-2694.229736

Figure 119. Acceleration-Time History: Test 5, Panel T6.



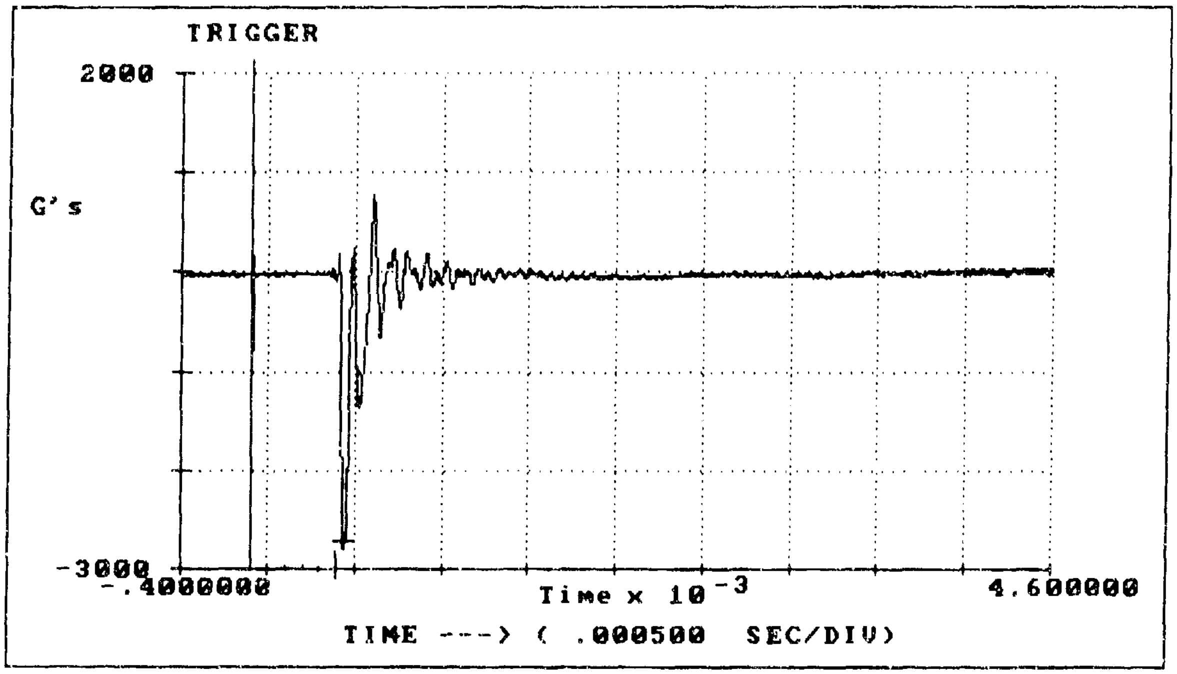
A-2 TRIGGER OCCURRED 15.773801 SECONDS AFTER START

LEGEND: 5 MAY 92

A-2

Time= .000629 G's =-1592.102173

Figure 120. Acceleration-Time History: Test 5, Panel M6.



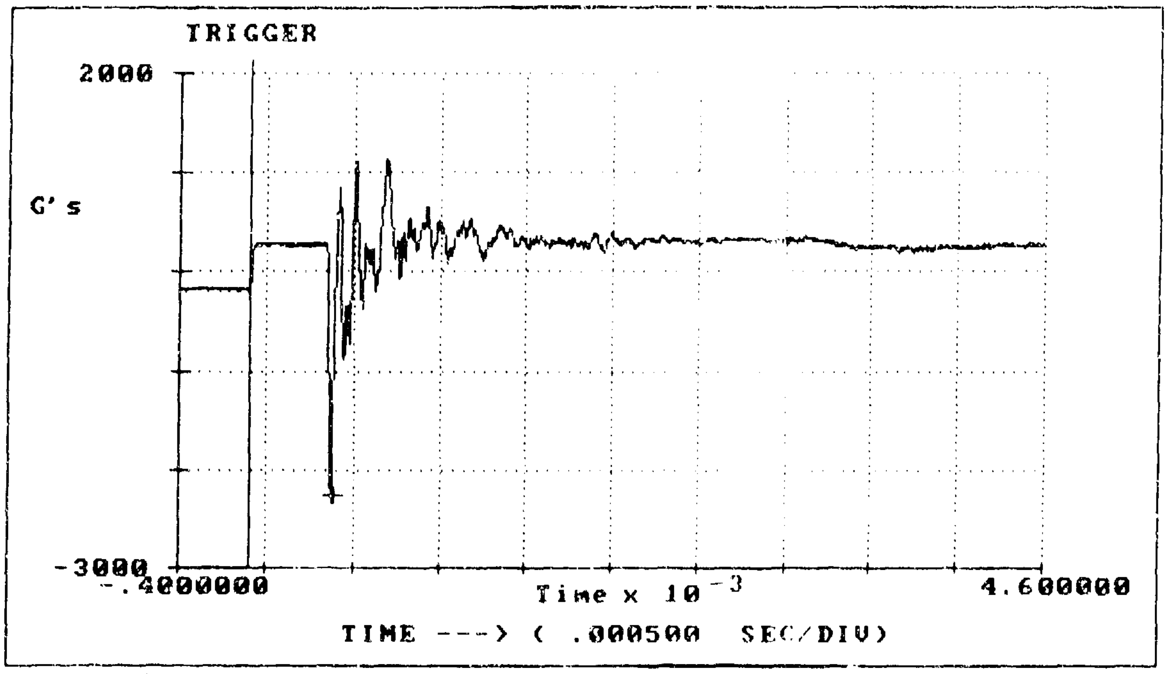
A-3 TRIGGER OCCURRED 15.773801 SECONDS AFTER START

LEGEND: 5 MAY 92

A-3

Time= .000532 G's =-2719.213135

Figure 121. Acceleration-Time History: Test 5, Panel B6.



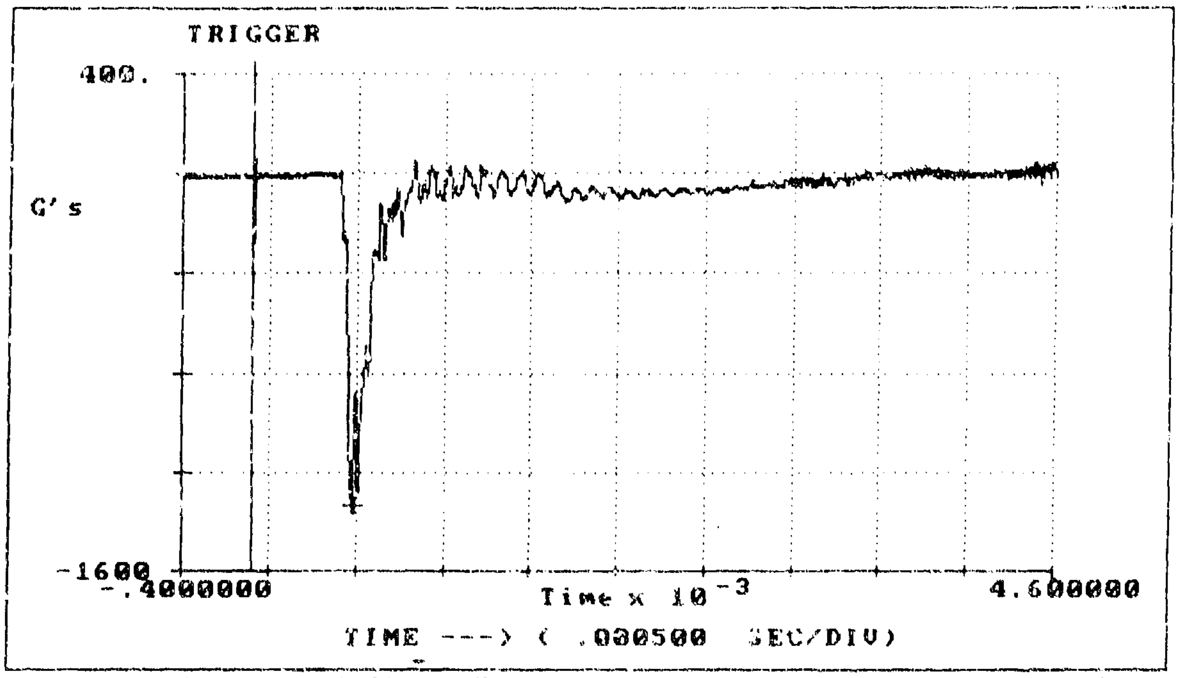
A-1 TRIGGER OCCURRED 15.225677 SECONDS AFTER START

LEGEND: 6 MAY 92

A-1

Time= .000474 G's =-2260.088379

Figure 122. Acceleration-Time History: Test 6, Panel T6.



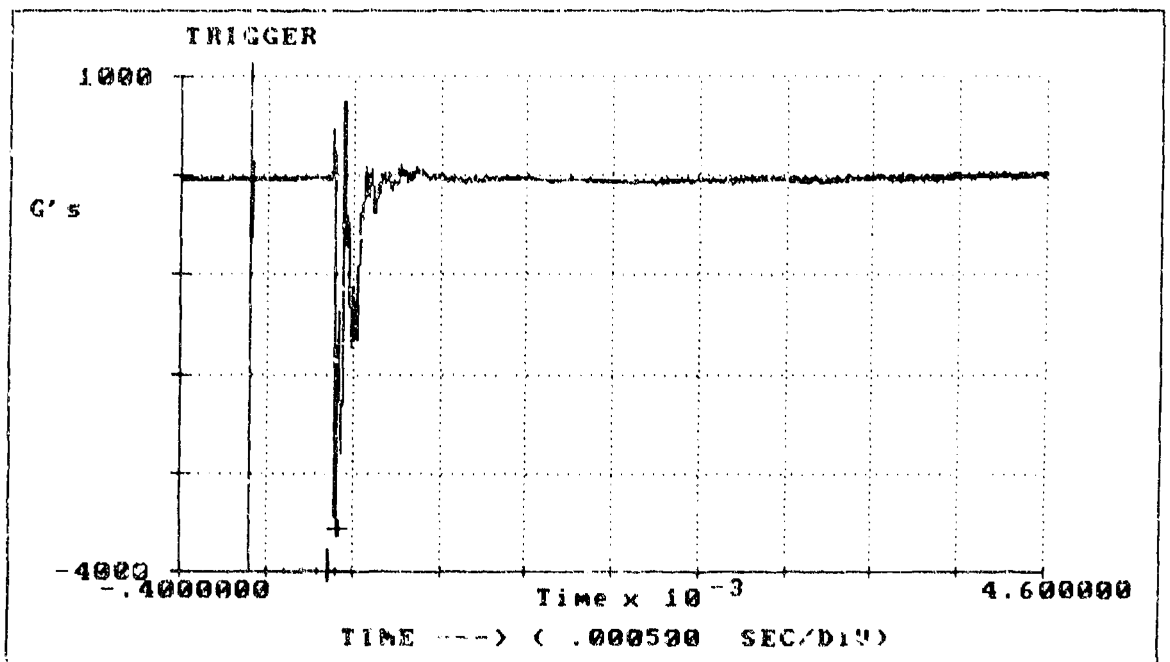
A-2 TRIGGER OCCURRED 15.225677 SECONDS AFTER START

LEGEND: 6 MAY 92

A-2

Time= .000574 G's =-1339.561768

Figure 123. Acceleration-Time History: Test 6, Panel M6.



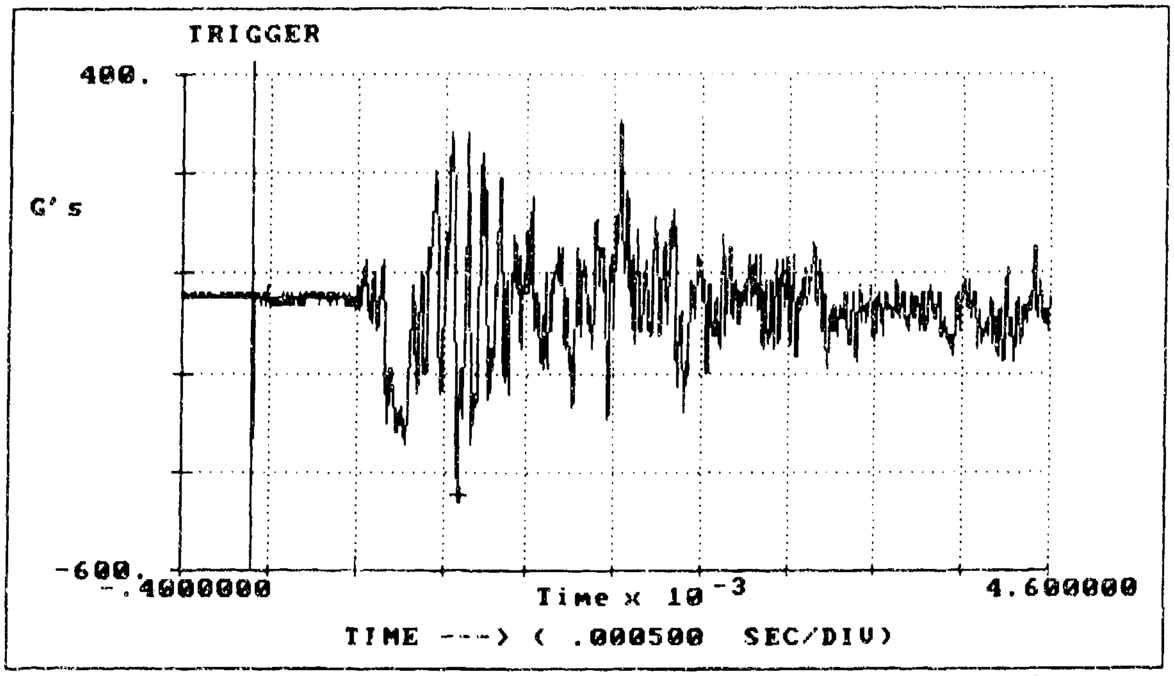
A-3 TRIGGER OCCURRED 15.225677 SECONDS AFTER START

LEGEND: 6 MAY 92

A-3

Time= .000438 G's =-3578.531738

Figure 124. Acceleration-Time History: Test 6, Panel B6.



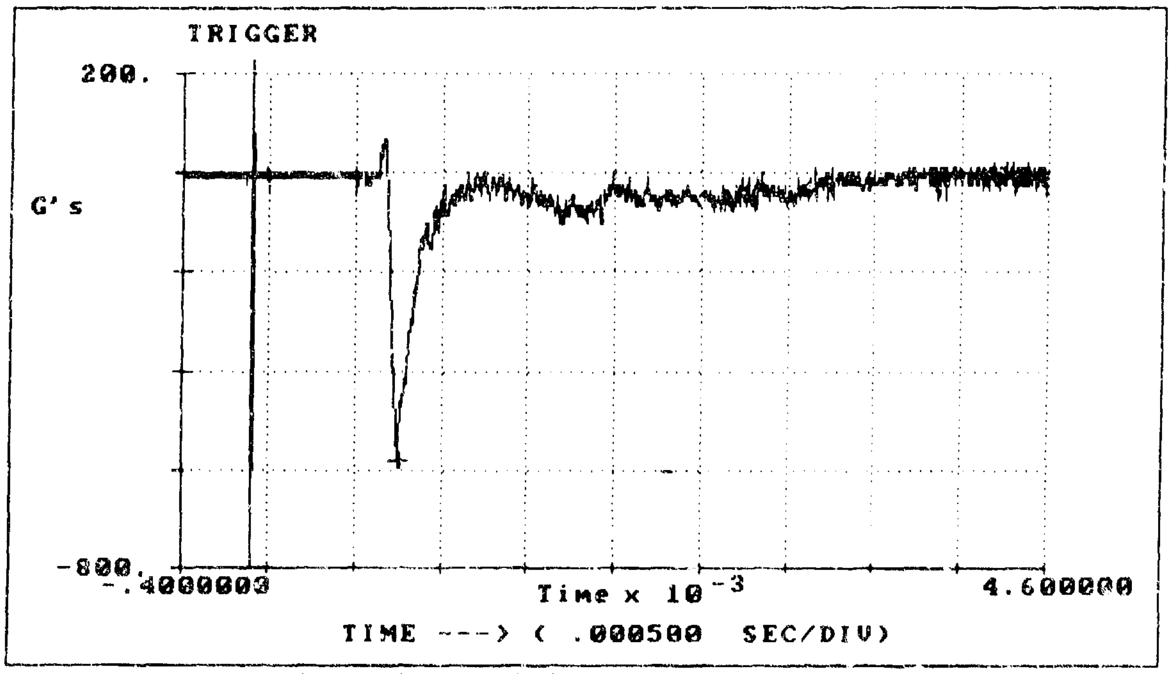
A-1 TRIGGER OCCURRED 16.360368 SECONDS AFTER START

LEGEND: 8 MAY 92

A-1

Time= .001188 G's =-446.910126

Figure 125. Acceleration Time History: Test 7, Panel T6.



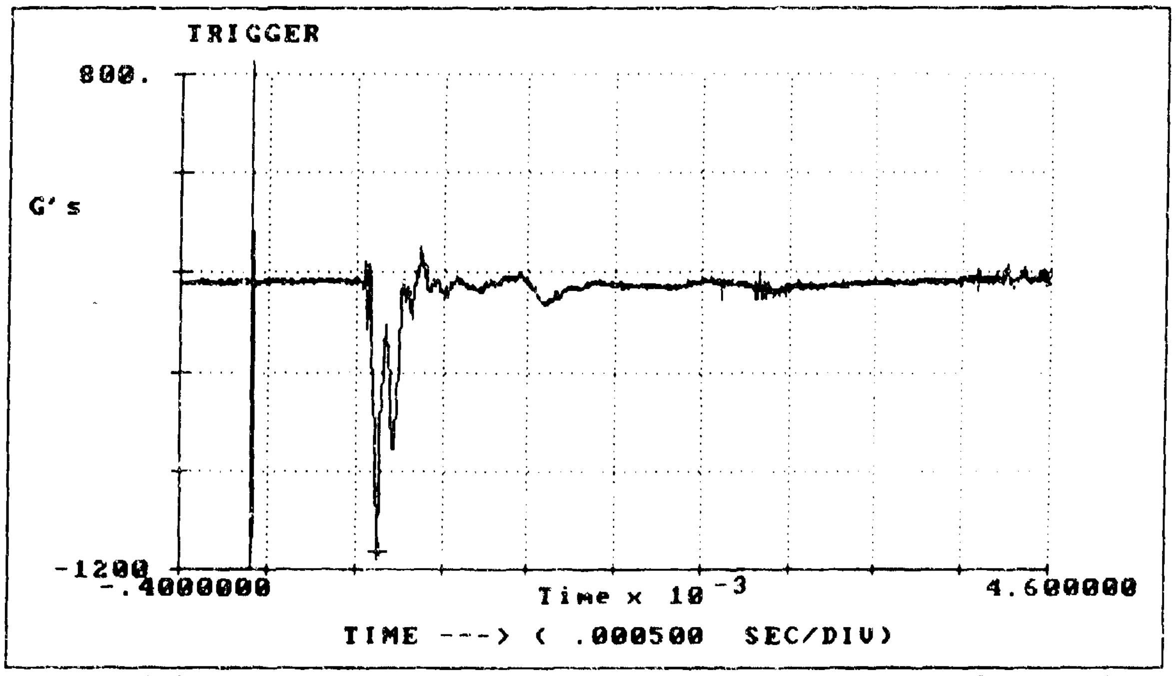
A-2 TRIGGER OCCURRED 16.360368 SECONDS AFTER START

LEGEND: 8 MAY 92

A-2

Time= .000844 G's =-581.940796

Figure 126. Acceleration-Time History: Test 7, Panel M6.



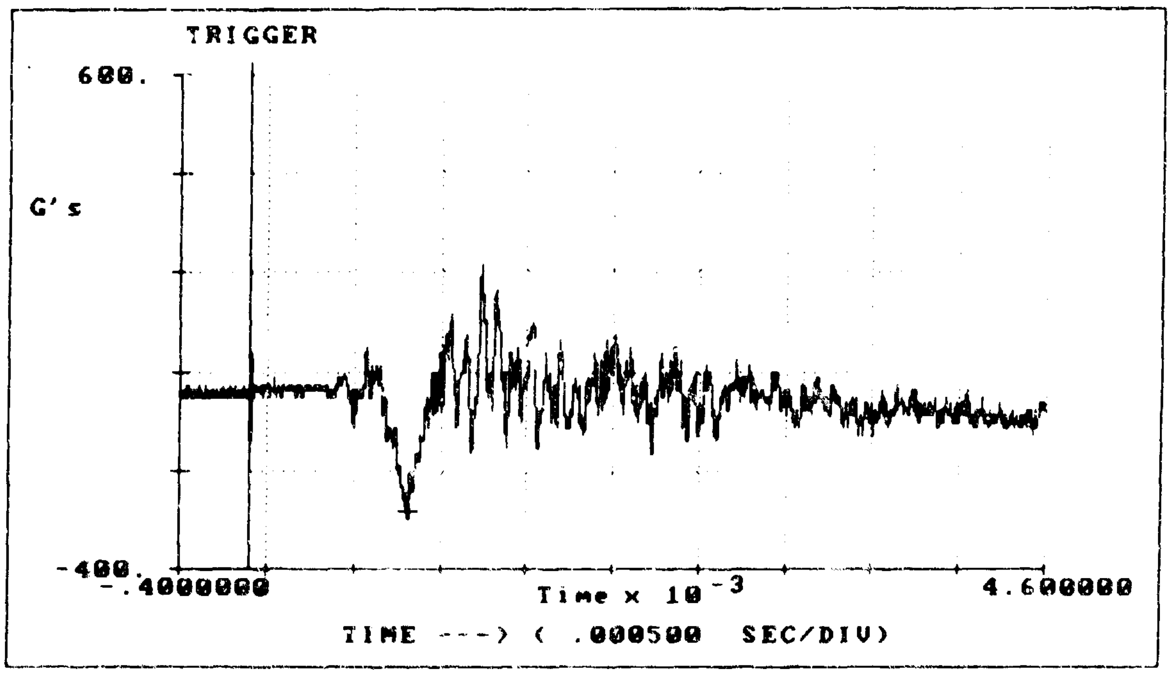
A-3 TRIGGER OCCURRED 16.360368 SECONDS AFTER START

LEGEND: 8 MAY 92

A-3

Time= .000724 G's =-1130.062622

Figure 127. Acceleration-Time History: Test 7, Panel B6.



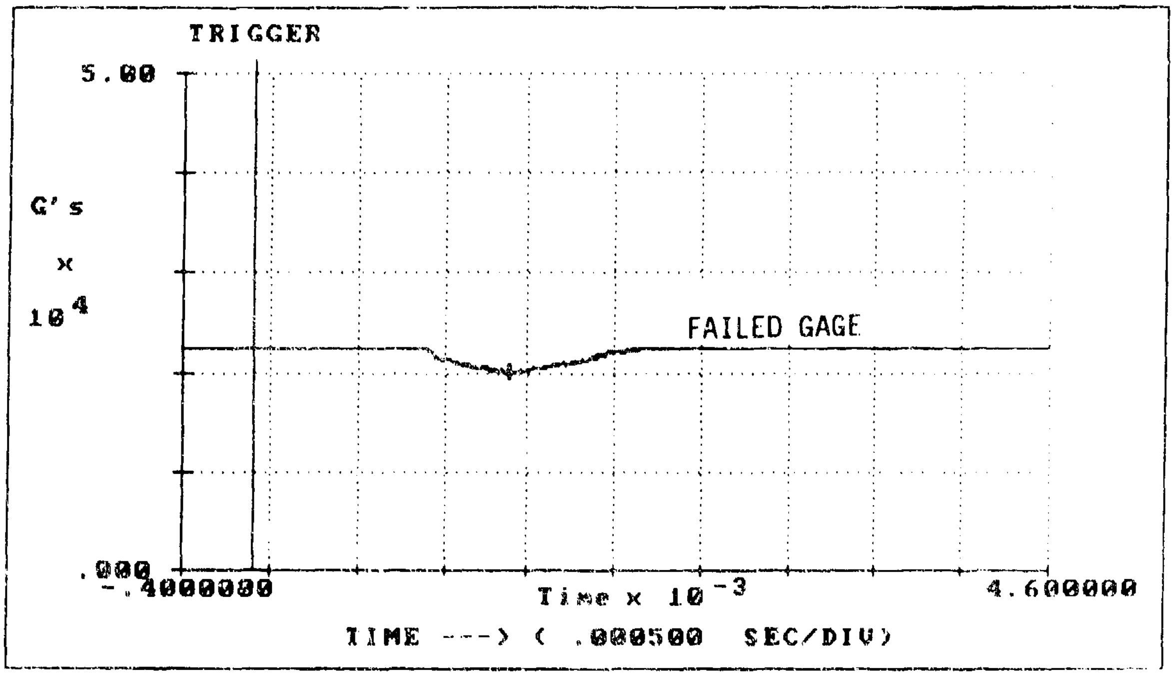
A-1 TRIGGER OCCURRED 24.589182 SECONDS AFTER START

LEGEND: 13 MAY 92

A-1

Time= .000982 G's =-280.914948

Figure 128 Acceleration-Time History: Test 8, Panel I6.



A-2 TRIGGER OCCURRED 24.589182 SECONDS AFTER START

LEGEND: 13 MAY 92

A-2 FAILED BEFORE SHOT

Time= .001488 G's = 20071.466797

Figure 129. Acceleration Time History: Test 8, Panel Mo.

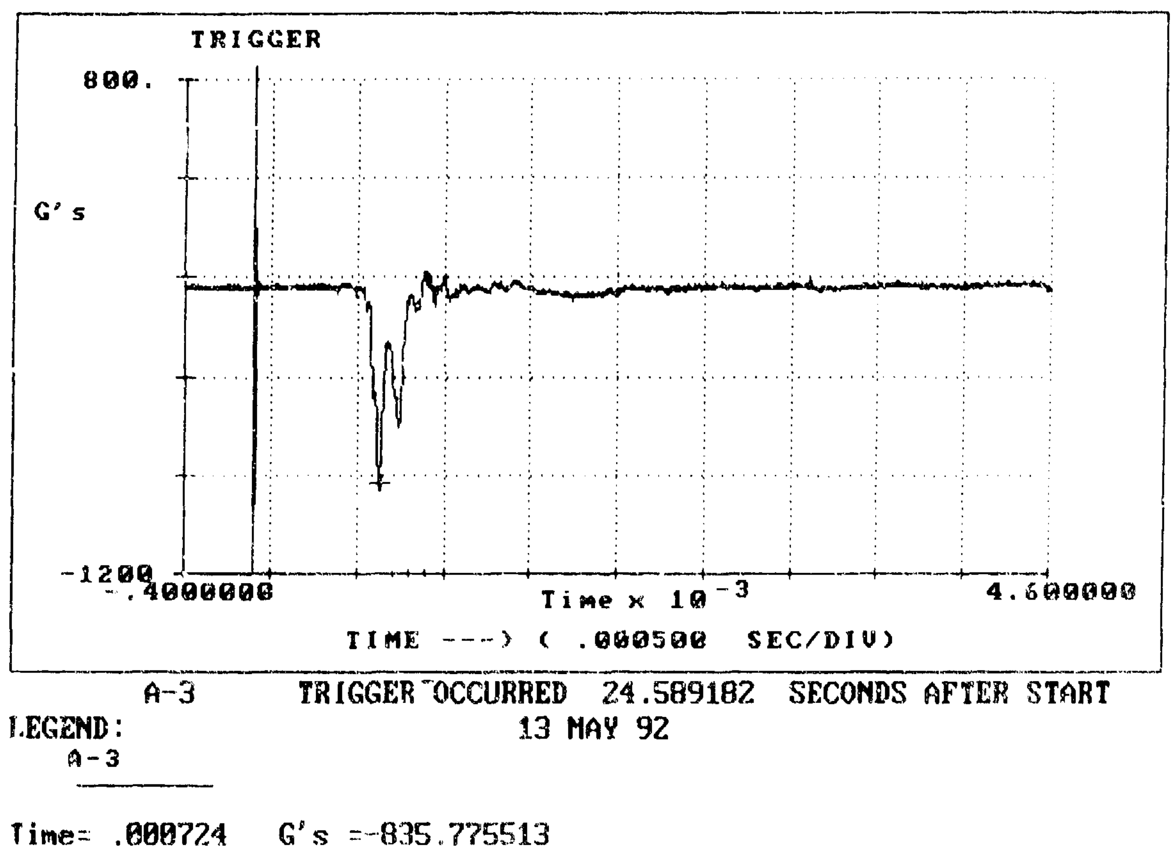
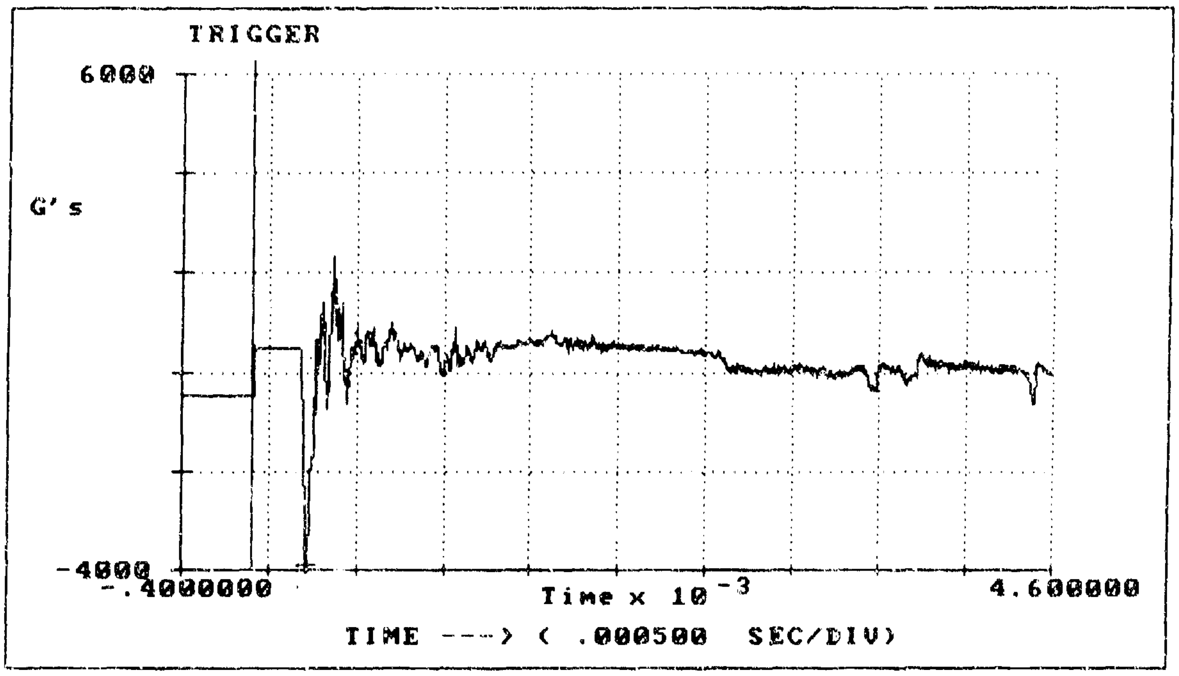


Figure 130. Acceleration-Time History: Test 8, Panel B6.



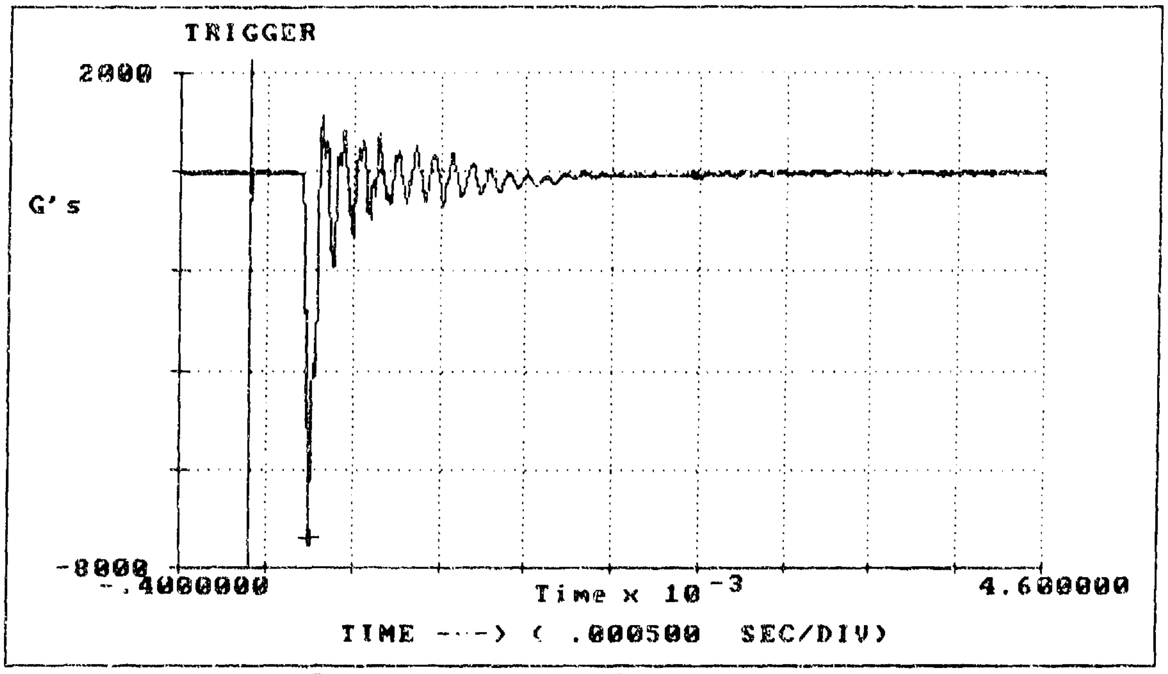
A-1 TRIGGER OCCURRED 25.931469 SECONDS AFTER START

LEGEND: 15 MAY 92

A-1

Time= .000312 G's =-3907.271484

Figure 131. Acceleration-Time History: Test 9, Panel T6.



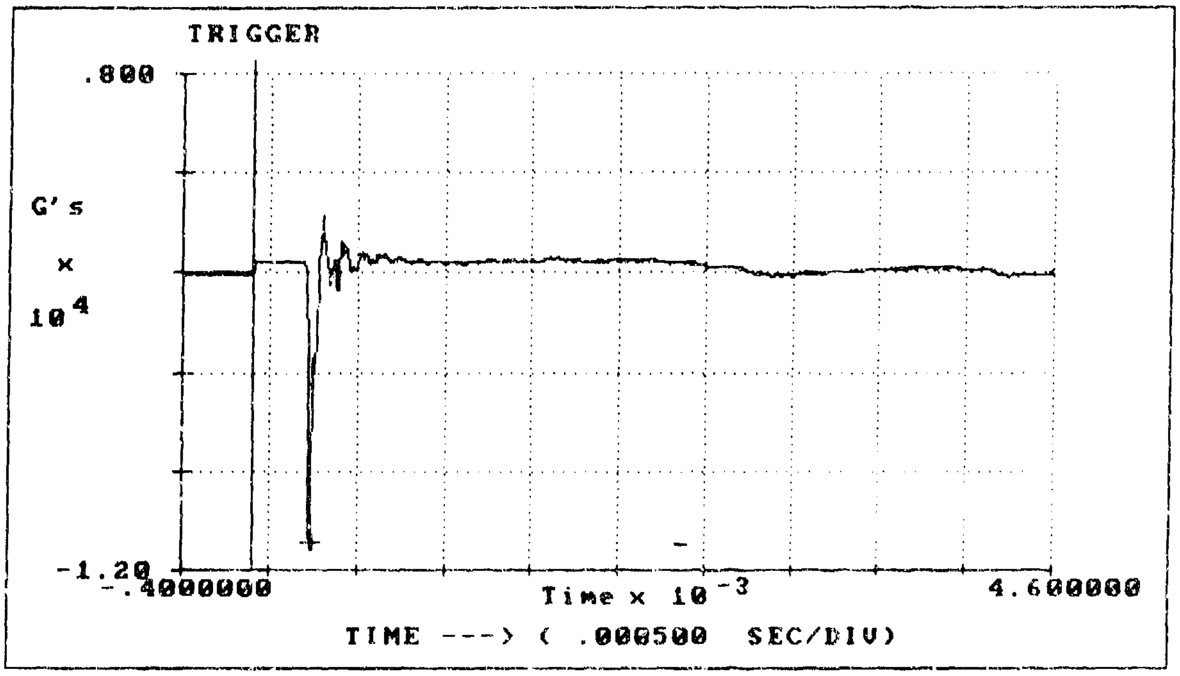
A-2 TRIGGER OCCURRED 25.931469 SECONDS AFTER START

LEGEND: 15 MAY 92

A-2

Time= .000344 G's =-7378.569824

Figure 132. Acceleration-Time History: Test 9, Panel M6.



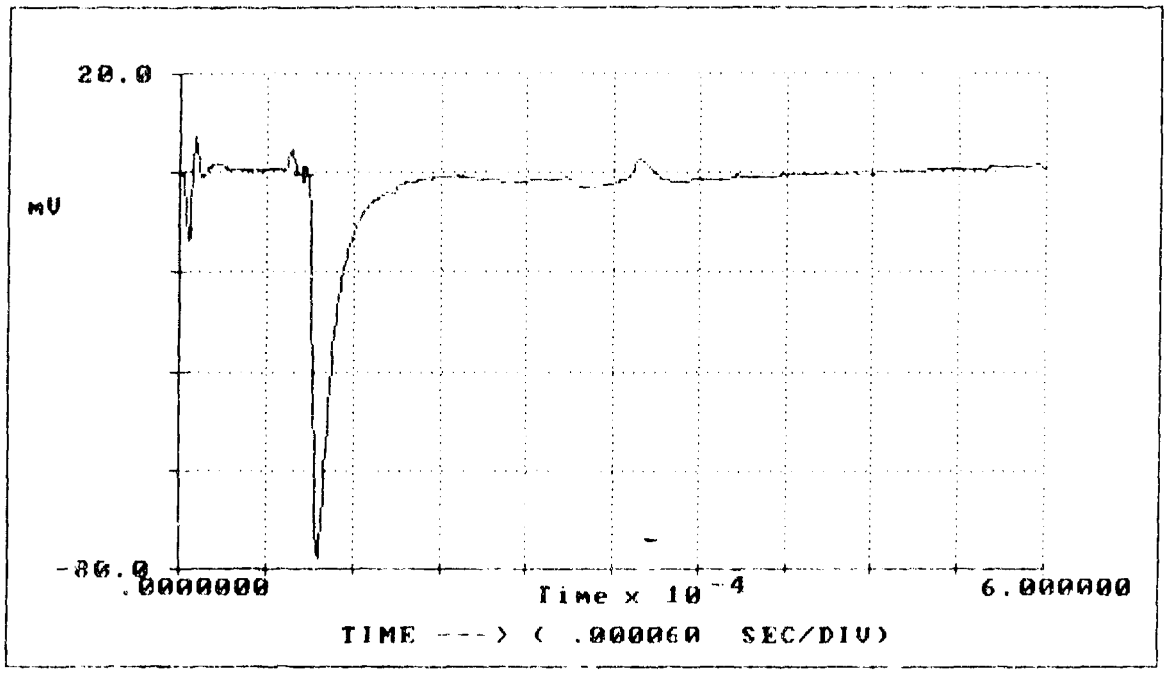
A-3 TRIGGER OCCURRED 25.931469 SECONDS AFTER START

LEGEND: 15 MAY 92

A-3

Time= .000326 G's =-10876.852539

Figure 133. Acceleration-Time History: Test 9, Panel B6.



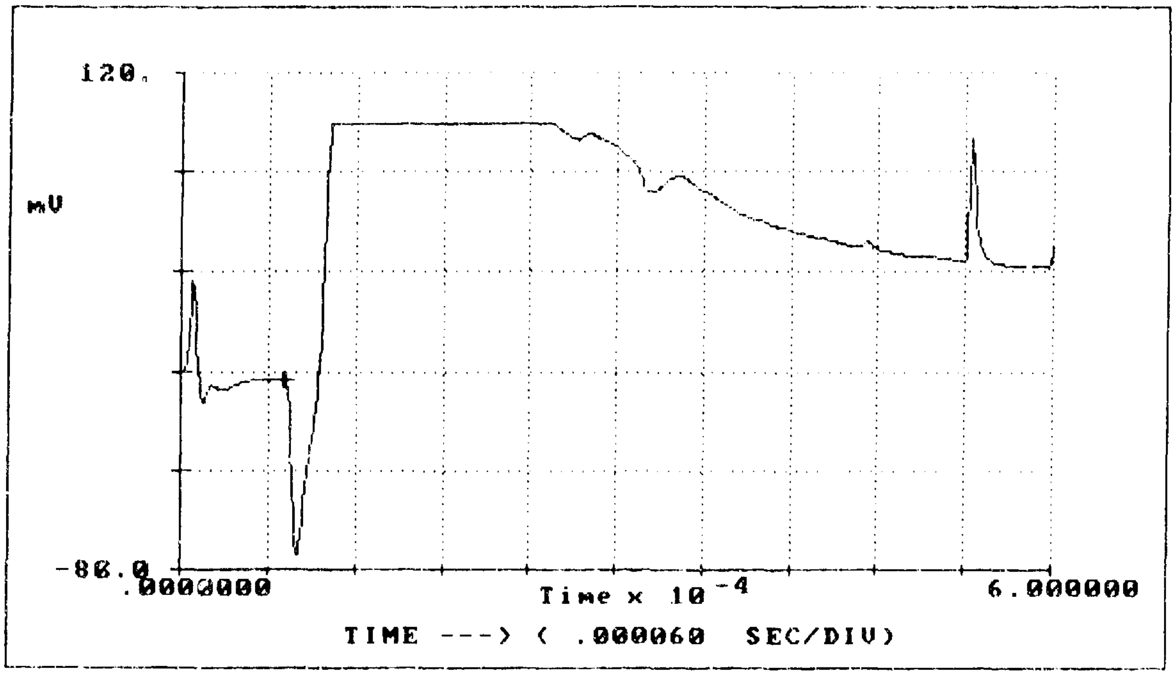
R2 TRIGGER OCCURRED 8.621700 SECONDS AFTER START

LEGEND: 29 JUL 1/8 W @ 2.5"

R2

Time= .000085 mV =-.292969

Figure 134. Voltage-Time History: Replicate Test- Gage at 2.5 in.



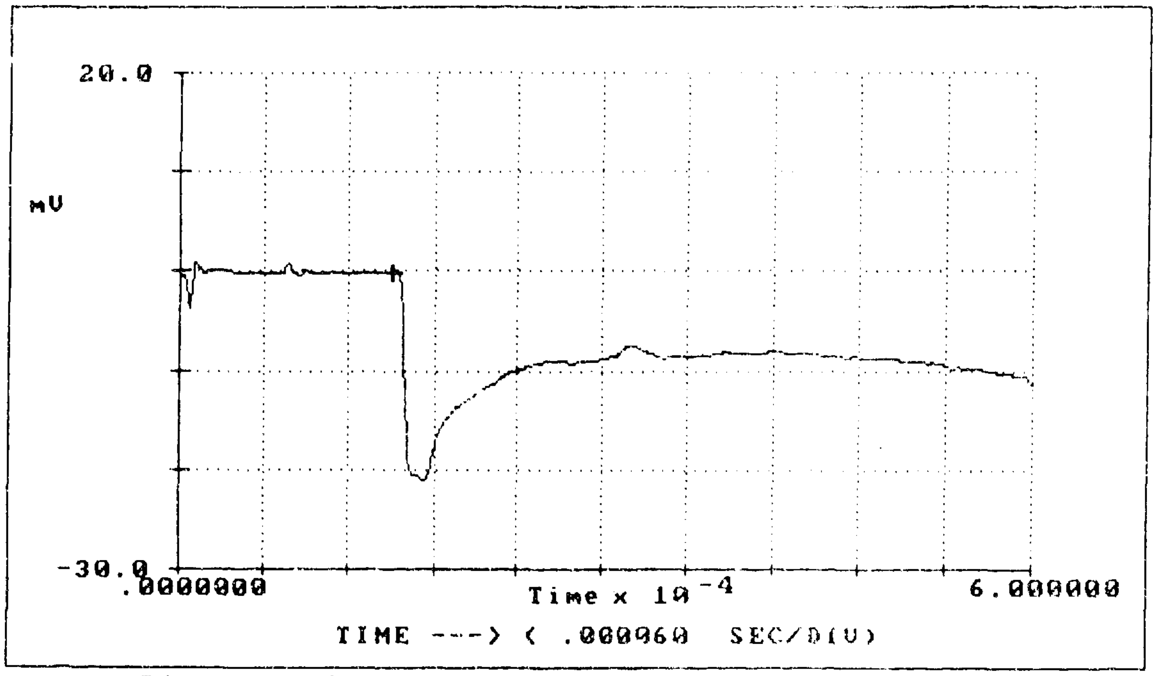
R3 TRIGGER OCCURRED 8.621700 SECONDS AFTER START

LEGEND: 29 JUL 1/8 W @ 3"

R3

Time= .000070 mV =-3.222656

Figure 135. Voltage-Time History: Replicate Test- Gage at 3.0 in.



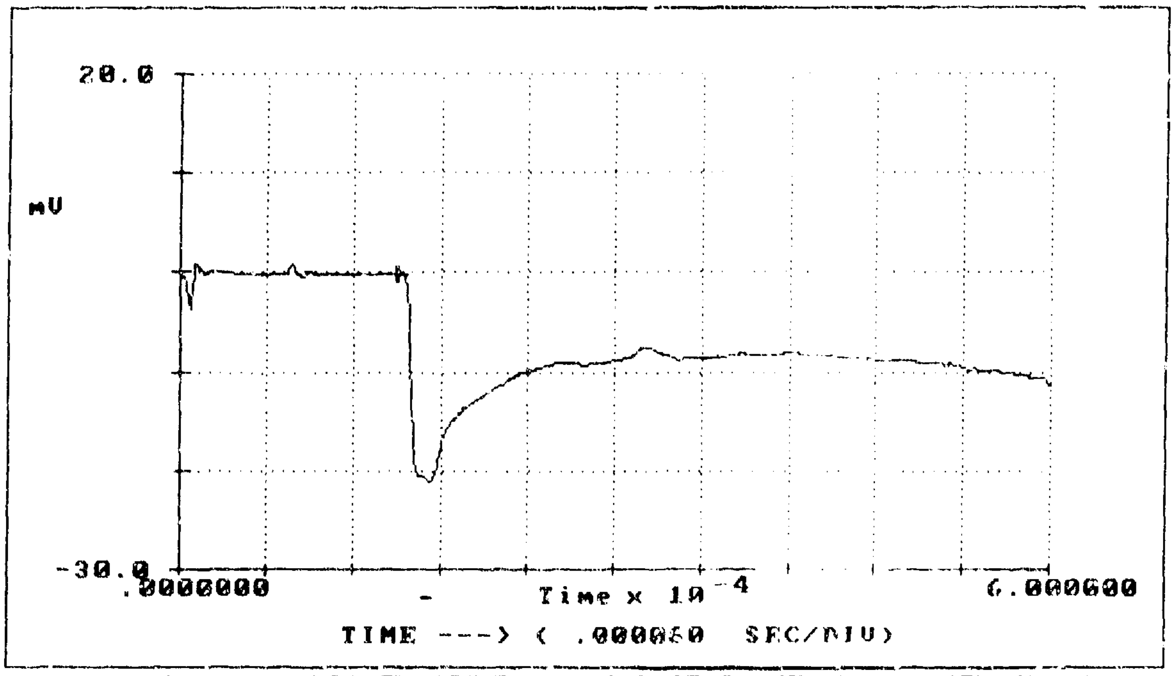
R4 TRIGGER OCCURRED 8.621700 SECONDS AFTER START

LEGEND: 29 JUL 1/8 V 0 5 "

R4

Time= .000150 mV =-.073242

Figure 136. Voltage-Time History: Replicate Test- Gage at 4.5 in.



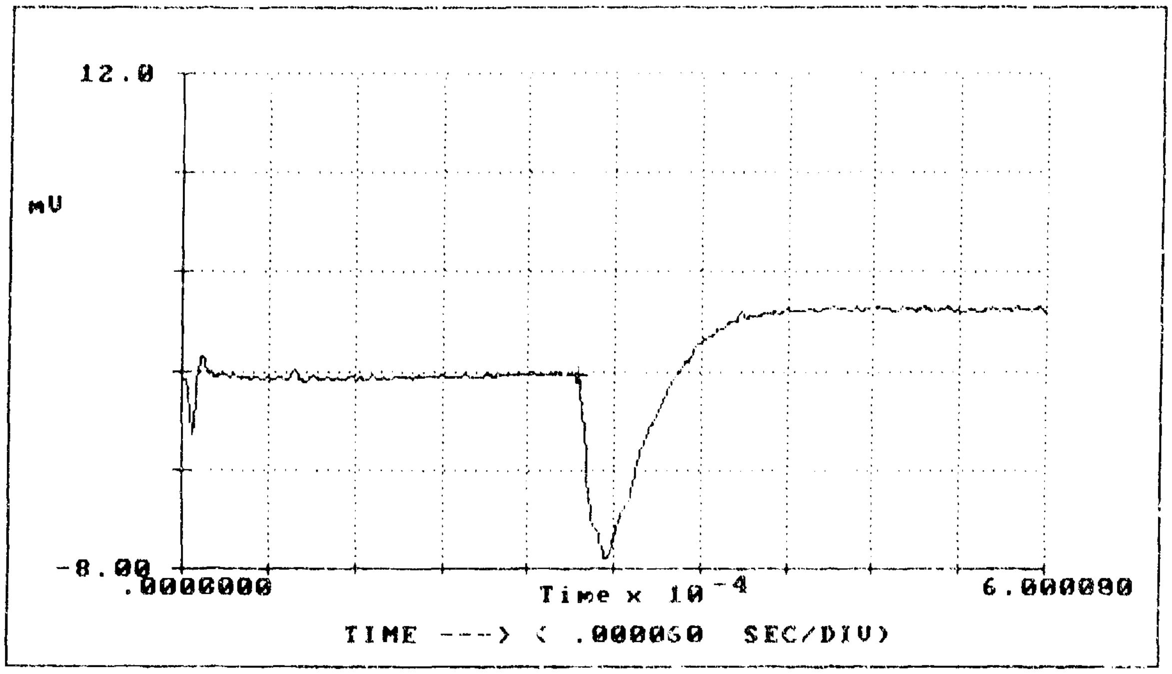
R4 TRIGGER OCCURRED 8.621700 SECONDS AFTER START

LEGEND: 29 JUL 1/8 W @ 5 "

R4

Time= .000150 mV =-.073242

Figure 137. Voltage-Time History: Replicate Test- Gage at 5.0 in.



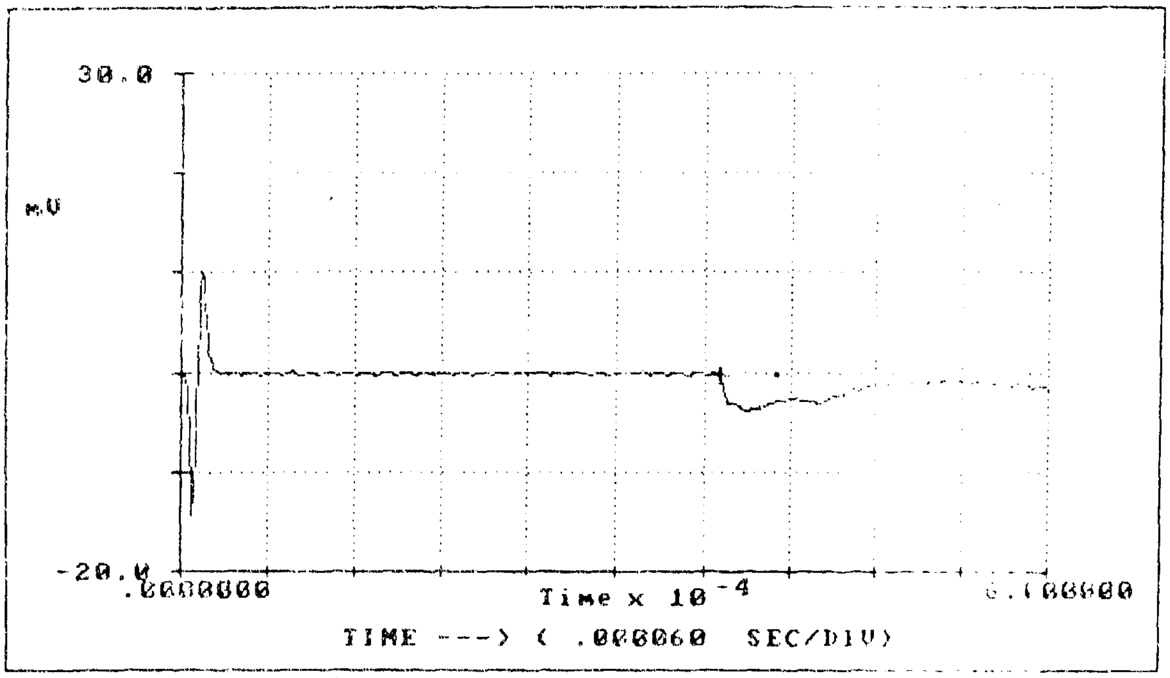
R5 TRIGGER OCCURRED 8.621760 SECONDS AFTER START

LEGEND: 29 JUL 1/9 W @ 7"

R5

Time= .000273 mV =-.136719

Figure 138. Voltage-Time History: Replicate Test- Gage at 7.0 in.



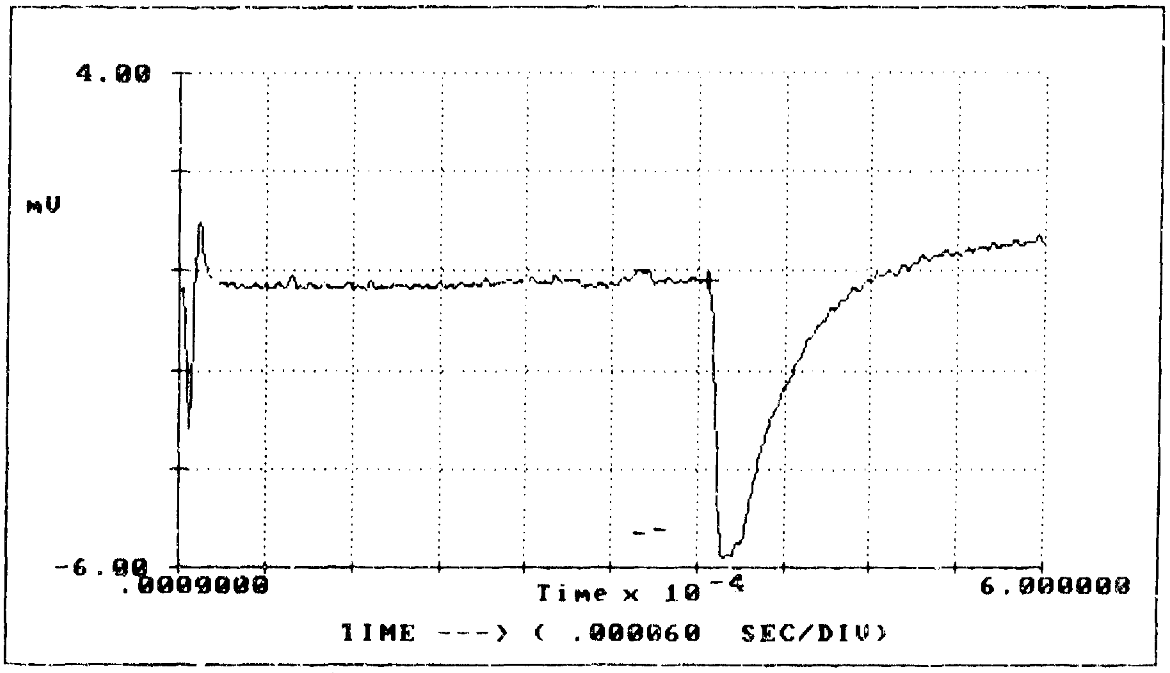
R1 TRIGGER OCCURRED 8.621700 SECONDS AFTER START

LEGEND: 29 JUL 1/8 W @ 8"

R1

Time= .000370 mV =-.302734

Figure 139. Voltage-Time History: Replicate Test- Gage at 8.0 in.



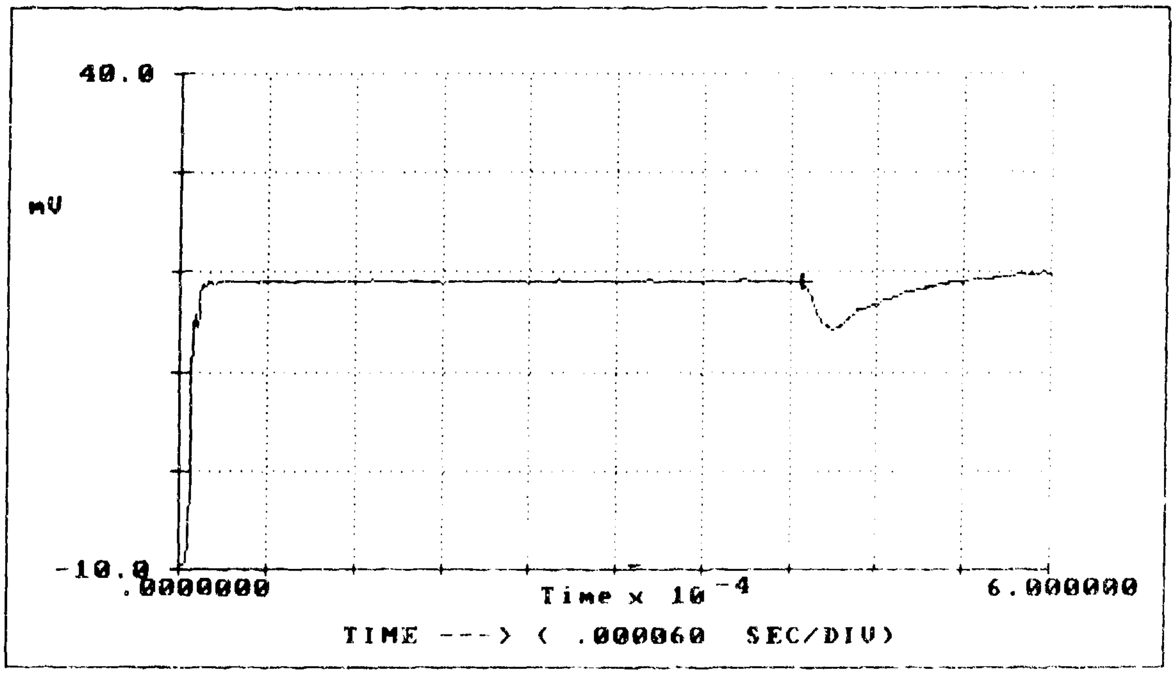
R7 TRIGGER OCCURRED 8.621700 SECONDS AFTER START

LEGEND: 29 JUL 1/8 W @ 8.5"

R7

Time= .000366 mV =-.205078

Figure 140. Voltage-Time History: Replicate Test- Gage at 8.5 in.



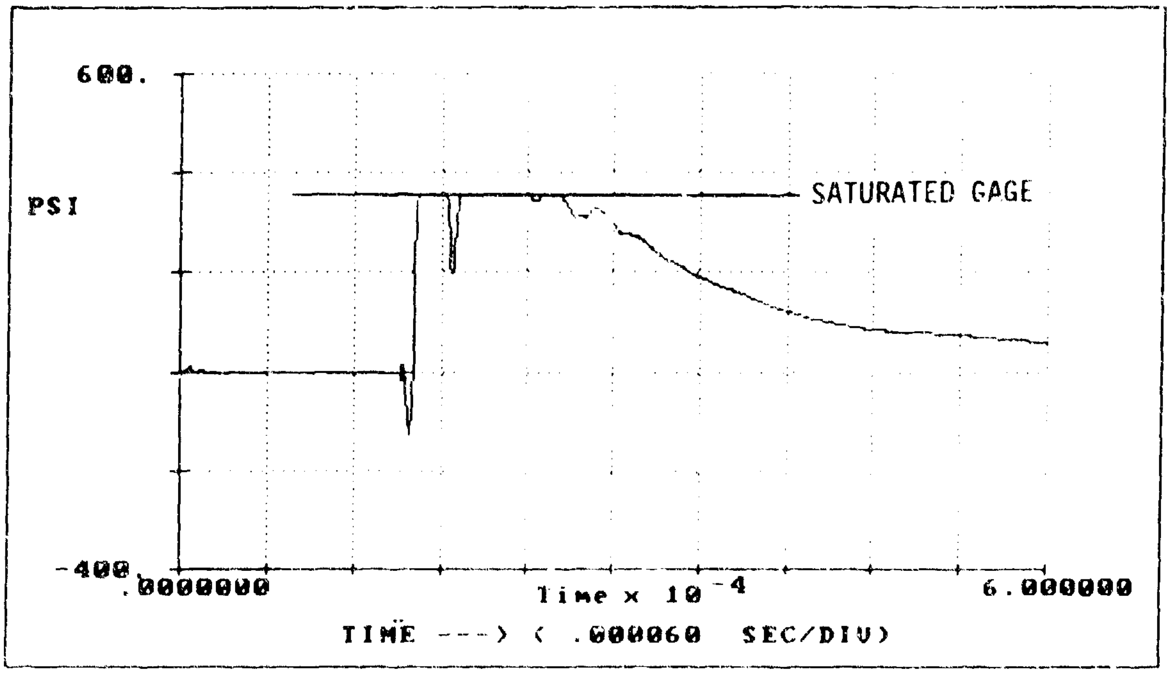
R6 TRIGGER OCCURRED 8.621700 SECONDS AFTER START

LEGEND: 29 JUL 1/8 W @ 9"

R6

Time= .000428 mV = 19.023438

Figure 141. Voltage-Time History: Replicate Test- Gage at 9.0 in.



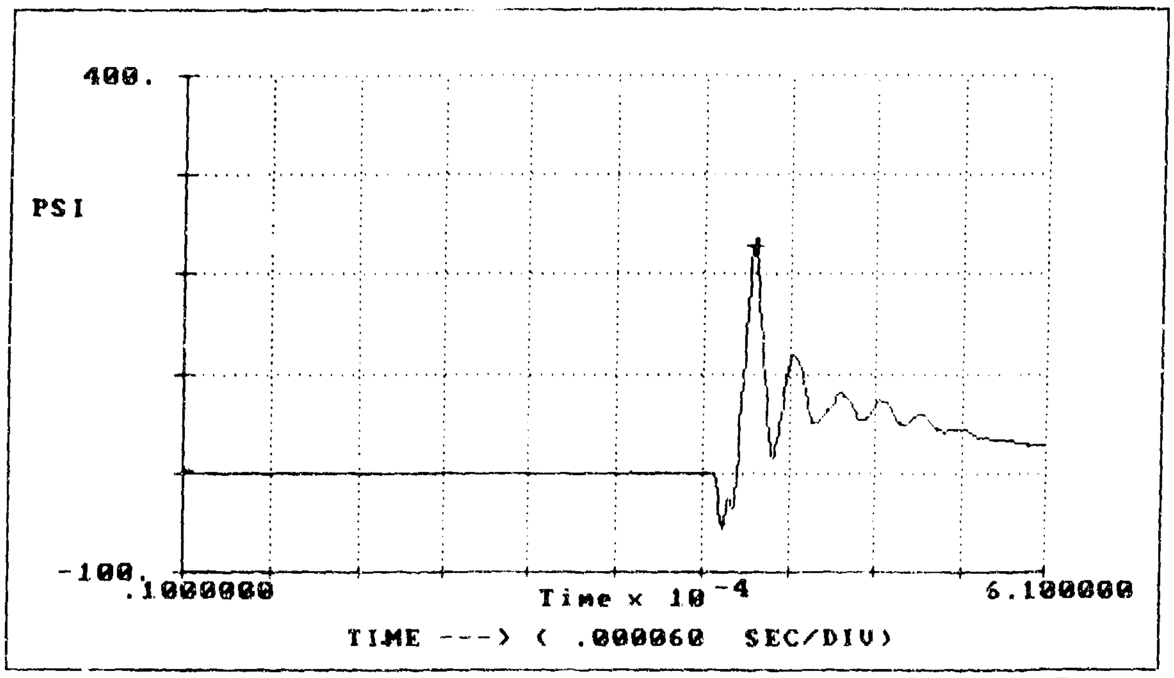
S1 TRIGGER OCCURRED 8.621700 SECONDS AFTER START

LEGEND: 29 JUL PRESSURE GAGE @ 4"

S1

Time= .000152 PSI =-.345197

Figure 142. Pressure-Time History: Replicate Test Gage at 4.0 in.



FF2 TRIGGER OCCURRED 9.729735 SECONDS AFTER START

LEGEND: PRESSURE GAGE @ 8.5

FF2

Time= .000405 PSI = 229.210999

Figure 143. Pressure-Time History: Replicate Test- Gage at 8.5 in.

B: PHOTOGRAPHS

Figures 144 - 162 present the construction sequence for preparation of a reinforced soil wall. Figures 163 - 169 present post-shot deformations of select walls.

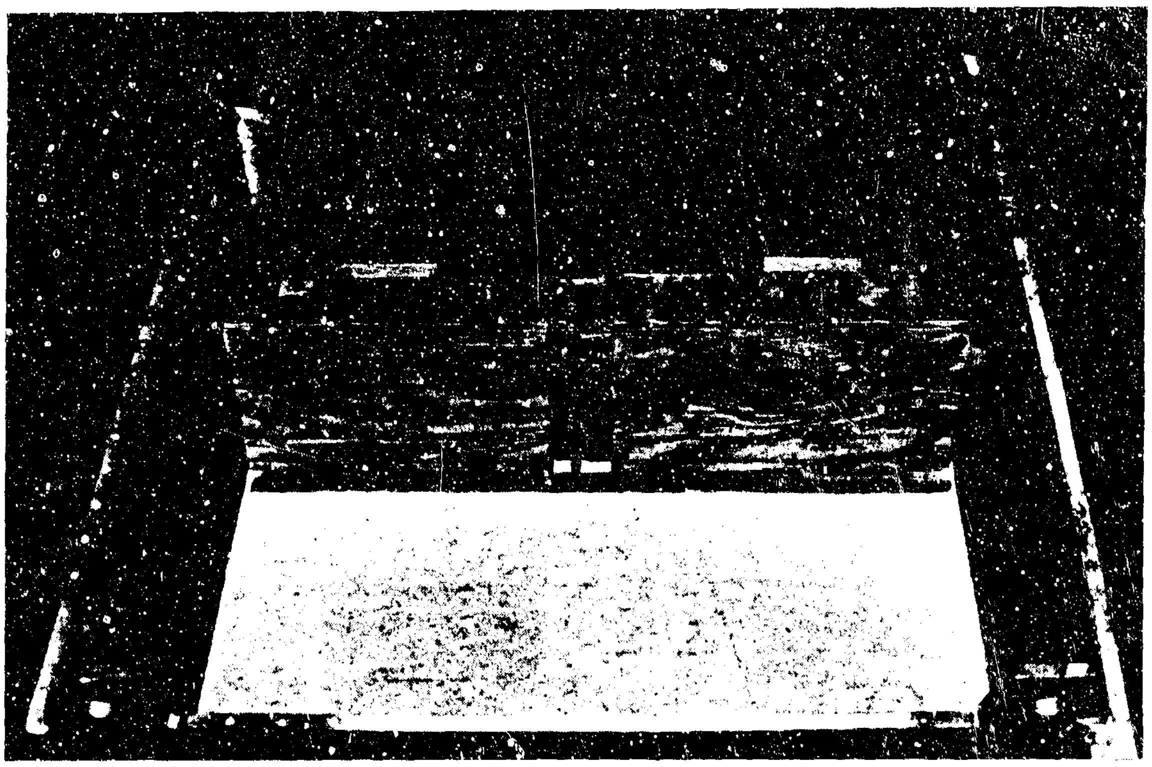


Figure 144. Pluviated Base and Bracing Block

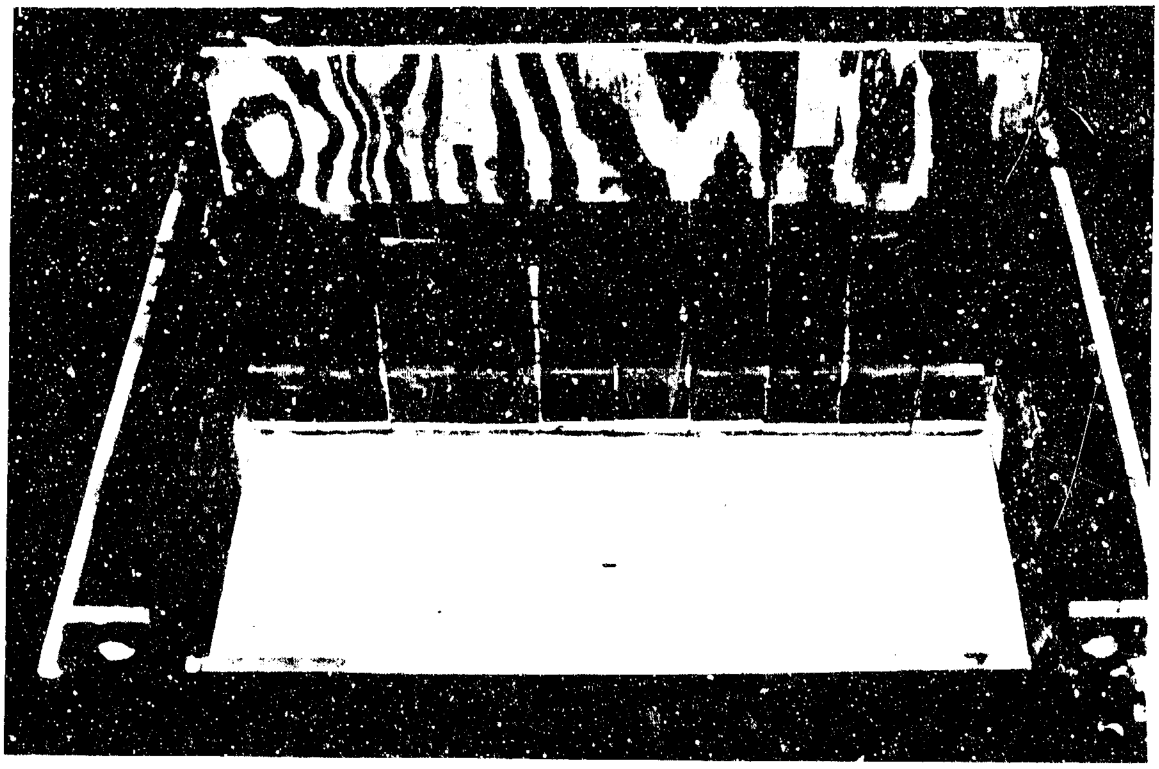


Figure 145. First Course of Facing Panels

Figure 146. First Level of Reinforcement

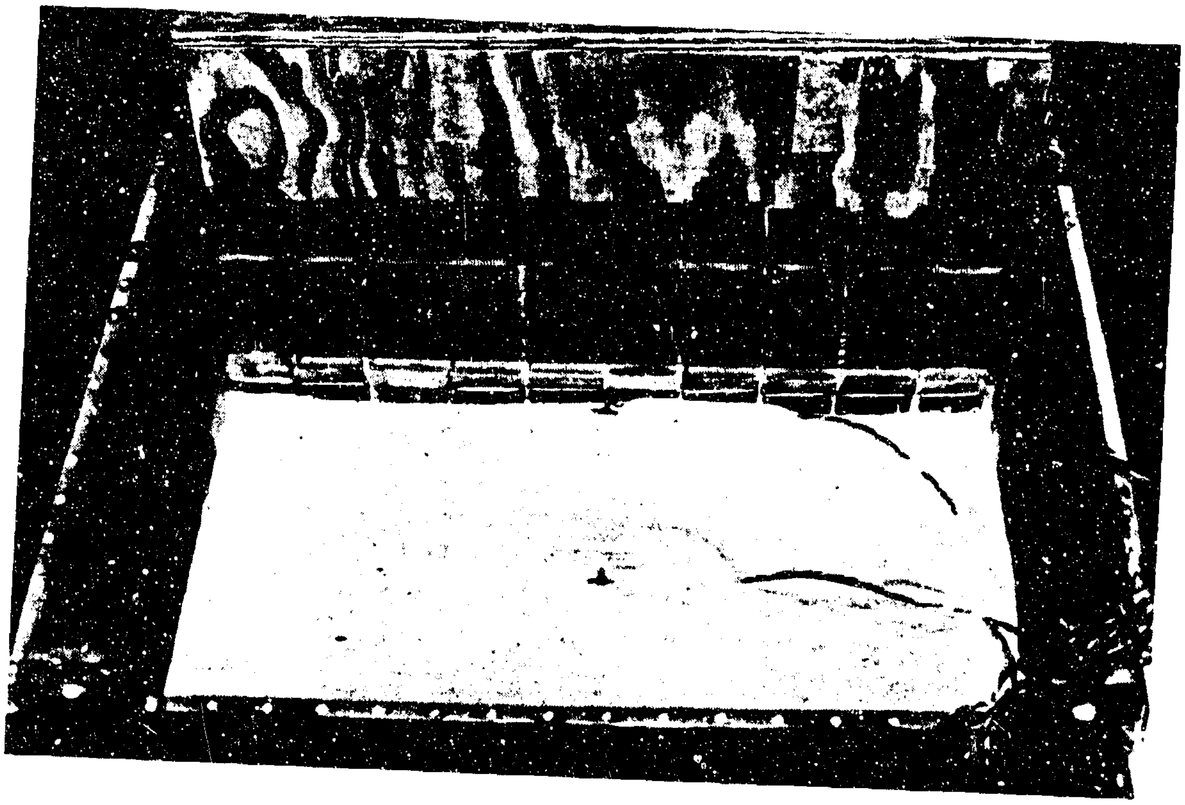


Figure 147. First Level of Instrumentation

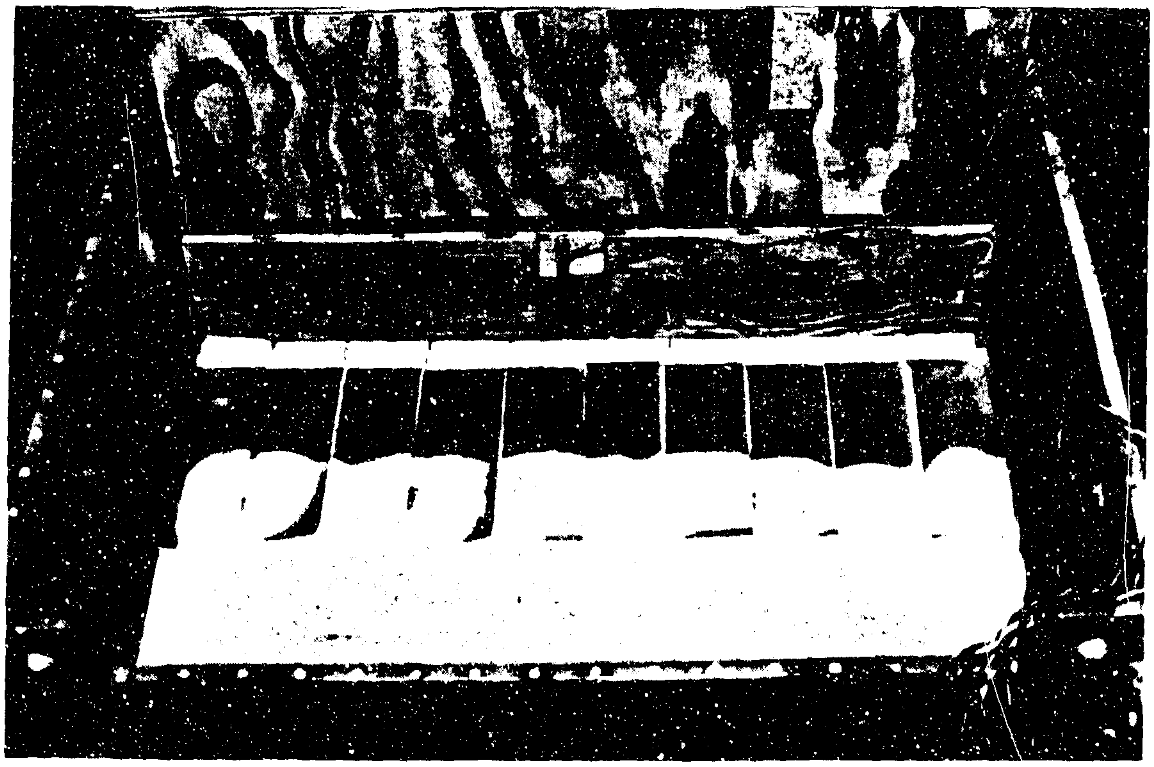


Figure 148. Second Level of Reinforcement

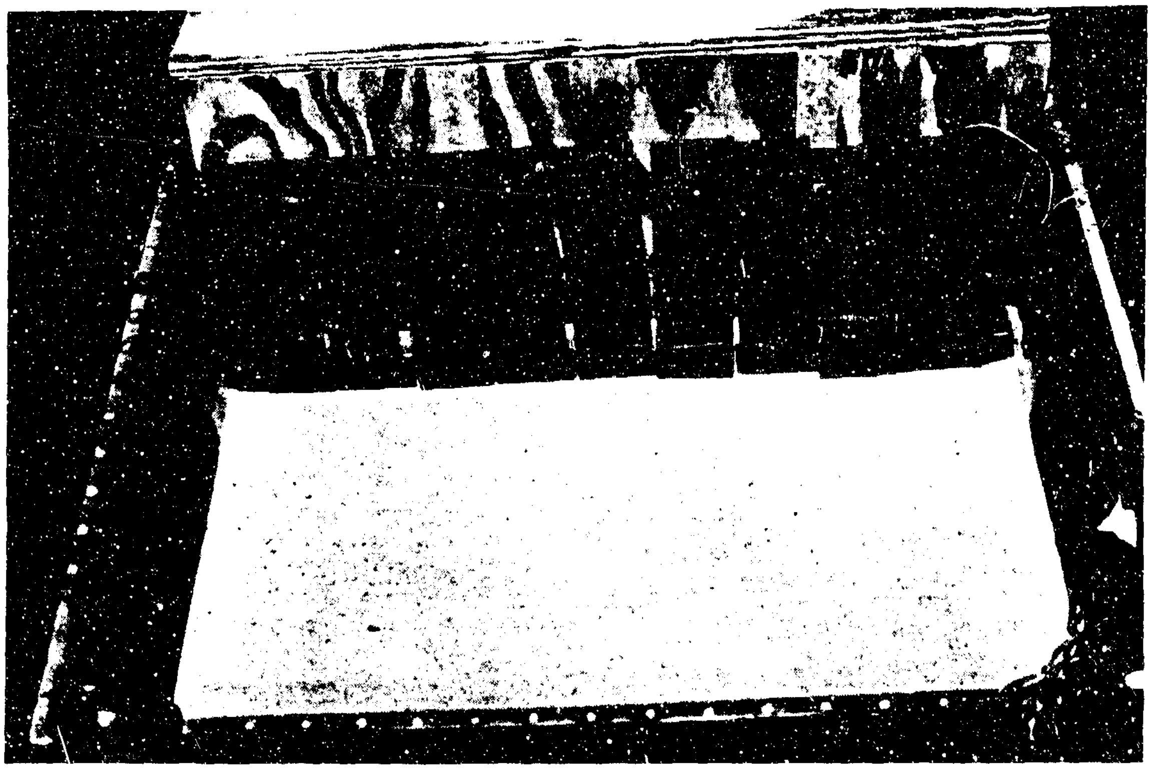


Figure 149. Second Course of Facing Panels

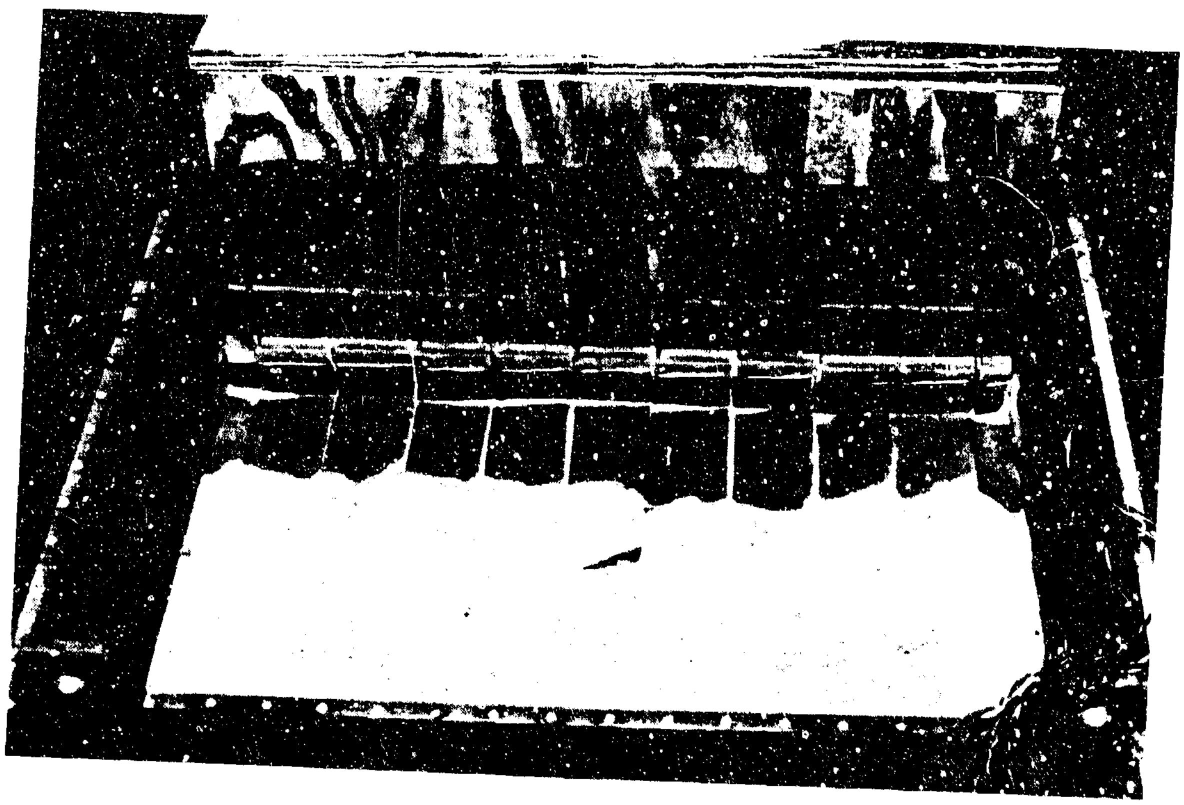


Figure 150. Third Level of Reinforcement

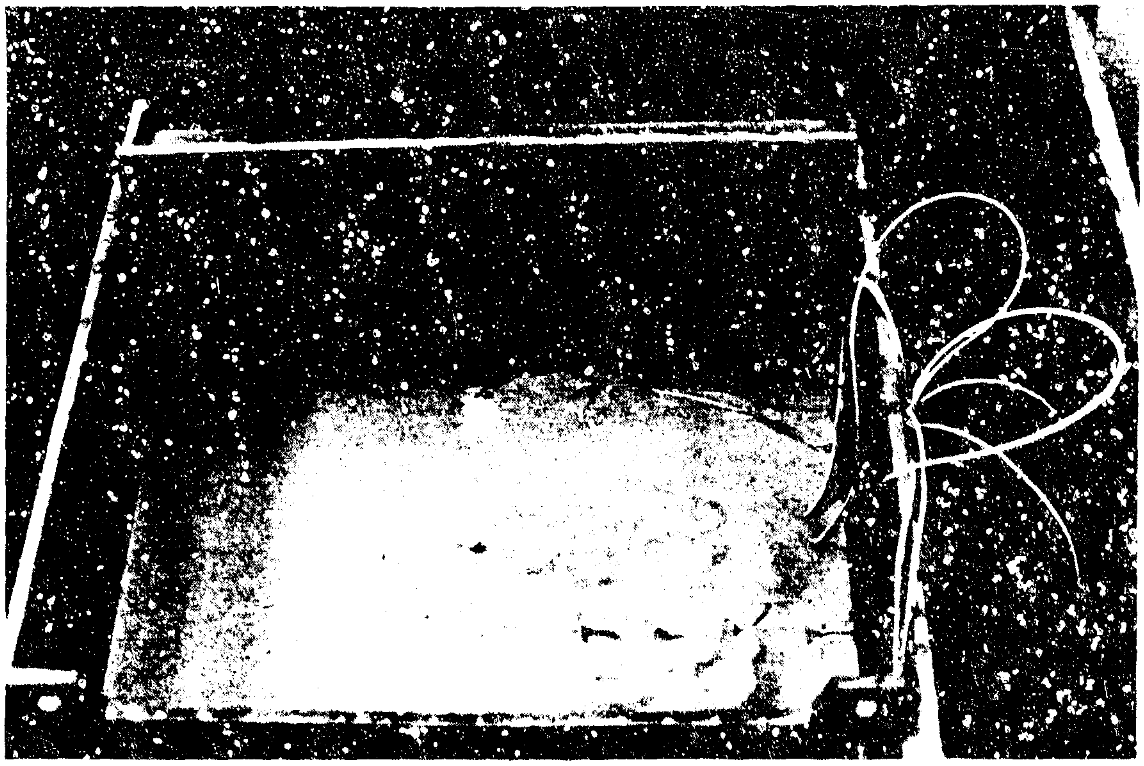


Figure 151. Second Level of Instrumentation

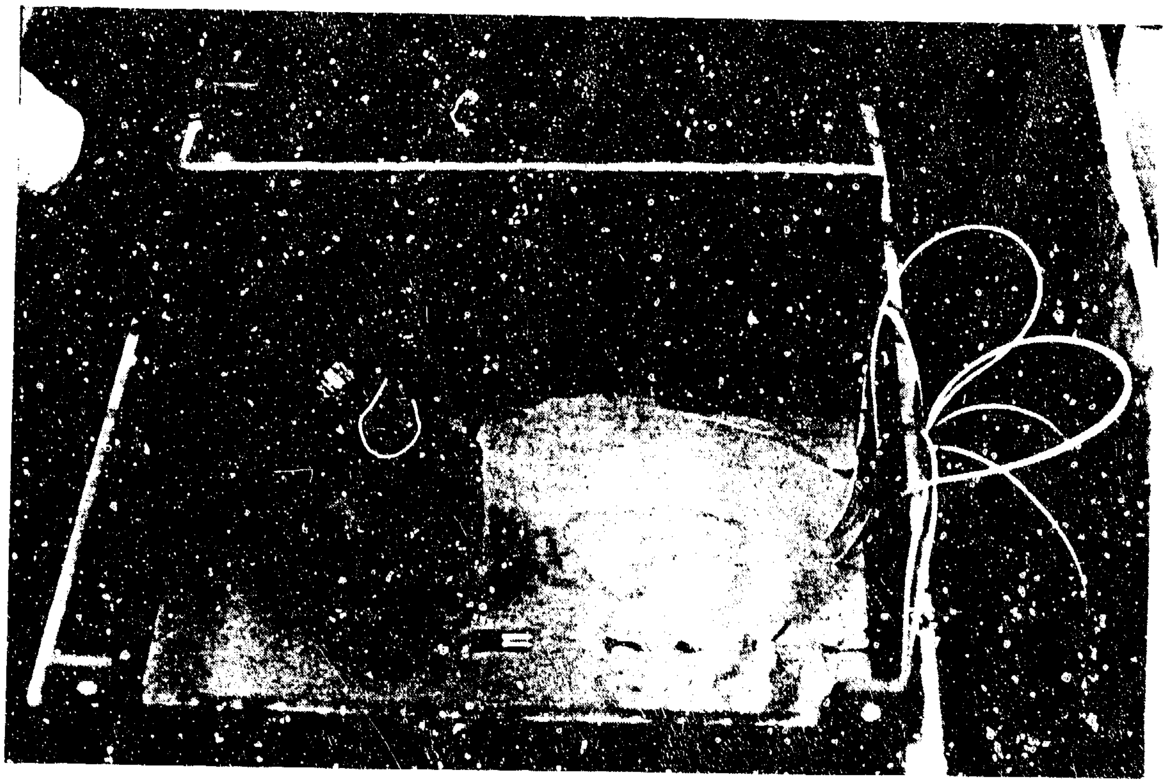


Figure 152. Detonator Placement

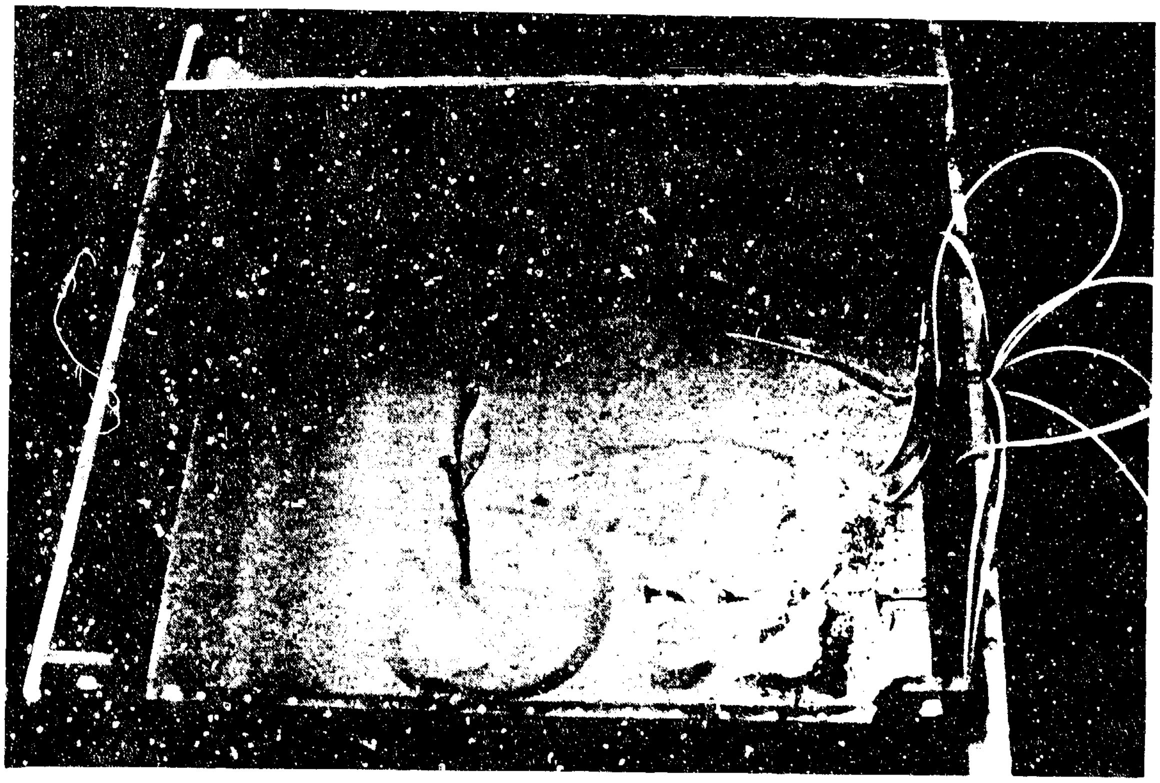


Figure 153. Buried Detonator

Figure 154. Fourth Level of Reinforcement

Figure 155. Third Course of Facing Panels

Figure 156. Fifth Level of Reinforcement

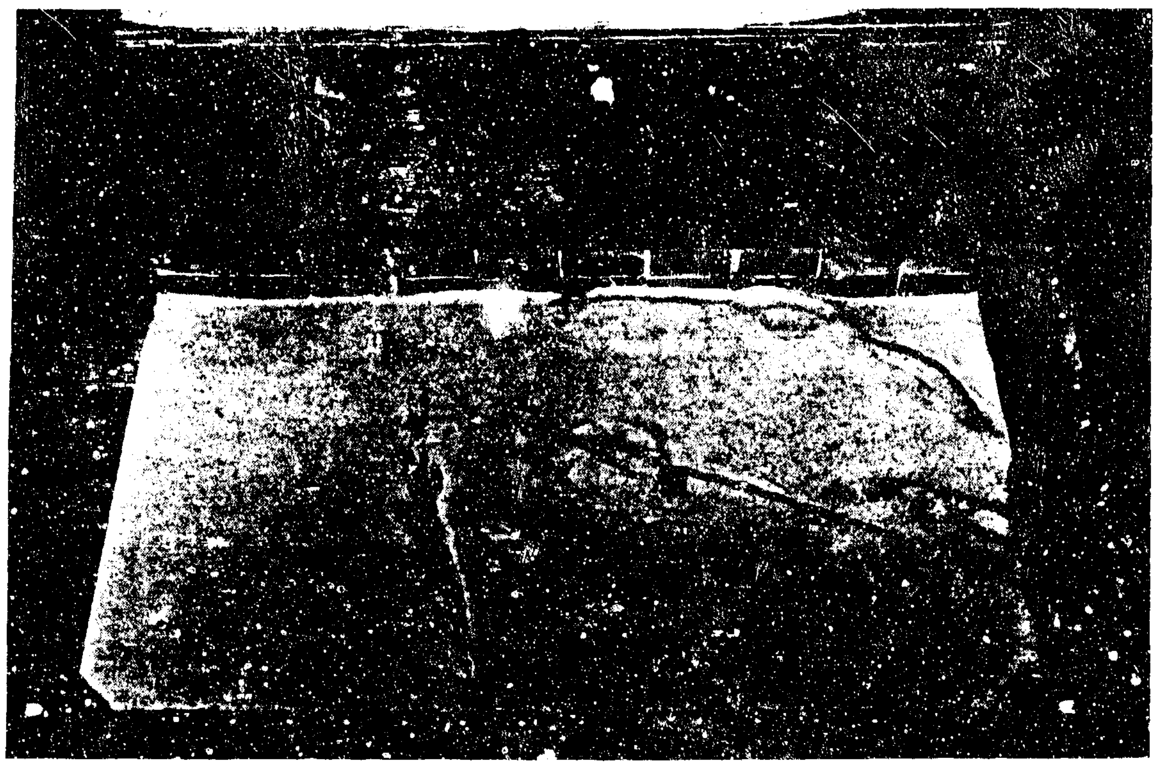


Figure 157. Third Level of Instrumentation

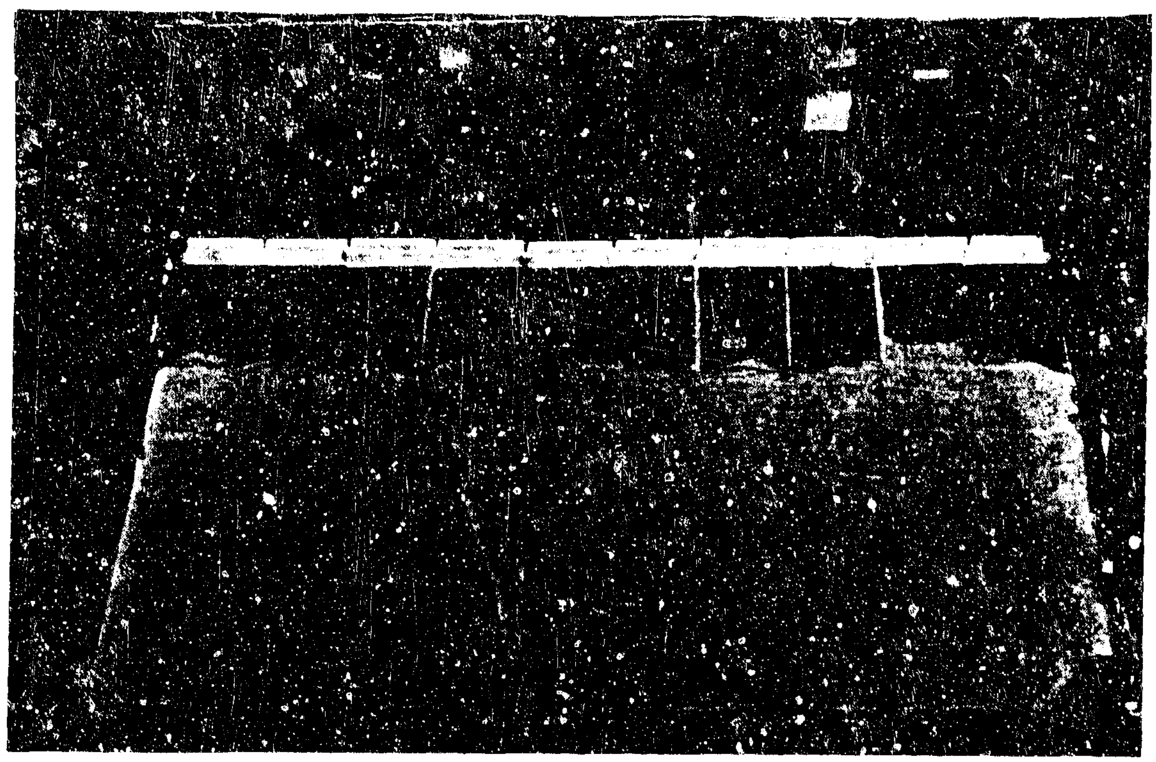


Figure 158. Sixth Level of Reinforcement

Figure 159. Completed Model

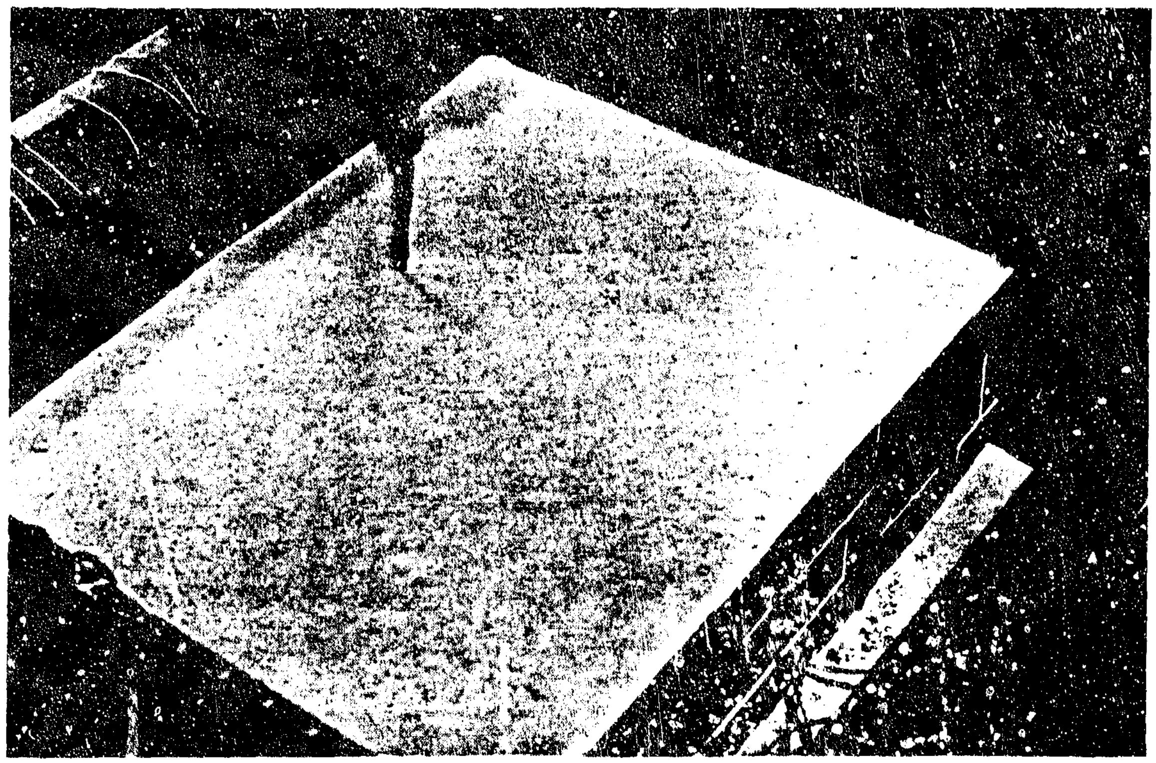


Figure 160. Model Mounted on Centrifuge

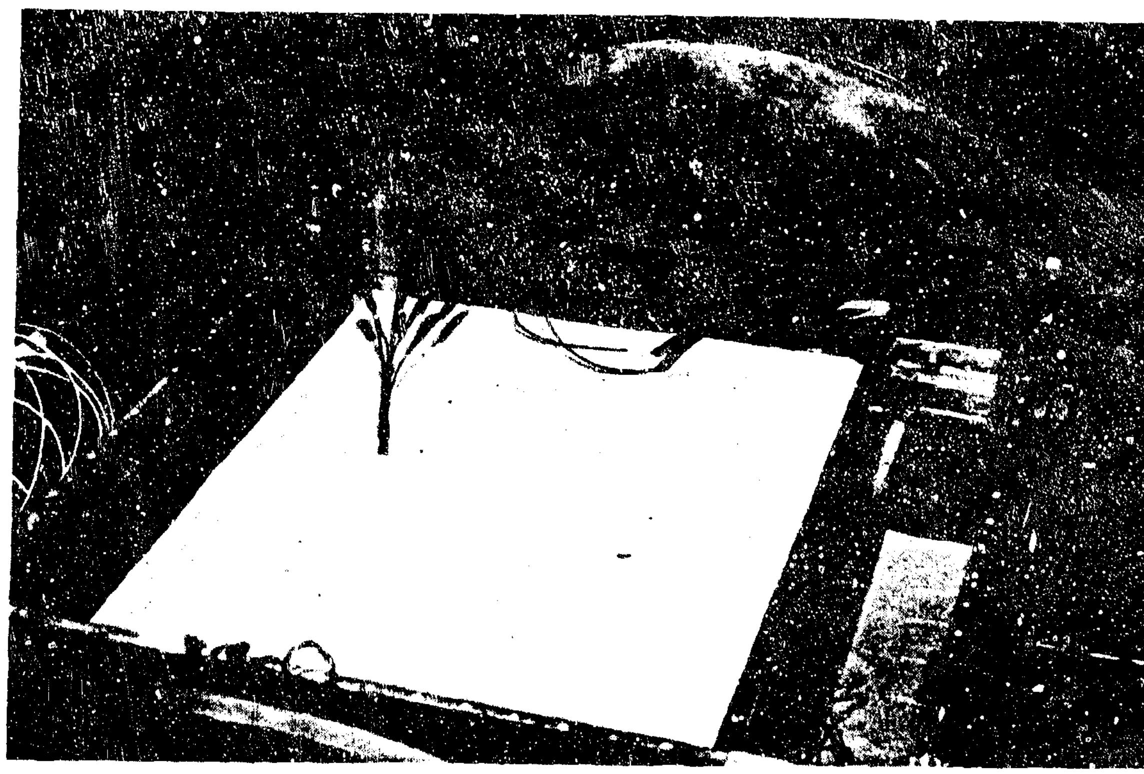


Figure 161. Wired Detonator and Top Restraint

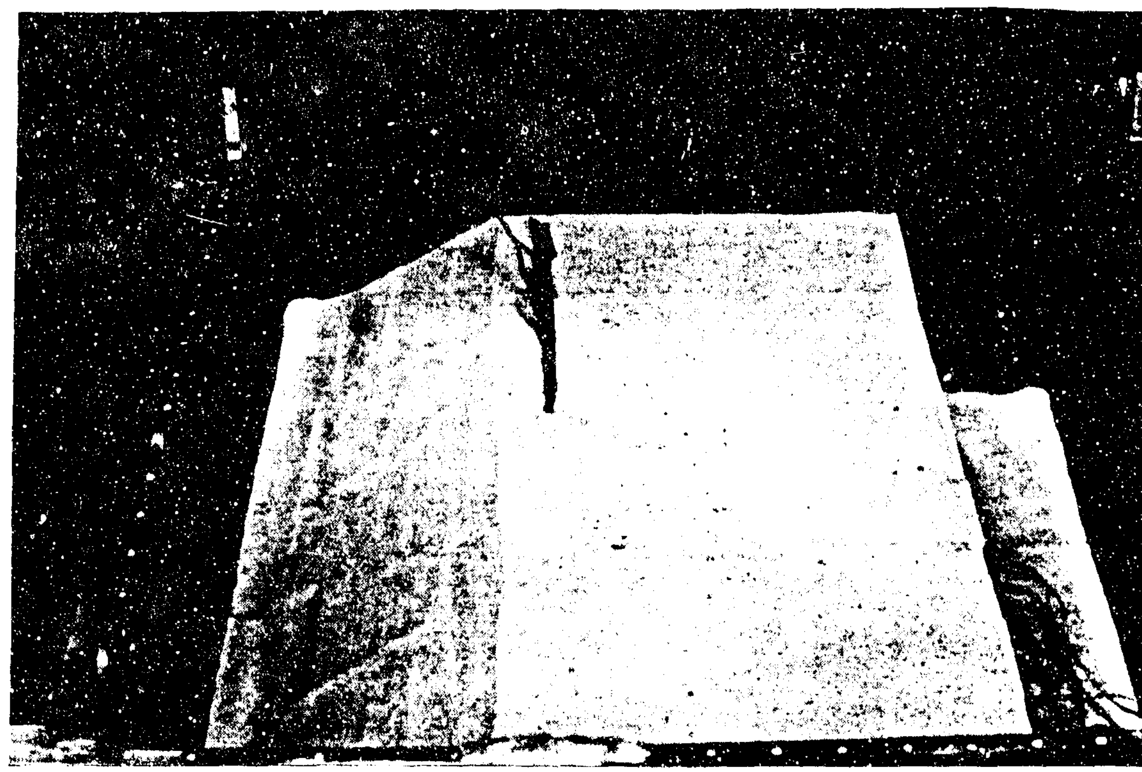


Figure 162. Berm

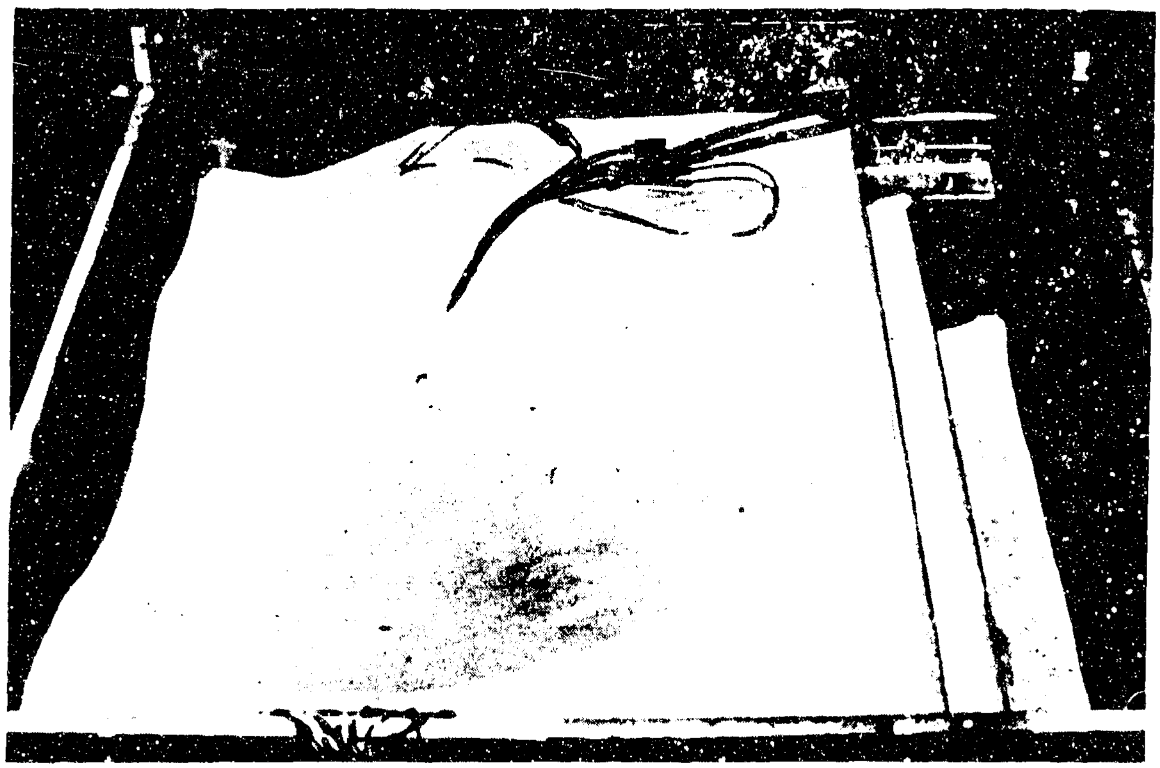


Figure 163. Test 5- Crater

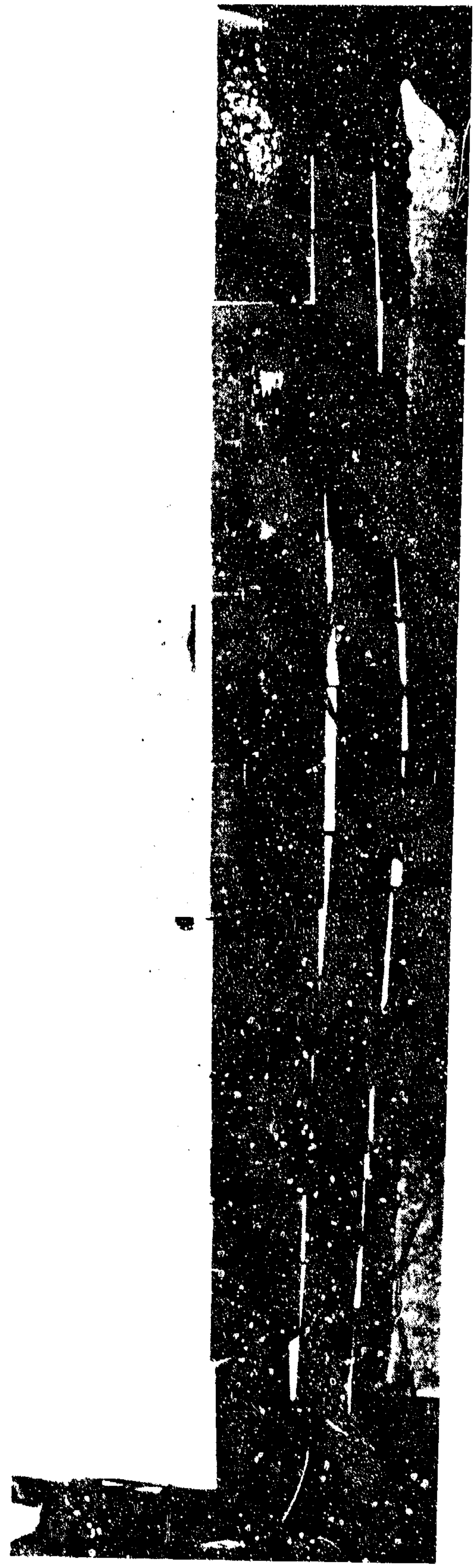


Figure 164. Test 5- Deformed Wall

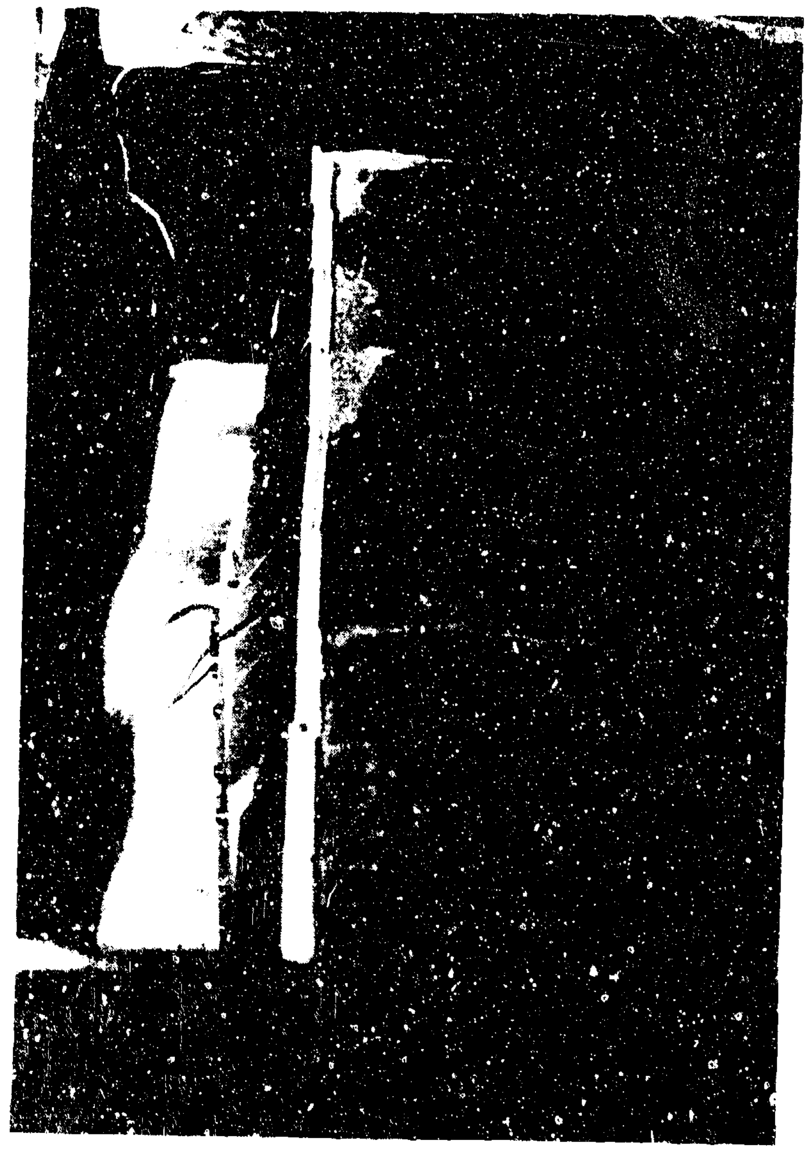


Figure 165. Test 1- Deformed Wall

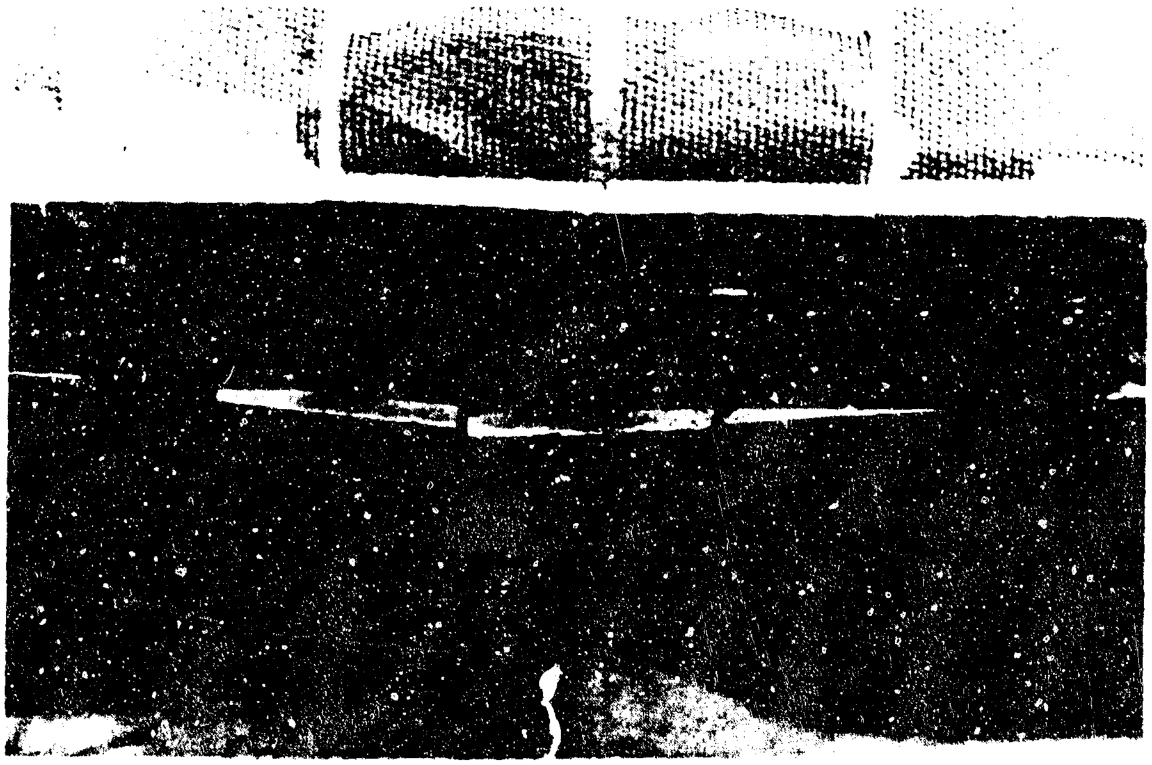


Figure 166. Test 1- Close-Up of Central Wall

Figure 167. Test 4- Deformed Wall

Figure 168. Test 4- Compression in Steel Reinforcing

Figure 169. Test 6 Deformed Wall