

# PILE DRIVING ANALYSIS

BY THE

WAVE EQUATION

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## TABLE OF CONTENTS

CHAPTER 1. INTRODUCTION.....	5
CHAPTER 2. BASIC USES OF THE WAVE EQUATION.....	7
Introduction.....	7
Hammer Selection.....	7
Selection of Driving Accessories.....	9
Cushion Selection.....	9
Helmet Selection.....	10
Pile Size.....	12
Prediction of Pile Load Capacity.....	13
Initial Driving.....	15
Final Driving.....	16
Soil Set Up or Relaxation.....	16
Driving Stresses in Point Bearing Piles.....	17
Use of Wave Equation for Field Control.....	19
Basic Output.....	21
Input Data Summary.....	22
Solution Summaries.....	22
Selection of Allowable Stresses for Pile Materials.....	23
CHAPTER 3. INFORMATION REQUIRED FOR ANALYSIS.....	23
Introduction.....	23
Problem Information Forms.....	26
Example Problem.....	29
Discussion of Solution of Example Problem.....	31
Recommendations Based on Example Solution.....	33
CHAPTER 4. THE COMPUTER PROGRAM.....	34
Introduction.....	34
General.....	34
The Numerical Solution.....	37
Idealization of Hammers.....	38
The Ram.....	38
The Anvil and Helmet.....	40
Ram Velocity at Impact.....	40
Open-end diesel hammers.....	40
Closed-end diesel hammers.....	41
Double-acting air and steam hammers.....	41
Single acting air and steam hammers.....	42
Idealization of Cushions.....	42
Idealization of the Pile.....	43
Pile Segment Length.....	43
Pile Segment Weight.....	44
Pile Segment Springs.....	44

Limiting Forces Between Pile Segments.....	45
Slack in Joints.....	45
Idealization for Soils.....	45
Soil Quake and Damping.....	47
APPENDIX A - COMPUTER PROGRAM INPUT DATA.....	48
Introduction.....	48
Program Input Data.....	48
NOP(I) Functions.....	48
APPENDIX B - CODING SHEETS.....	53
APPENDIX C - HAMMER, CUSHION, AND SOIL PROPERTIES.....	54
TABLE C1 - Summary of Steam Hammer Properties.....	54
TABLE C2 - Summary of Diesel Hammer Properties.....	56
TABLE C3 - Summary of Constants for Commonly Used Cushion and Capblock Materials.....	57
TABLE C4 - SOIL PROPERTIES.....	57
APPENDIX D - SAMPLE PROBLEMS.....	58
Case I.....	58
Case II.....	63
Case III.....	64
Case IV.....	66
Case V.....	67
Case VI.....	68
Case VII.....	69
Case VIII.....	70
Case IX.....	71
Case X.....	73
Case XI.....	75
Case XII.....	78
Case XIII.....	79
Case XIV.....	81
Case XV.....	82
Case XVI.....	84
Case XVII.....	86
APPENDIX F - LIST OF SELECTED REFERENCES.....	88
APPENDIX G - MICROWAVE/EDITWAVE.....	92
Introduction - MICROWAVE.....	93
Program Operation.....	93
EDITWAVE.....	93
MICROWAVE.....	96
Sample Computer Session.....	97
To run the data using MICROWAVE.....	122

## LIST OF FIGURES

<b>Figure 1.</b> RUT vs Blow Count Curves for Comparison of Different Pile Driving Hammers; Cases I, II, and III .....	9
<b>Figure 2.</b> RUT vs. Blow Count Curves for Comparing the Effects of Varying Cushion Thickness Using a Delmag D-15 Hammer; Cases III, IV, and V .....	11
<b>Figure 3.</b> RUT vs Blow Count Curves for Comparing the Effects of Changing Helmet Weight Using a Delmag D-15 Hammer; Cases V and VI.....	12
<b>Figure 4.</b> RUT vs Blow Count Curves for Comparing the Influence of Changing a Pile's Cross-sectional Area Using a Vulcan 010 Hammer; Cases VII, VIII, and IX.....	14
<b>Figure 5.</b> Pile Load Capacity vs Time After Driving to Determine Soil Set-up or Recovery of Strength After Driving in Cohesive Soil (After Reference 29).....	15
<b>Figure 6.</b> RUT vs Blow Count for a Tapered Pile Driven with a Vulcan 010 Hammer to Full Penetration; Case X.....	16
<b>Figure 7.</b> Soil Resistance Distribution for a Tapered Pile During Driving and for Long Term Capacity; Cases XI and XII.....	17
<b>Figure 8.</b> RUT vs Blow Count for a Tapered Pile Using a Vulcan 010 Hammer; Case XI.....	18
<b>Figure 9.</b> RUT vs Blow Count for a Tapered Pile Using a Vulcan 010 Hammer; Case XII.....	19
<b>Figure 10.</b> RUT vs Blow Count for a Kobe K-25 Hammer Driving a 60 Foot Pipe Pile; Case XIII.....	20
<b>Figure 11.</b> RUT vs Blow Count for a Delmag D-44 Hammer Driving a 60 Foot Pipe Pile to 40 Foot Penetration; Case XIV.....	21
<b>Figure 12.</b> RUT vs Blow Count for a Vulcan 30C Hammer Driving a 10 Inch by 10 Inch Prestressed Concrete Pile; Case XV.....	22
<b>Figure 13.</b> RUT vs Blow Count for a Link Belt 312 Hammer Driving a 12" by 12" Prestressed Concrete Pile; Case XVI.....	23
<b>Figure 14.</b> RUT vs Blow Count for an MKT DE-30 Hammer Driving an HP8x36 Steel Pile; Case XVII.....	24
<b>Figure 15.</b> Cross-sectional View of a Drop or Steam Hammer for Representation of Various Sections.....	28
<b>Figure 16.</b> Cross-sectional View of a Diesel Hammer for Representation of Various Sections..	29
<b>Figure 17.</b> Cross-sectional View of a Pipe Pile with an Add-on Section .....	34
<b>Figure 18.</b> Penetration Below the Mudline for a Soil Boring Sample .....	35
<b>Figure 19.</b> Pile Penetration in Feet vs Resistance to Penetration in kips .....	36
<b>Figure 20.</b> Assumed Soil Resistance Distribution for Problems 1&2, Distributed Along the Side and at the Point of the Piles for Varying Penetrations.....	37
<b>Figure 21.</b> Wave Equation Results for Example Problems 1 & 2.....	37
<b>Figure 22.</b> Idealization of a Pile for Purpose of Analysis - Pile is Divided into Uniform Concentrated Weights and Springs.....	39
<b>Figure 23.</b> Idealization of Steam Hammer with Capblock and Cushion in Hammer-Pile System	43
<b>Figure 24.</b> Idealization of Steam Hammer with Capblock Only in Hammer-Pile System .....	44
<b>Figure 25.</b> Idealization of Diesel Hammer with Capblock Only in Hammer/Pile System.....	45
<b>Figure 26.</b> Definition of Coefficient of Restitution for Cushioning Material .....	47
<b>Figure 27.</b> Soil Load/Deformation Characteristics.....	50
<b>Figure 28.</b> Idealization of Steam and Drop Hammers .....	58

<b>Figure 29.</b> Idealization of Diesel Hammers.....	58
<b>Figure 30.</b> Idealization for Case I.....	64
<b>Figure 31.</b> Tapered Pile with a 5 Gage Wall Driven with a Vulcan 010 Hammer; Case X.....	77
<b>Figure 32.</b> Raymond Step-Taper Pile Driven with a Vulcan 010 and Kobe K-25 Hammers to Full Embedment; Cases XI and XII.....	80

## LIST OF TABLES

TABLE 1 - Stresses for Various Hammers .....	10
TABLE 2 - Stresses for Various Cushions.....	12
TABLE 3 - Stresses for Various Helmet Weights .....	13
TABLE 4 - Stresses in Point Bearing Pile - CASE XIV .....	21
TABLE C1 - Summary of Steam Hammer Properties .....	59
TABLE C2 - Summary of Diesel Hammer Properties .....	60
TABLE C3 - Summary of Constants for Commonly Used Cushion and Capblock Materials	61
TABLE C4 - SOIL PROPERTIES* .....	62

## CHAPTER 1. INTRODUCTION

During the past few years, the use of the wave equation to investigate the dynamic behavior of piling during driving has become more and more popular. Widespread interest in the method was started in 1960 by E.A.L. Smith who used a numerical solution to investigate the effects of such factors as ram weight, ram velocity, cushion and pile properties, and the dynamic behavior of the soil during driving. Since then, a vast amount of experimental data has been taken to determine just what input values should be used in the program, and numerous full-scale pile tests have been correlated which now permit engineering judgement to be coupled with the mathematical accuracy of the wave equation.

In recent years, the wave equation has been used extensively by both state highway departments and private contractors to predict the ability of given pile driving hammers to successfully install pile foundations.

In general, the computer solution is used to obtain the following information for a single blow of the hammer:

1. To predict the driving stresses induced in the pile.
2. To determine the resulting motion of the pile during the impact.
3. To determine the resistance to penetration afforded by the soil at the time of driving.

This information then enables the engineer to answer such questions as:

1. Can a given hammer drive the pile to the required depth of penetration?
2. What rate of penetration will the hammer provide, i.e., how long will it take to install

the pile?

3. To what maximum penetration can the pile be driven?
4. What is the maximum resistance to penetration that the hammer can overcome?
5. Will excessive stresses be set up in the pile or hammer during driving?

The wave equation is quite often used as an aid in design. For example, it is commonly used:

1. To indicate the static resistance to penetration of the pile afforded by the soil at the time of driving. (Note that the wave equation only predicts the resistance to penetration at the time of driving since soil set up, group effect, negative friction, and other time effects may influence the long-term bearing capacity. Only the use of engineering soil mechanics can transform the resistance to penetration at the time of driving into the long-term bearing capacity).

2. To optimize the cushion, i.e., to determine which cushion will effectively limit the driving stresses induced in the hammer and pile, and yet will still produce the maximum possible permanent set per blow of the hammer.

3. To determine the correct size of the driving hammer. This reduces the chance of picking a very large and expensive hammer whose capacity is not needed, as well as the more unfortunate situation of picking a small hammer whose driving capacity is found to be inadequate to drive the pile to the required grade.

4. To design the pile itself, since the driving stresses can be determined. For example, tensile cracking of prestressed concrete piles, and the buckling of pipe piles are but two examples of driving failures which have been corrected by use of the wave equation. The choice of pile dimensions not only affects the driving stresses, but the drivability of the pile itself. For example, in some cases, a pile with a small cross-sectional area cannot be driven to grade, whereas a pile having a larger cross sectional area can. Thus, with the use of the wave equation the economic merit of being able to drive the stiffer pile to a greater depth can be studied.

5. To determine the influence of the driving accessories. It has been shown that in many cases the driving accessories absorb a major portion of the total energy output of the hammer. In some cases, these accessories account for a 50% reduction in the energy output of the hammer. The use of the wave equation enables the selection of optimum driving accessories required to minimize these losses.

6. The wave equation is also a powerful engineering aid for the structural engineer, since numerous alternative designs can be quickly studied at very little expense. Such a study greatly increases the probability that the final design will be the most economical and least subject to installation problems.

In the discussions which follow, sample problems have been solved and the results plotted to demonstrate how the wave equation is utilized to solve various problems. Discussion of the method by which the given input data are utilized, and how values are assigned to the computer program are given in Appendix D.

Basically, the wave equation is used to describe how stress waves are transmitted in a long rod when a force is applied at one end of the rod. The idea of applying the wave equation to pile

driving first came from D.V. Issacs, in 1931. But it was not until 1960 that widespread interest in this method was generated by E.A.L. Smith, who proposed a numerical solution to investigate the effects of such factors as ram weight, ram velocity, cushion and pile properties, and the dynamic behavior of the soil during driving. The theory behind the wave equation has not used until this time because the equations involved in the calculations were too difficult due to complications from the actions of the ram, the capblock, the pile, and the soil. However, the development of high-speed digital computers permitted the wave equation to be applied to practical pile driving problems.

In application, the hammer-pile-soil system is idealized as a series of concentrated weight connected by weightless springs. This idealization is described in detail in the users manual. Whereas the wave equation accurately models the true dynamic behavior of driven piles, previous methods of analysis such as standard pile driving equations do not. Furthermore, standard pile driving equations cannot be used to predict the driving stresses generated in piles, as can the wave equation.

The purpose in developing this manual was to assist highway engineers in the understanding, use, and practical application of pile driving analysis by the wave equation. Thus, a simplified users manual with numerous example problems, including preparation of input data, and an interpretation of the results are included.

The previous users manuals prepared by the Texas Transportation Institute at Texas A&M University were written mainly for research use rather than production runs. Also, the previous manuals and programs include numerous options of no value to highway engineers, and were of research interest only. The current manual has been extensively simplified, and the computer program modified to run much faster than earlier versions.

## CHAPTER 2. BASIC USES OF THE WAVE EQUATION

### Introduction

The uses of the wave equation shown herein are hammer selection, selection of driving accessories, effect of pile size, prediction of pile load capacity, determination of driving stresses in point bearing piles, use of the wave equation for field control, basic output, and selection of allowable stresses for pile materials.

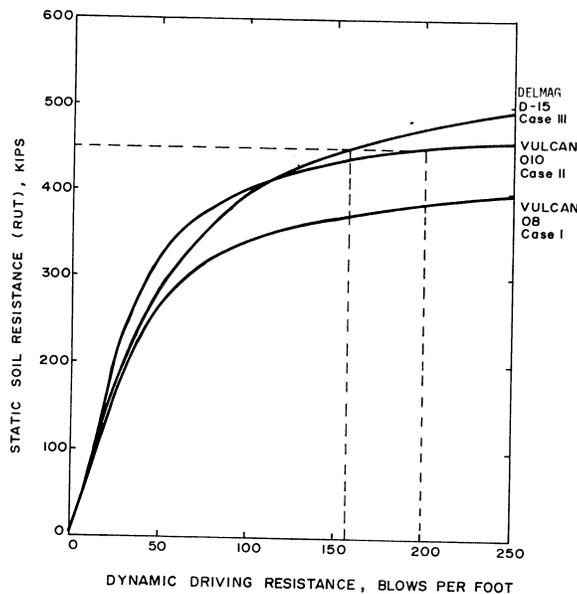
### Hammer Selection

The proper selection of the hammer to drive a given pile is necessary in order to insure the ability of the hammer to drive the pile to the desired penetration, and to prevent over stressing of the pile. The following cases have been analyzed using the wave equation to compare the differences between the drivability of three different hammers driving a typical concrete pile.

Case I - Vulcan 08 Hammer

Case II - Vulcan 010 Hammer  
Case III - Delmag D-15 Hammer

The cases studied in this comparison utilized two steam hammers and one diesel hammer. The two steam hammers studied were the Vulcan 08 and 010 hammers. The diesel hammer was a Delmag D-15. Properties of these and other typical hammers for use in the wave equation are listed in Appendix C. The pile used for this comparison was a 12-inch square prestressed concrete pile 60 feet long, driven 30 feet in clay. Detailed information regarding the set up for these example cases may be found in Appendix D. The pile is to be driven to an ultimate static soil resistance of 900 kips in clay having a "sensitivity" or "set up" factor of 2.0.



As previously mentioned, the wave equation can be used to predict the permanent set per blow of a given hammers which can then be used to plot curves similar to those in Figure 1. These curves relate the ultimate static soil resistance at the time of driving to the number of blows required to advance the pile one foot. Since a resistance of 900 kips desired, and since the soil is expected to "set up" by 2.0, the desired resistance during driving will be  $900 \text{ kips} / 2.0 = 450 \text{ kips}$ . In other words, if a resistance to penetration at the time of driving equal to 450 kips can be attained, the soil will set up to the desired value of 900 kips. The sensitivity of any given soil must be determined by soils test, unless the pile is driven in a sand, which normally has a set up factor of 1.0. A comparison of unremolded vs. remolded tests is commonly used as a basis for determining a soil's sensitivity.

From Figure 1, it is seen that either the Vulcan 010 or Delmag D-15 hammers will drive the pile to the required level of resistance, with the D-15 hammer driving the pile faster at final penetration. However, as seen from Table 1, which lists the maximum stresses determined by the

wave equation, the maximum stresses induced during driving are relatively high and problems with pile breakage may occur. For the D-15 hammer, maximum stresses of 5131 psi compression and 2143 psi tension were experienced.

TABLE 1 - Stresses for Various Hammers

A comparison of maximum compressive and tension stresses, for a 12-inch by 12-inch prestressed concrete pile using two steam hammers and one diesel hammer: Case I-Vulcan 08, Case II- Vulcan 010, Case III-Delmag D-15 hammer.

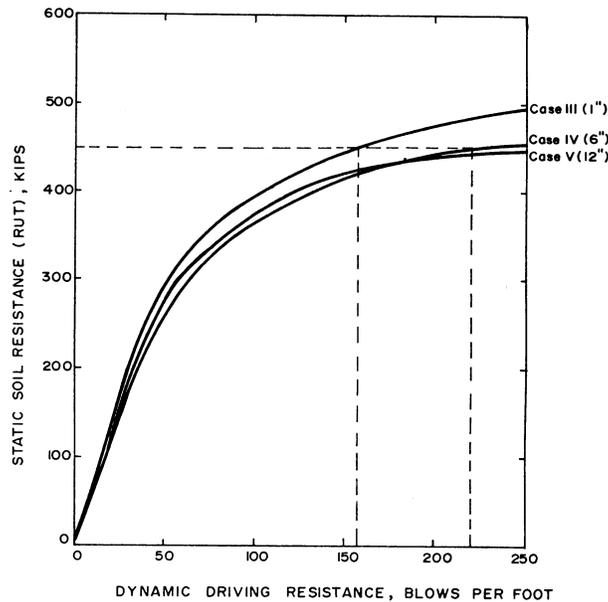
	Case I Vulcan 08		Case II Vulcan 010		Case III Delmag D-15	
RUT Kips	Maximum Compressive psi	Maximum Tension psi	Maximum Compressive psi	Maximum Tension psi	Maximum Compressive psi	Maximum Tension psi
50	4358.4	-1704.8	4461.3	-1469.8	5130.6	-2143.4
100	4358.4	- 809.4	4461.3	-1161.7	5130.6	-1538.5
150	4358.4	- 574.0	4461.3	- 306.9	5130.6	-1083.3
200	4358.4	- 448.9	4561.4	- 266.2	5130.6	- 764.3
300	4384.6	- 923.2	4678.1	- 894.2	5130.6	-1129.0
400	4424.2	-1185.6	4741.8	-1246.5	5130.6	-1678.9
500	4477.6	-1249.8	4833.6	-1518.7	5130.6	-2075.6

Obviously, any number of additional hammers could be studied to determine the relative merit of each one. For example, at final penetration (450 kips) the expected blow count will be around 157 blows per foot if the D-15 hammer is used. It is possible that a larger hammer, perhaps a Vulcan 014, although more expensive, might be more economical in the long run if the pile could be installed faster. This could be determined by simply adding the 014 hammer to the previous study.

#### Selection of Driving Accessories

##### (a) Cushion Selection

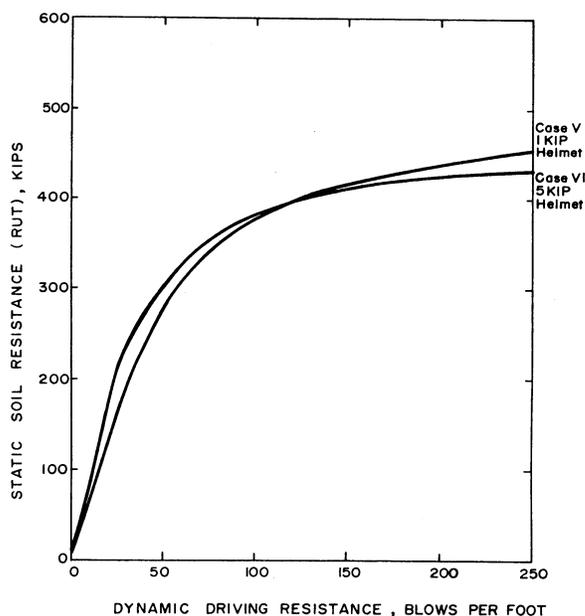
As noted in the previous section, high driving stresses can sometimes become a problem. This is normally corrected by choosing a different driving hammer, or by increasing the capblock or cushion thickness. Assuming that the D-15 hammer is selected to drive the 60-foot concrete pile of the previous example, the effect of varying the cushion thickness from 1-inch (Case III), to 6 and 12-inches will now be investigated (Case IV = 6-inch cushion, Case V = 12-inch cushion).



The maximum stresses determined by the wave equation for Cases III through V are listed in Table 2. If the allowable tensile stress is given as 2000 psi and a maximum compressive stress of 5000 psi is specified, it is seen that the 6-inch thick oak cushion would be required to prevent overstressing of the pile. Note that changing the cushion thickness also influences the ability to drive the pile, as seen in Figure 2. In this case, the increase in cushion thickness from 1-inch to 6-inches increased the blow count from 157 to 220 blows per foot at final penetration (450 kips resistance). Increasing the cushion thickness to 12-inches will make driving to 450 kips difficult as seen in Figure 2 (Case V).

#### (b) Helmet Selection

A helmet or pile cap is used to adapt the driving hammer to the pile. The weight of the helmet is represented as a single rigid weight. Although increasing the weight of the helmet is sometimes attempted to reduce driving stresses, this is not normally done since it will, in some cases, decrease the ability to drive the pile to the desired penetration. Typical helmet properties for use in the wave equation vary widely from case to case and must be determined from the contractor. For the following investigation, the 1.0 kip helmet of the D-15 hammer of Case V was increased to 5.0 kips (Case VI) and its effect determined.



Note from the summary of stresses in Table 3, that the maximum stresses are reduced, such that in this case the change in helmet weight was effective in reducing the driving stresses. Note also from Figure 3, that the drivability of the pile was relatively unchanged.

TABLE 2 - Stresses for Various Cushions

A comparison of maximum compressive and tension stresses for a 12-inch by 12-inch prestressed concrete pile using a Delmag D-15 hammer and varying the cushion thickness: Case III-1 inch cushion, Case IV 6 inch cushion, Case V-12 inch cushion.

	Case III Delmag D-15		Case IV Delmag D-15		Case V Delmag D-15	
RUT	Maximum Compressive psi	Maximum Tension psi	Maximum Compressive psi	Maximum Tension psi	Maximum Compressive psi	Maximum Tension psi
50	5130.6	-2143.4	3614	-1950	2976	-1652
100	5130.6	-1538.5	3749	-1233	3159	-1039
150	5130.6	-1083.3	3890	-1030	3328	- 728
200	5130.6	- 764.3	4019	- 723	3486	- 607
300	5130.6	-1129.0	4267	-1052	3763	- 896
400	5130.6	-1678.9	4486	-1256	3998	-1579
500	5130.6	-2075.6	4679	-1612	4202	-1990

TABLE 3 - Stresses for Various Helmet Weights

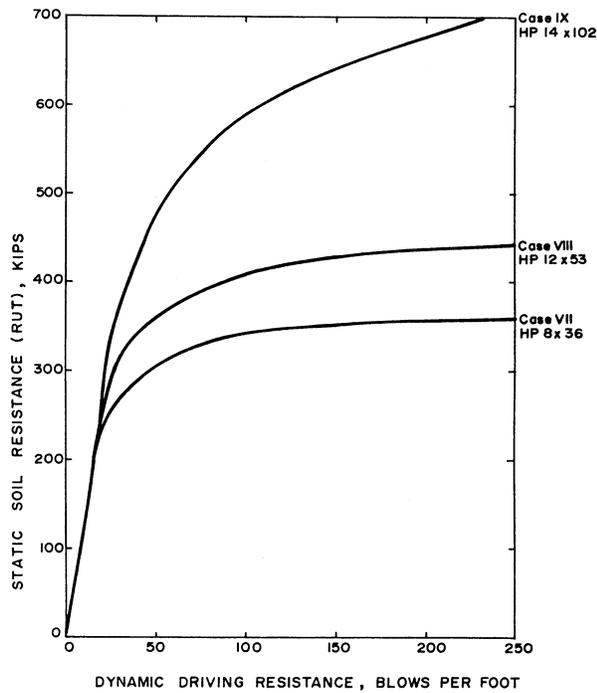
A comparison of maximum compressive and tensile stresses for a 12-inch by 12-inch prestressed concrete pile using a Delmag D-15 hammer and varying the helmet weight. Case V= 1 Kip helmet, Case VI= 5 Kip helmet.

RUT kips	Case V Delmag D-15		Case VI Delmag D-15	
	Maximum Compressive psi	Maximum Tension psi	Maximum Compressive psi	Maximum Tension psi
50	2976	-1652	2373	- 692
100	3159	-1039	2534	- 391
150	3328	- 728	2706	- 341
200	3486	- 607	2946	- 539
300	3763	- 896	3344	- 973
400	3998	-1579	3609	-1411
500	4202	-1990	3761	-1685

#### Pile Size

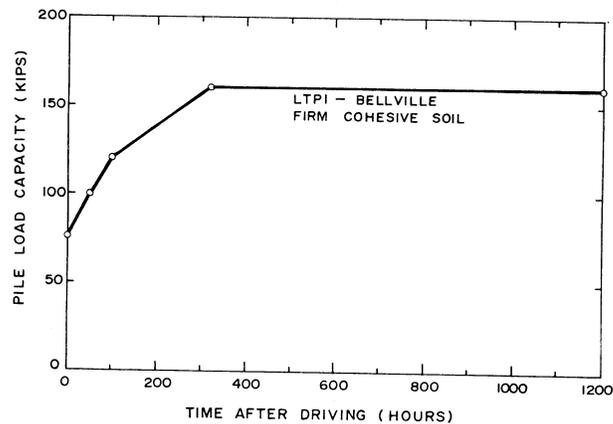
The size of the pile selected can also significantly affect the ability to reach a given resistance as well as the stresses induced during driving. The following cases were analyzed to demonstrate the influence of changing the pile size. Assume that a Vulcan 010 hammer is to be used to drive a 100-foot HP steel pile to a penetration of 80-feet. The pile selections are:

Case	Pile	Cross-Sectional Area
VII	HP8x36	10.6-inch <sup>2</sup>
VIII	HP12x53	15.6-inch <sup>2</sup>
IX	HP14x102	30.0-inch <sup>2</sup>



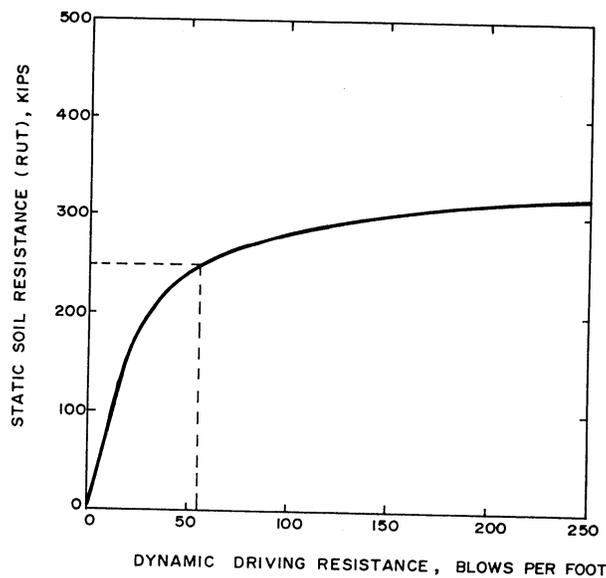
The curves which compare the ability of the hammer to drive the piles for these cases are shown in Figure 4. These curves relate total soil resistance at the time of driving to the number of blows required to advance the pile 1-foot. Note from Figure 4 that the heavier piles have a dramatically increased ability to overcome resistance. Thus, if the only hammer available to drive the piles was the Vulcan 010, and the desired soil resistance immediately after driving is 400 kips, the HP8x36 pile could not be driven to the desired penetration, since the pile would refuse at 360 kips. For cases VII, VIII, and IX (see Appendix D), the soil parameters assumed that the piles were to be driven in sand. In this case, 90% of the total soil resistance was assumed to be distributed uniformly along the side of the pile, with 10% of the total placed in point bearing. Also the soil damping factors used were for sand. Since sand usually does not "set up" after driving stops, the soil resistance predicted by the wave equation (which would be the soil resistance immediately after driving) should equal the long-term capacity of the pile.

#### Prediction of Pile Load Capacity



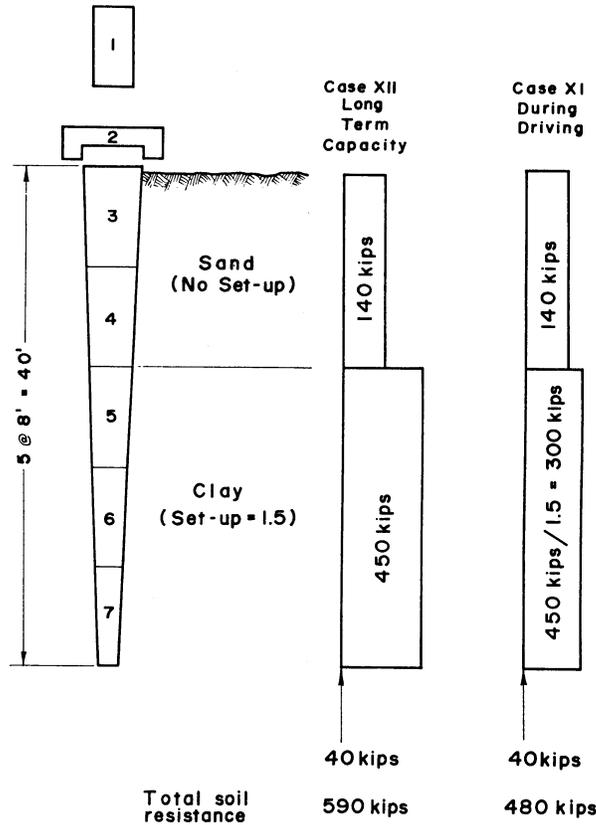
The engineer is most interested in the static load carrying capacity of the piles being driven. In the past, he has had to rely on judgment based on empirical pile driving formulas or static load tests. However, use of the wave equation permits a much more realistic estimate to be made using results generated by the program. In the case of clays, or other soils in which "sensitivity" or "set up" of the soil is present, the soil resistance at the time of driving will be less than the long-term capacity of the pile. A typical example of this phenomena is shown in Figure 5, which relates the bearing capacity of a pile which was load-tested at various times after driving.

Note that the load test performed immediately after driving indicated a capacity of 76 kips, whereas the test after 1200 hours indicated a capacity of 160 kips. Thus, this particular soil had a set up factor of  $160/76 = 2.11$ . This factor is usually determined by soils tests or during the driving of test piles before production driving begins.



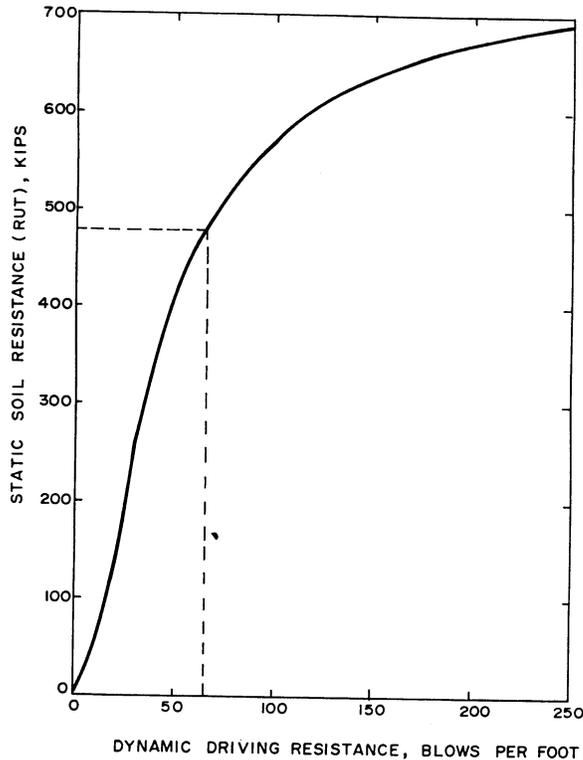
In the case of sands, there is usually no observed set up, and the driving resistance immediately after driving (as predicted by the wave equation) will be the same as the long-term capacity of the pile. In the case where a pile is driven through clay and tipped in sand, only the soil capacity of the

clay should be modified by a set up factor. For example, assume that a tapered pile is to be driven through clay having a long-term resistance of 400 kips and tipped in sand with a long-term bearing resistance of 50 kips (Case X). Further assume that the clay has a sensitivity of 2.0, i.e., that during driving, the clay will be remolded and its capacity during driving will be reduced to one-half of its long-term capacity. Then the resistance immediately after driving should be half of the clay capacity (due to remolding) plus the full sand capacity, or  $400 \text{ kips} / 2.0 + 50 \text{ kips} = 250 \text{ kips}$ . Thus, from Figure 6, a rate of penetration of around 55 blows per foot should be expected at final penetration.



(a) Initial Driving

As a second example, assume that a 40-foot tapered, mandrel driven pile (Case XI) will be installed to full embedment (40 feet) through a sand lens into a stiff clay as shown in Figure 7. The long-term capacity for each strata are to be divided by the corresponding set up factors to yield the resistances shown as "During Driving". Note that a set up factor is not applied to the point of the pile even though the soil is a clay, since the soil under the pile tip has not been remolded.



The soil resistance input data for use in the wave equation is thus listed under "During Driving" in Figure 7. Figure 8 relates the resistance to penetration vs. blow count observed while the pile is being driven, i.e., while the soil is in a "remolded" state. Since the required soil resistance at full penetration is 480 kips, Figure 8 indicates that a final blow count of 68 blows per foot is required. (The 480 kips is determined by summing the "During Driving" resistances shown in Figure 7).

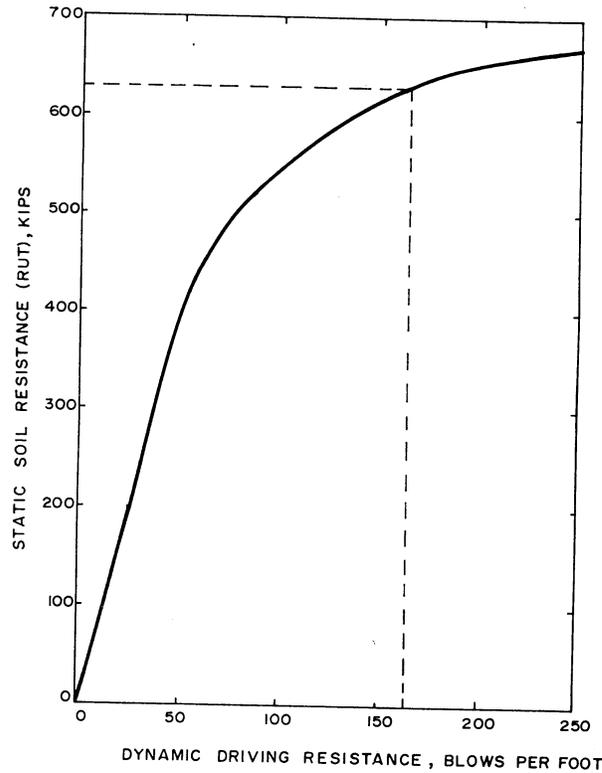
(b) Final Driving

If the pile of Case XI above were to be re-driven several days later after the soil has set up to its full capacity, the input parameters for the soil resistance would change to those listed under "Long-Term Capacity" in Figure 7. The results of this change in resistance distribution is shown in Figure 9 for Case XII. Note that due to the set up in the clay, the resistance has now increased from 480 kips to 630 kips. Thus, as seen from Figure 9, it should take around 164 blows per foot to break the pile loose.

(c) Soil Set Up or Relaxation

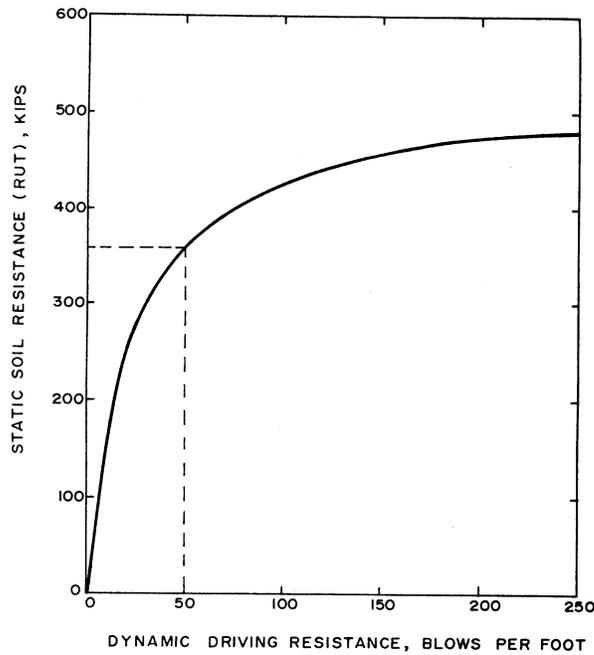
The same procedure as shown above can be used to determine how much a given soil will "set up" or "relax" after some period of time. For example, assume that a 60-foot long 12-inch diameter pipe pile with a 0.15-inch wall is to be driven to a penetration of 40-feet into a soft clay, using a Kobe 25 diesel hammer (Case XIII). The observed blow count in the field at the end of driving was 50 blows per foot, corresponding to a soil resistance of 360 kips (see Figure 10). After 15 days, the pile was re-driven with the same hammer, and required 150 blows per foot to advance the pile. Thus, from Figure 10, it is found that the soil resistance had set up to a value of

455 kips. Thus, the soil had a set up factor  $455/360 = 1.26$ . If the pile were easier to drive after the 15-day delay, relaxation would obviously have occurred.



### Driving Stresses in Point Bearing Piles

The determination of driving stresses in point bearing piles is performed in a manner similar to other soil types, i.e., the probable soil resistances to be encountered during driving are entered into the program, and a wave equation analysis performed. For example, assume that the steel pipe pile of Case XIV is to be driven through a soft clay to a point bearing in rock. The soil tests indicate that 100% of the soil resistance will be encountered under the point of the pile.



The results of this case are plotted in Figure 11, which shows total soil resistance at the time of driving vs. blows per foot required to advance the pile 1-foot. Resulting maximum stresses are listed in Table 4. Obviously the pile is greatly overstressed, and either a smaller hammer must be used, or the pile size will have to be increased.

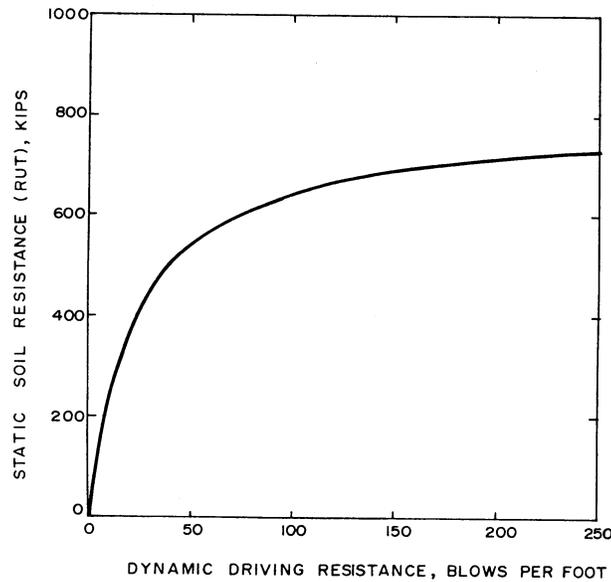


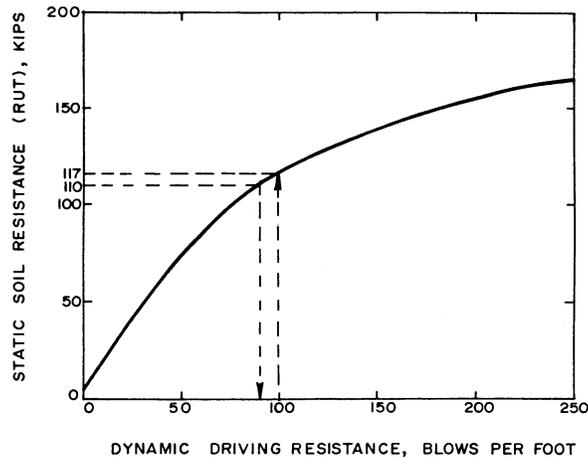
TABLE 4 - Stresses in Point Bearing Pile - CASE XIV

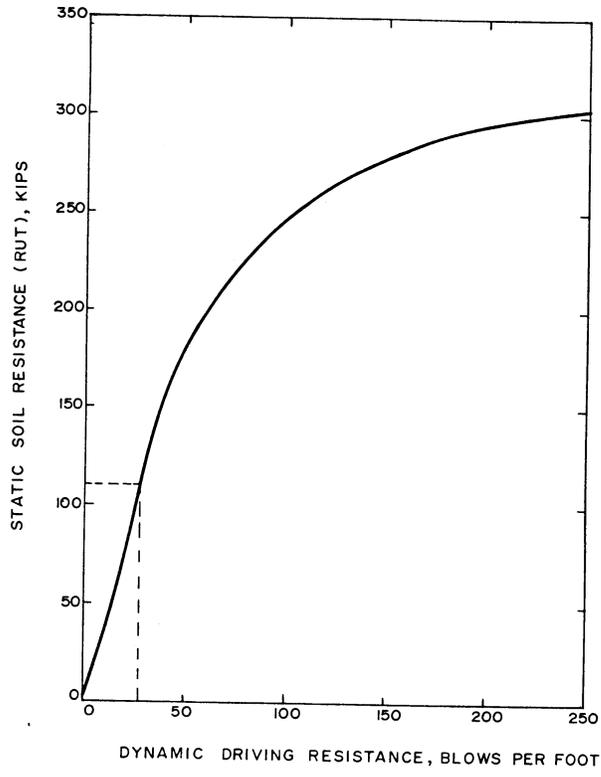
Total Soil	Maximum Compressive	Maximum Tensile

Resistance (kips)	Stress (psi)	Stress (psi)
100	58,047	0
200	72,061	5,338
300	80,113	8,369
400	91,518	11,372
500	106,750	14,647
600	116,686	14,427
700	119,006	4,310

### Use of Wave Equation for Field Control

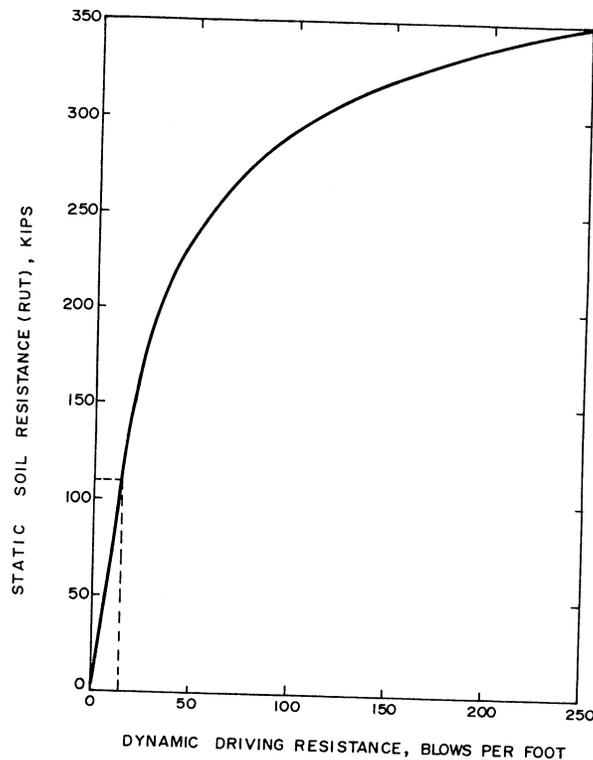
One of the more important uses of the wave equation is its application toward field control and acceptance of piles during construction. For example, assume that the concrete pile of Case XV is to carry an ultimate load of 300 kips. The pile is to be driven by a Vulcan 30C hammer. During driving of test piles which were to be load-tested, it was noted that at the specified penetration, the hammer was driving at 100 blows per foot. After 15 days, when the soil had set up to its full strength, the piles were load-tested to an ultimate load of 320 kips.





Thus, as seen in Figure 12, at the end of driving the resistance was 117 kips, and the soil set up was therefore  $320/117 = 2.74$ . Since the desired ultimate resistance was only 300 kips, the desired resistance at the end of driving should be  $300/2.74 = 110$  kips, which corresponds to a blow count of 90 blows per foot (see Figure 12). Thus, the remaining piles in this area were driven to a blow count of 90 blows per foot. The slight change in depth of penetration will not affect the curve of Figure 12 and can thus be neglected. However, if the penetration was seriously changed, the curve of Figure 12 should probably be rerun.

As a further example, assume that later piles in this area were to be changed from the 10"x10" to 12"x12" piles which were to be driven by a Link Belt 312 diesel hammer (Case XVI). Since a total resistance of 300 kips is desired, the new piles should be driven to a resistance of  $300/2.74 = 110$  kips, as before. Thus, as seen from Figure 13, the new piles driven with the Link Belt 312 hammer should be driven to a blow count of 27 blows per foot.



Similarly, if the piles were changed to an HP8x36, driven by an MKT-DE 30 diesel hammer (Case XVII), the pile should be driven to a blow count of 14 blows per foot (see Figure 14).

#### Basic Output

The output for the computer program is composed of three Basic sections.

1. Summary of input data fed to the program.

2. Time dependent solution for forces and displacements of selected elements.

3. Summary of maximum compressive and tensile forces (or stresses), maximum observed displacements, and the permanent set per blow of the hammer plus miscellaneous information regarding the problem.

(a) Input Data Summary

Pertinent information input to the program is printed out, as is an alphanumeric identification for each problem. Descriptions and detailed discussions of the input data are given later in this report, and are not repeated here.

(b) Time Dependent Quantities

To assist the user in determining whether a problem solution is complete, and to assist in locating possible input data errors when they occur, the computer will output forces (or stresses, as desired) at six points along the pile. These forces, labeled "F", are output at constant time intervals, as specified by the user. It is normal to print every second or every fifth time interval so the travel of force down the pile can be followed.

The main purpose of this output is to assist the user in locating possible input data errors if they occur. For example, an improperly located decimal for a given spring rate in the pile will usually show up as a dramatic change in force transmitted past that point.

Displacements (labeled "D") vs. time for selected elements are also output. Their main purpose is to assist the user in determining whether a solution is indeed complete. For example, if a particular solution were run for a maximum of 200 iterations, and the displacement of the point at this iteration still has a large downward motion, the problem should be rerun with an increased number of iterations.

c) Solution Summaries

The final solution summaries include a listing of the maximum compressive and tensile forces (or stresses, as desired) induced in the pile during driving, and the maximum displacements observed for each element. Also listed is the time interval in which these maximums were observed.

It is important to compare the time interval in which the maximum point displacement occurred, with the total number of time intervals the problem ran to insure that the point of the pile has indeed stopped moving down and is "rebounding". If the point is still moving down, the problem solution has been shut down too early and should be rerun.

Also listed are:

1. The permanent set of the pile for a single blow of the hammer, i.e., how far into the ground has the pile been permanently advanced due to one hammer blow.
2. The number of hammer blows required to advance the pile 1 inch, assuming that the soil resistance remains constant over that additional inch of penetration, and the number of blows required to advance the pile 1 foot.
3. The pile weight.
4. The total static soil resistance to penetration at the time of driving.

#### Selection of Allowable Stresses for Pile Materials

Although allowable stresses for comparison with maximums predicted by the wave equation are known only by inference and by the past experience of the authors, it is believed that the following values are applicable. Further, though work has been done on the strength of rapidly loaded concrete, this work has not been correlated with stresses induced in driven piles. However, it is generally accepted that at high rates of loading, concrete exhibits an increase in strength. For this reason, the authors recommend the following allowable stresses for concrete.

Allowable tensile stress =  $5\sqrt{f_c'}$   
 Allowable compressive stress =  $0.7f_c'$  where  
 $f_c'$  = the 28-day compressive strength as normally defined.

Past experience has shown that if stresses are held below these allowables, spalling and tensile cracking are unlikely to occur. Similarly, allowable stresses in steel should be held to within 70% of the yield stress. Values for wood are normally held below 100% of the static strengths.

Note that the above values for concrete exclude the effect of any prestress in the pile. For example, assume that a pile with  $f_c' = 5000$  psi is prestressed to 800 psi compression. The allowable driving stresses would then be

Allowed tensile stress =  $5\sqrt{5000 \text{ psi}} + 800 \text{ psi} = 1150 \text{ psi}$   
 Allowed compressive stress =  $(0.7)(5000 \text{ psi}) - 800 \text{ psi} = 2700 \text{ psi}$

## CHAPTER 3. INFORMATION REQUIRED FOR ANALYSIS

### Introduction

The following was written to familiarize those engineers engaged in the design and analysis of foundation piling with the use, potential, and advantages of pile driving analysis by the wave equation, but who have no direct interest in the theory behind the program. It will also

acquaint the engineer with the type of input information needed to obtain the solution.

To facilitate the collection of this information, a series of forms are provided. The engineer may use these forms either to transmit the necessary information to the person in charge of setting up and solving the problem or to accumulate the information required to prepare his own input data.

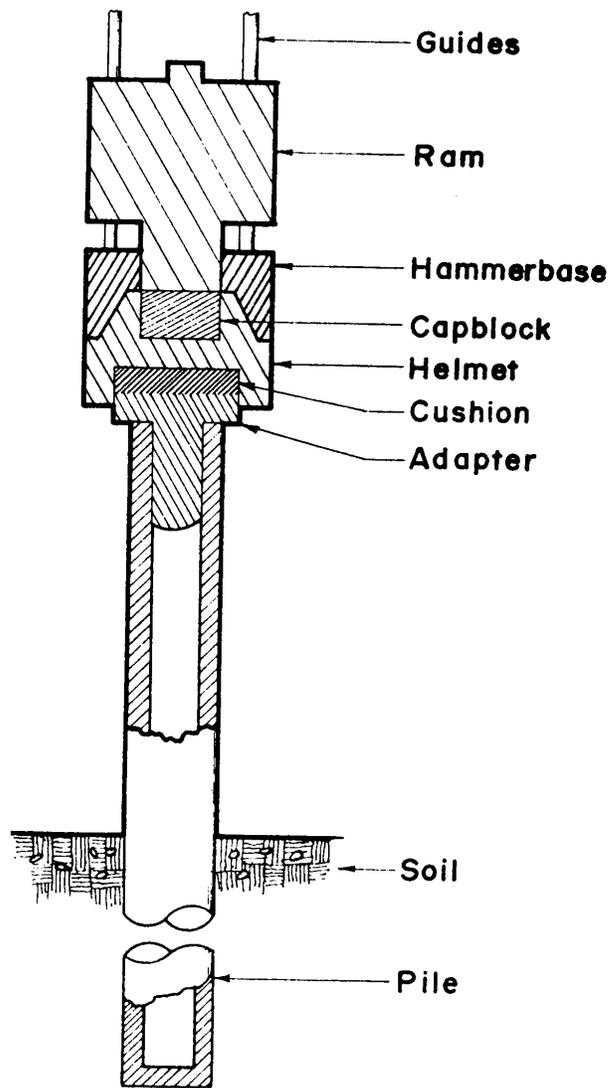
In general, information concerning the following variables is required:

- (a) Hammer
- (b) Driving Accessories
- (c) Pile
- (d) Soil
- (e) Problem Background

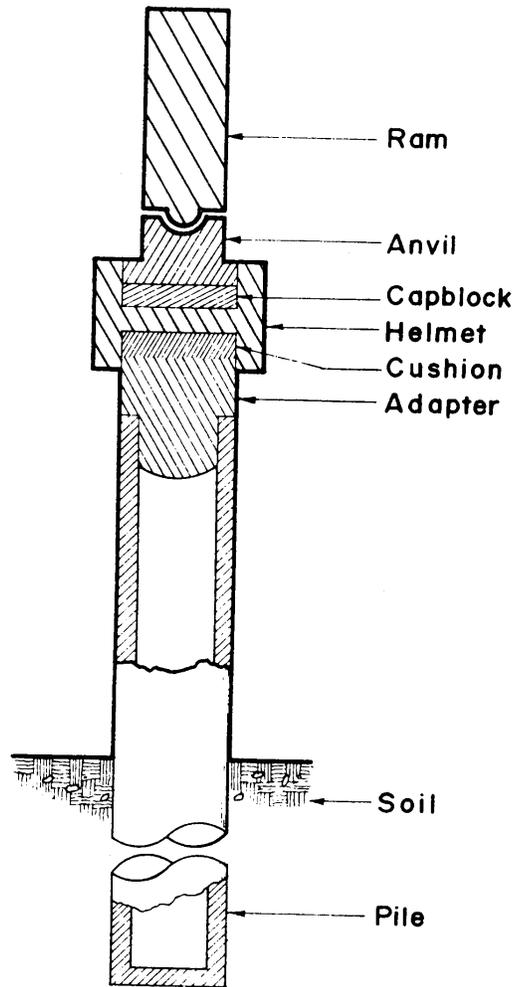
It should be emphasized that the more complete and accurate information available, the more accurate will be the results. For this reason, the forms are set up to accept as much information as possible. However, even when much of the information requested is unknown and must be assumed, a relatively accurate and useful solution can still be obtained.

When the forms request information which is unknown by the engineer, he may leave the space blank, in which case the programmer must enter values based on previous experience. The user may also enter an assumed value followed by a question mark, in which case the programmer will check the value to insure it is reasonable. Should they agree, it will be used as entered but if the value seems questionable, they will probably want to discuss it with the user. Any information which the engineer knows is correct should be entered without a question mark. In this case, the value will be assumed correct and entered as given.

As will be noted, the required information is broken into several sections. In each succeeding section, more detailed information is requested. For example, under "Hammer Information", the minimum information desired is the hammer type. However, even if the particular hammer was unknown, this space could be left blank and several different normally used hammers would be studied and their relative effectiveness compared.



Figures 15 and 16 give cross-sectional views and definitions of terms for a steam hammer and diesel hammer, respectively.



Problem Information Forms

A) Hammer Information

1) Hammer Type:

2) Hammer Energy:

Total output

Influencing factors

3) Ram Stroke:

Observed (single-acting hammers)

Equivalent (double-acting hammers)

4) Velocity of Ram at Impact:

Operating Pressure:

Steam hammer pressure

Diesel hammer explosive pressure force

B) Driving Accessories

1) Capblock Properties:

Material

Modulus of Elasticity

Coefficient of Restitution

Dimensions

Direction of grain

Condition

2) Cushion Properties:

Material

Modulus of Elasticity

Coefficient of Restitution

Dimensions

Direction of grain

Condition

3) Pile Cap Weight:

Other (Describe fully - weight, position, etc.)

C) Pile Information

Material

Unit weight

Total length

Cross-sectional area\*

\*Applicable only if pile is uniform. If pile is tapered or stepped, a sketch showing section lengths and corresponding cross-sectional areas should be included.

Modulus of elasticity

Other factors (Describe fully)

Area of steel reinforcement, if present

Prestress force in pile, if present

D) Soil Properties

Depth of pile embedment

Type of soil

Sketch of soil profile (on additional sheet)

Tabulation of soil strength tests (unconfined compression, remolded and undisturbed tests, miniature vane, confined tests, etc., on additional sheet)

Total soil resistance from load-test

Resistance at point of pile

Resistance on side of pile

Distribution of soil resistance on side of pile (on additional sheet)

E) Problem Background - (Use additional sheet if necessary to describe nature of problem observations, special conditions, etc.)

## Example Problem

The following problem is given to illustrate the type of information required to set up the solution.

In this case, a 36 inch pipe pile of varying wall thickness is to be driven by a Vulcan 020 hammer. The solution is needed because there is some question as to whether or not the pile will be able to penetrate a sand lens lying some 60 feet above the required design penetration.

### Problem Information Forms

#### A) Hammer Information

- 1) Hammer Type: Vulcan 020
- 2) Hammer Energy:  
Total output 60,000 ft-lb  
Influencing factors Probable hammer efficiency = 80%
- 3) Ram Stroke:  
Observed (single-acting hammers) 3.0 feet  
Equivalent (double-acting hammers)
- 4) Velocity of Ram at Impact:  $V = \sqrt{2 * g * h * 0.8} = 12.4 \text{ ft/sec}$   
Operating Pressure:  
Steam hammer pressure 130 psi  
Diesel hammer explosive pressure force

#### B) Driving Accessories

- 1) Capblock Properties:  
Material Micarta 1/4" sheets  
Modulus of Elasticity 700,000 psi  
Coefficient of Restitution 0.6  
Dimensions 13-11/16" diameter by 6-1/2" thick  
Direction of grain  
Condition Excellent - recently replaced
- 2) Cushion Properties: No cushion used  
Material  
Modulus of Elasticity  
Coefficient of Restitution  
Dimensions  
Direction of grain  
Condition
- 3) Pile Cap Weight: 5,000 pounds  
Other (Describe fully - weight, position, etc.)

#### C) Pile Properties

Material Steel

Unit weight 490 lb/ft<sup>3</sup>

Total length 350 ft.

Cross-sectional area\* See Figure 17

Modulus of elasticity 30 X 10<sup>6</sup> psi

Other factors (Describe fully) 36" O.D. pipe pile with wall thickness variations as noted on attached sheet. Pile driven open-ended but would expect plug to form at tip of pile.

Area of steel reinforcement, if present -----

Prestress force in pile, if present -----

#### D) Soil Information

##### 1) Soil Properties:

Depth of pile embedment 110' (Prob. 1) & 165' (Prob. 2)

Type of soil See Figure 18

##### 2) Soil Properties:

Sketch of soil profile (on additional sheet) See Figure 18

Total soil resistance from load test none made

(From Figure 19, RUTotal - 1360 kips & 1560 kips)

##### 3) Soil Properties: (For Problem 1 and Problem 2)

Resistance at point of pile (From Figure 19, 1040 & 760 kips)

Resistance on side of pile (From Figure 19, 320 & 800 kips)

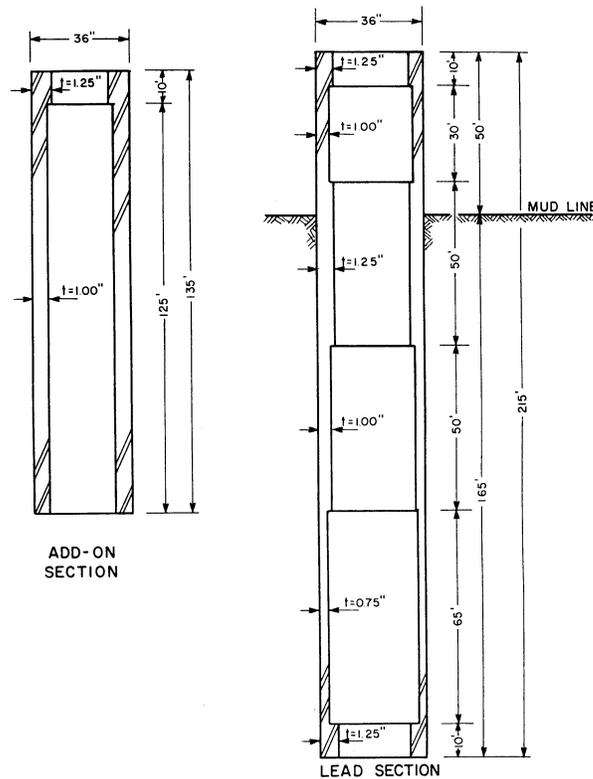
Distribution of soil resistance on side of pile (on additional sheet) See Figure 20

#### E) Problem Background - (Use additional sheet if necessary to describe nature of problem observations, special conditions, etc.)

1) It is not known whether or not the Vulcan 020 hammer will have sufficient capacity to penetrate the sand lens encountered at 100 foot penetration. How likely is it that jetting will be required?

2) Once the sand lens has been penetrated, will the 020 hammer drive the pile to the design penetration?

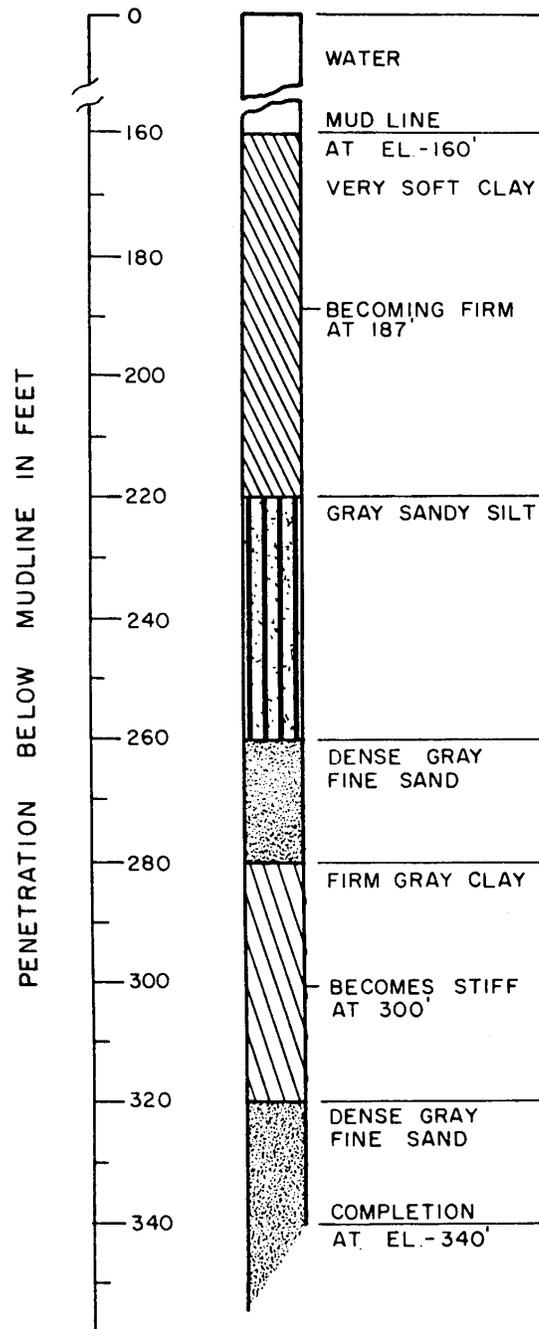
3) In order to study alternate possible pile configurations, is it possible to determine to what final penetration the pile could be driven?



### Discussion of Solution of Example Problem

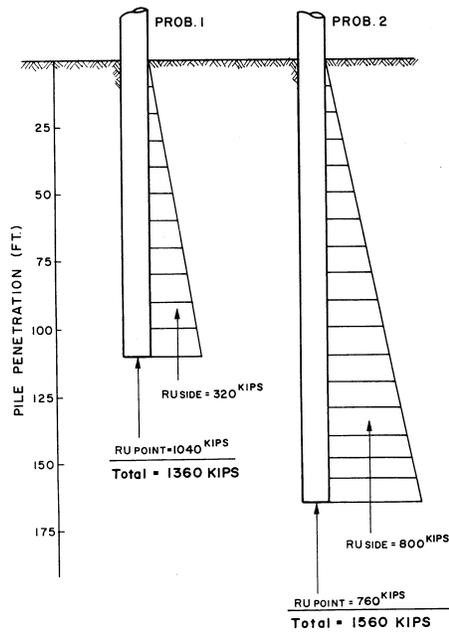
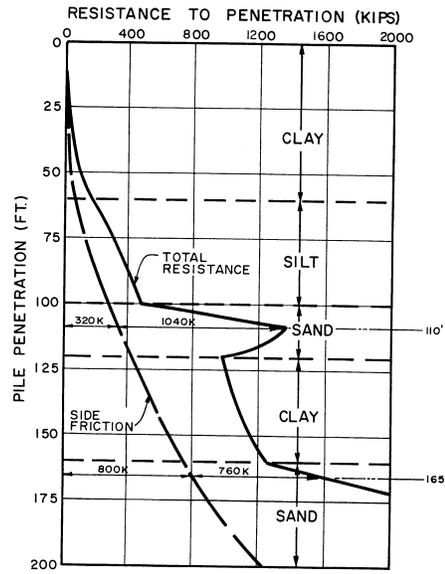
The results of the wave equation analysis are presented in Figure 21 in the form of curves which enable the user to determine the blow count corresponding to any given resistance encountered by the pile. For example, according to the soil information given in Figure 19, the resistance at a penetration of 110 feet will be 1360 kips. Entering this value in Figure 21 and projecting horizontally to curve 1 indicates a rate of penetration of around 96 blows per foot. Therefore, the contractor should have no difficulty in penetrating the sand lens.

At a penetration of 165 feet, the soils information of Figure 19 indicates a resistance of around 1560 kips. Entering this value in Figure 21 and projecting horizontally to curve 2 also gives a blow count around 96 blows per foot, indicating no problems should arise in driving the pile to the required depth after penetrating the sand lens.

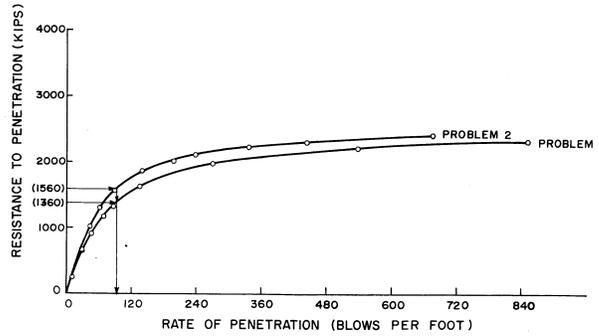


If a rate of penetration of around 360 blows per foot is assumed to be practical refusal, curve 2 of Figure 21 indicates that the Vulcan 020 hammer should be able to drive this pile to a final resistance to penetration of over 2200 kips. Thus, by using the soils information presented in Figure 19, it is seen that the pile could probably be driven to a final depth of penetration of over 175 feet. The slight change in penetration will affect the solution very little, and Figure 19 will be

sufficiently accurate. However, should a major change in penetration be indicated, the problem should probably be re-run at the new penetration.



### Recommendations Based on Example Solution



1. It is recommended that the Vulcan 020 hammer be used to install the foundation piles. Even though a larger hammer could develop a higher ultimate resistance to penetration, the Vulcan 020 hammer is recommended for the following reasons:

a. The 020 hammer has the ability to drive the pile to a final resistance of penetration of over 2200 kips, whereas a resistance of only 1560 kips is required.

b. The time required to install the piles should be nominal since only 36 blows per foot are required to develop the 1560 kips capacity.

2. Because of its ability to be driven easily, the pile of Figure 17 should be acceptable.

3. Because of the ability of the Vulcan 020 hammer to drive the pile to a resistance to penetration of over 2200 kips, it is unlikely that installation problems will arise, assuming that the soils information supplied is representative of the area in which the structure is to be installed.

## CHAPTER 4. THE COMPUTER PROGRAM

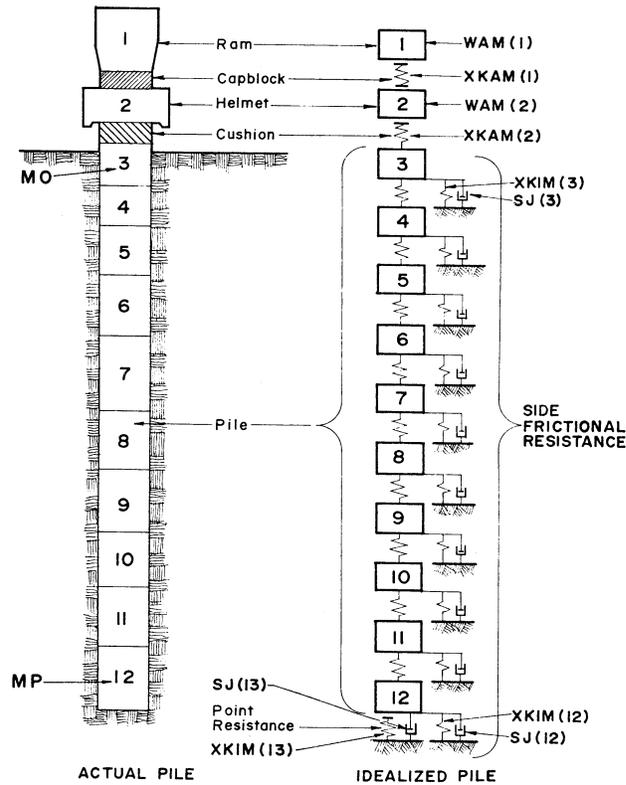
### Introduction

The computer program discussed herein is based on idealizing the actual pile driving system as a series of concentrated weights and springs. A comparison of an actual pile driving system with the idealized model is shown in Figure 22.

The ram and helmet are assumed to be rigid concentrated masses between which a spring is inserted to represent the elasticity of the cushion. The pile is idealized as a similar series of concentrated weights and weightless springs.

### General

Figure 22 shows a typical pile system and the idealization for this system. The idealization includes a simulation of the soil medium as well as the pile driver and pile. The pile hammer and pile are idealized as a system of concentrated weights connected by weightless springs. The springs represent the stiffness of the pile, cushion, and in some cases, the pile driver's ram. The soil medium is assumed to be weightless, i.e., the pile moves through the soil and does not move the adjacent soil mass, and is simulated by a spring and damper (dashpot) on each pile segment



whose real counterpart is embedded in the soil. Additions or deletions to the real system (for example, addition of an anvil between the ram and capblock) can be handled easily.

Weights are denoted by WAM and internal springs (cushions and pile springs) are denoted by XKAM. Soil springs (external springs) are denoted by XKIM and soil dashpots are represented by SJ. The "top" weight of the system is denoted as WAM(1), and the adjacent masses are numbered sequentially to the point of the pile. Since there is no pile spring beneath the last pile weight, there will always be one less internal spring than the number of weights. The external springs are numbered according to the weight upon which they act. Hence, if WAM(5) is the first weight in the soil, its associated soil spring is XKIM(5). The soil spring beneath the point of the pile is denoted by a number one larger than that of the last pile weight. A similar notation applies to the soil dashpots.

To simulate a given system, the following information is required:

1. The pile driver
    - a. Initial velocity of the ram at the instant of impact
    - b. Weight of the ram
    - c. Explosive force (in the case of a diesel hammer)
    - d. Weight of the anvil (if present)
  
  2. Pile driving accessories
    - a. Spring constant of the cushion between the ram and helmet.
    - b. Weight of the helmet
    - c. Spring constant of the capblock between the helmet and pile (if present)
  
  3. Pile characteristics
    - a. total length and cross-sectional area (if uniform)
    - b. length of cross-sectional area of each variation in cross-section (if nonuniform)
    - c. unit weight of the pile material
    - d. modulus of elasticity of the pile material
    - e. damping coefficient of the pile material
  
  4. Soil characteristics
    - a. length of pile embedment in the soil.
    - b. types of soil penetrated (soil profile)
    - c. magnitude and distribution of the static resistance to penetration distributed along the side of the piled.
    - d. magnitude of the static resistance at the tip of the pile
    - e. ultimate elastic displacement of the soil along the side of the pile and at the tip of the pile
- It should be recognized that the solution obtained with the program represents the results for one blow of the hammer at the specified soil embedment and soil resistance.

#### The Solution

The solution to an idealized pile driving problem is accomplished by a numerical technique proposed by Smith (24), which is based on concentrating the distributed mass of the pile into a series of relatively small weights, WAM(1) through WAM(MP), connected by weightless springs XKAM(1) through XKAM(MP-1), with the addition of soil resistance acting on the masses, as illustrated in Figure 22. Also, time was divided into small increments. The numerical solution to the wave equation is then applied by the repeated use of the following equations, developed by Smith (21):

$$D(m,t) = D(m,t-1) + 12 \cdot \text{delt} \cdot V(m,t-1) \quad \text{Eq. 4.1}$$

$$C(m,t) = D(m,t) - D(m+1,t) \quad \text{Eq. 4.2}$$

$$F(m,t) = C(m,t)K(m) \quad \text{Eq. 4.3}$$

$$R(m,t) = [D(m,t) - D'(m,t)]K'(m)[1 + J(m)V(m,t-1)] \quad \text{Eq. 4.4}$$

$$V(m,t) = V(m,t-1) + [F(m-1,t) - F(m,t) - R(m,t)]g \cdot \text{delt} / W(m) \quad \text{Eq. 4.5}$$

where  $m$  is the mass number;  $t$  denotes the time interval number;  $\Delta t$  is the size of the time interval (sec);  $D(m,t)$  is the total displacement of mass number  $m$  during time interval  $t$  (in.);  $V(m,t)$  is the velocity of mass  $m$  during time interval  $t$  (ft/sec);  $C(m,t)$  is the compression of the spring  $m$  during time interval  $t$  (in.);  $F(m,t)$  is the force exerted by spring number  $m$  between segment numbers  $(m)$  and  $(m+1)$  during time interval  $t$  (kips); and  $K(m)$  is the spring rate of element  $m$  (kip/in.).

Note that since certain parameters do not change with time, they are assigned a single subscript. The quantity  $R(m,t)$  is the total soil resistance acting on segment  $m$  (kip);  $K'(m)$  is the spring rate of the soil spring causing the external soil resistance force on mass  $m$  (kip/in.);  $D'(m, t)$  is the total inelastic soil displacement or soil inelastic yield during the time  $t$  at segment  $m$  (in.);  $J(m)$  is a damping constant for the soil acting on segment number  $(m)$  (sec/ft);  $g$  is the gravitational acceleration (ft/sec<sup>2</sup>); and  $W(m)$  is the weight of segment number  $m$  (kip).

### The Numerical Solution

The basic steps required for the numerical solution by the wave equation are outlined below (see Figure 22 ):

1. The velocity of the top weight is set equal to the initial velocity of the pile driving ram at the instant of impact.
2. A short time interval  $\Delta t$  is permitted to elapse (on the order of 1/5000 second).
3. The ram velocity is assumed to be uniform during this time interval and a new position of the ram is calculated.
4. Since the velocities of all other weights are zero, their displacements after the elapse of the first time interval will remain zero.
5. Because of the movement of the ram during the first time interval, the top spring is compressed and the resulting force may be calculated from the spring constant for that spring.
6. The force developed in the capblock acts between the ram and the helmet. This unbalanced force tends to reduce the downward velocity of the ram and to increase the velocity of the helmet from zero. New ram and helmet velocities are calculated, the other weight velocities still being zero.
7. A second time interval is permitted to elapse.
8. Assuming that the new ram and helmet velocities are uniform during the second elapsed time interval, their new displacements are calculated. These new displacements result in new spring compressions in the first and second springs from which new spring forces may be computed. This results in unbalanced forces on the first three weights and new velocities for these weights

may be determined. This procedure is continued until maximum stresses and displacements have been found.

It should be emphasized that the results of this procedure are for a single blow of the ram with the pile at a specified embedment in the soil. To determine the number of blows of the ram required to attain one foot of penetration at this pile embedment, it is assumed that the calculated permanent set per blow of the ram will be uniform during the one foot penetration. Hence, the reciprocal of the permanent set per blow is used to predict the number of blows per foot of penetration at the given embedment.

There is no limitation to the number of time intervals which can elapse during the computer solution. However, the significant results are generally obtained after a relatively few number of intervals have elapsed. The following equation may be used to determine an estimate of the number of iterations which will normally be adequate for determining the solution to a problem.

$$NSTOP = 30L_p/L_{min}$$

where NSTOP = maximum number of iterations,  $L_p$  = length of pile, and  $L_{min}$  = length of shortest pile segment used in the analysis. This is usually greater than necessary, so the program incorporates an automatic shut-off which can be used to shorten the running time should the user desire.

#### Idealization of Hammers

The program is formulated to handle drop hammers, steam hammers and diesel hammers. The techniques presented in this section are general in scope and are presented for illustration purposes.

Figures 23 through 25 describe the idealization for the following cases:

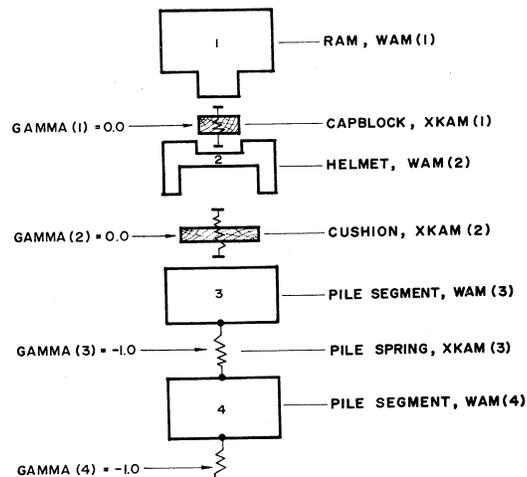
1. Case I - Steam Hammer with ram, capblock, helmet, cushion and pile (Figure 23),
2. Case II - Steam Hammer with ram, capblock, helmet, and pile, (Figure 24 ), and
3. Case III - Diesel Hammer with ram, anvil, capblock, helmet and pile (Figure 25).

#### The Ram

The idealization of the ram of a pile driver depends upon its construction. Drop hammers and steam hammers are usually constructed so that the ram impacts directly on a cushion (the capblock), whereas the ram of a diesel hammer impacts directly on an anvil. Rams which impact

directly on a cushion can be represented accurately by a single concentrated weight of infinite stiffness (i.e. the ram is assumed rigid). Thus, according to Figure 23, WAM(1) is equal to the weight of the ram and XKAM(1) represents the capblock spring. However, a ram which impacts directly on an anvil must be represented by at least one concentrated weight and a weightless spring (Figure 25), since every weight must be separated from its neighboring weight by a spring. The concentrated weight of the ram is WAM(1) and the associated spring constant is calculated by

$$XKAM(1) = K(RAM) = \frac{\pi(DT)(DB)E}{4L}$$

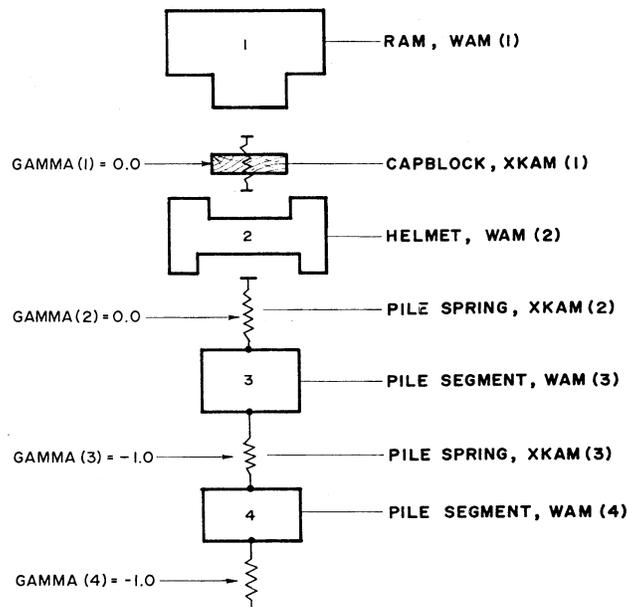


where  $XKAM(1)$  = spring constant of ram for the diesel hammer to be inserted between the ram and anvil weights (kips/in),  $DT$  is the diameter of the top of the ram (in),  $DB$  is the diameter of the base of the ram, which comes in contact with the anvil (in),  $E$  is the modulus of elasticity of the ram material (ksi), and  $L$  is the length of the ram (in).

It has been found that the diameter of contact between the ram and anvil is usually around 1/10 of the full ram diameter, such that this equation becomes

$$XKAM(1) = XKAM(RAM) = \frac{\pi E (DR)^2}{40L}$$

where  $DR$  is diameter of the ram.



### The Anvil and Helmet

The idealization of the helmet and the anvil is similar to that of the ram in that they are ordinarily short bodies which can each be represented with sufficient accuracy by single rigid weights. The anvil is represented by WAM(2) and is considered a rigid weight, since it is relatively short. Appendix C shows the idealization and pertinent information for common hammers.

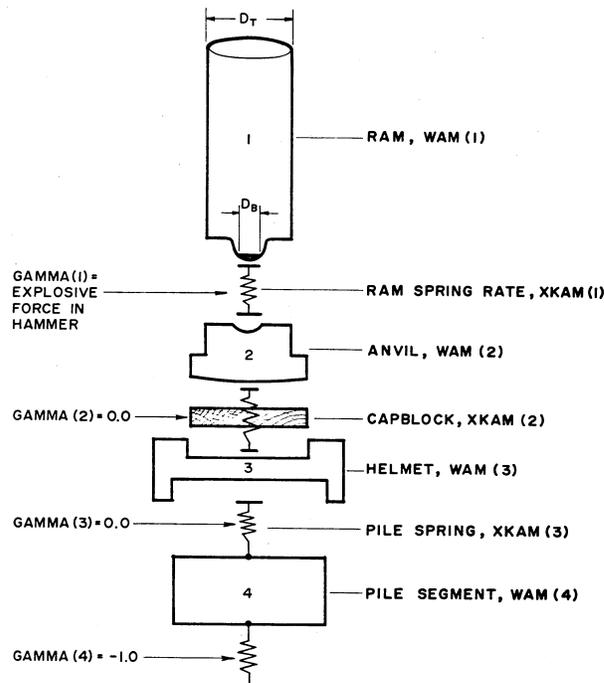
### Ram Velocity at Impact

The initial ram velocity, VELMI, of the ram for specific hammer types can be calculated as follows:

1. Open-end diesel hammers

$$VELMI = \text{sqrt}[2g(h-c)(e)]$$

where VELMI = initial ram velocity (ft/sec)



$h$  = observed total stroke of ram (ft)

$c$  = distance from anvil to exhaust ports (ft)

$e$  = efficiency of hammer

$g = 32.2 \text{ ft/sec}^2$

## 2. Closed-end diesel hammers

$$\text{VELMI} = \sqrt{2g(he-c)(e)}$$

where VELMI = initial ram velocity (ft/sec)

$he$  = equivalent stroke derived from bounce chamber pressure gage(ft) ( $he = E/WAM(1)$ ;  $E$  = Indicated Ram Energy)

$c$  = distance from anvil to exhaust ports (ft)

$e$  = efficiency of hammer

## 3. Double-acting air and steam hammers

$$\text{VELMI} = \sqrt{2g(he)(e)}$$

where  $h_e$  = equivalent ram stroke (ft)

$e$  = efficiency of hammer

#### 4. Single acting air and steam hammers

$$VELMI = \sqrt{2g(h)(e)}$$

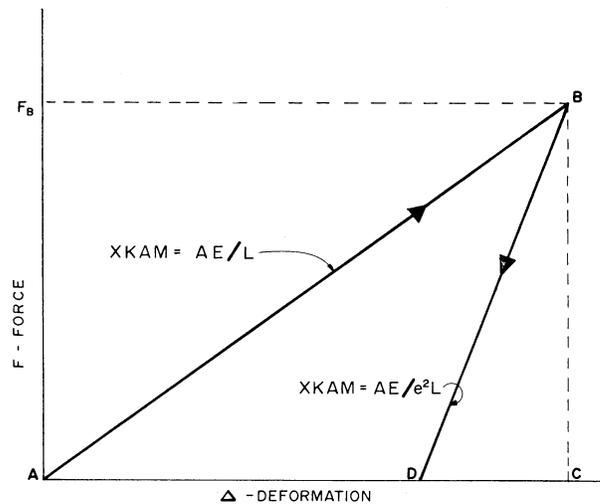
where  $h$  = ram stroke (ft)

$e$  = efficiency of hammer

Work done on the pile by the diesel explosive force is automatically accounted for by including an explosive pressure as later shown. In the hammer idealization, note that the elements of the pile hammer are physically separated, i.e., the ram is capable of transmitting compressive force to the anvil but not tension. The same is true between the anvil and helmet and the helmet and the head of the pile. The program contains provisions for eliminating the ability of various elements to transmit these tensile forces. The mechanics of this provision are explained in the following sections.

#### Idealization of Cushions

The primary purpose of cushion material in a pile driver assembly is to limit impact stresses in both the pile and the ram. An inherent disadvantage to the use of cushions is that much of the available impact energy may be absorbed as the result of nonlinear load-deformation characteristics. The idealization of the cushion material consists of specifying a spring constant for the load-deformation characteristics and a coefficient of restitution for the energy absorbing characteristics.



It has been shown that a cushion material can be adequately described if its load-deformation behavior is represented by two straight lines of different slope (Figure 26). The slope of the loading line is denoted as the spring constant of the cushion. The slope of the unloading line is determined from the cushion spring constant and coefficient of restitution of the cushion material such that the area enclosed by the two lines is proportional to the energy absorbed by the material. Appendix C gives values of cushion material constants. The spring constant of a cushion can be calculated using its modulus of elasticity from Appendix C:

$$\text{XKAM}(\text{cushion}) = AE/L$$

where

XKAM(cushion) = spring constant of cushion (ksi)

E = Modulus of Elasticity (ksi)

L = thickness of cushion (in)

It should be noted that an exact description of the behavior of the cushion during driving is difficult because of cushion deterioration through heating, compaction, and wear during use. For this reason, further refinement in the idealization of the cushion does not seem warranted. Average values for well compacted yet acceptable cushions were determined by field studies and are presented in Appendix C.

#### Idealization of the Pile

The idealization of the pile is handled by breaking the pile into discrete segments. Each segment is represented by its weight and a spring representing its total stiffness.

#### Pile Segment Length

To calculate the concentrated weights and spring constants for a pile, it is necessary to

establish a criterion for segmenting the pile into discrete weights and springs. Piles should be divided into segments not to exceed approximately 10 feet in length. Sufficient solution accuracy is obtained if the pile is broken into approximately 10-foot lengths. A slight increase in solution accuracy is possible by using segment lengths of less than 10 feet, however, this usually is not justified because of the increase in solution time and the relative accuracy of the input data. Further, it is desirable that the lengths of all the segments in the hammer-pile system be approximately equal.

Two different cases arise in segmenting a pile. One case is that of a pile with a uniform cross-section. The length of the pile may be such that it can be divided into an integer number of 10-foot segments. For the later case, the pile should be divided into an integer number of segments, the length of which are close to 10 feet. For example, a pile with a total length of 313.5 feet could be divided into 33 segments of 9.5 feet per segment or 31 segments of 10.113 feet per segment. Comparable solution accuracy would be obtained with either division scheme.

A second case arises when dealing with piles of nonuniform cross-section, where variations in cross-section do not occur at 10-foot intervals. For example, a pipe pile may have an 8-foot, 1-inch wall section, a 20-foot 1-inch wall section, and a 150-foot, 1-inch wall section for its makeup. Since it is desirable to have approximately equal segment lengths, the shortest segment length required by the cross-sectional variations will be used as a basis for dividing the other sections of the pile. Hence, the 8-foot section is considered to be the base segment length. The 20-foot section can be divided into two segments of 10 feet each or three segments of 6.667 feet each. The 150-foot section can be divided into either 18 segments 8.333 feet each or 19 segments 7.895 feet each.

### Pile Segment Weight

The weight of a segment of the pile can be calculated from:

$$WAM(I) = [A(I)][L(I)][d]$$

where WAM(I) = weight of the I-th segment in the system (kips)

A(I) = cross-sectional area of the I-th segment (in<sup>2</sup>)

L(I) = length of the I-th segment(in)

d = unit density of the material (kips/in<sup>3</sup>)

### Pile Segment Springs

The spring constant associated with a segment in a pile can be calculated from:

$$XKAM(I) = [A(I)][E]/[L(I)]$$

where XKAM(I) = spring constant associated with the I-th spring in the system (kips)

A(I) = cross-sectional area of the I-th spring (in<sup>2</sup>)

E = modulus of elasticity of the material (ksi)

$L(I)$  = length of segment of the I-th spring (in)

Note that the number of springs in the pile equals one less than the number of corresponding weights.

If a cushion is used between the helmet and the head of the pile, its spring constant may be placed between the helmet and the first pile weight, and the remaining pile segment springs may be moved below their corresponding weights. If no cushion is utilized, the spring rate of the first pile spring must be placed between the helmet and the head of the pile, and all following springs moved above their corresponding weights.

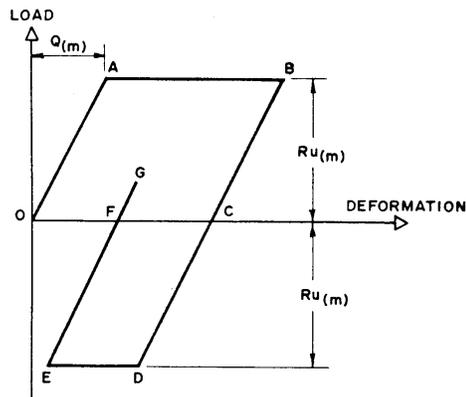
#### Limiting Forces Between Pile Segments

$GAMMA(I)$  represents the minimum force that can be exerted in the I-th spring (compressive forces positive). If the parts composing the pile driver and accessories are physically separated and cannot transmit tension, then values of  $GAMMA(I)$  for the hammer assembly springs will be set equal to 0.0. In the case of diesel hammers, the minimum force in the spring under the ram is equal to the explosive force; In this case  $GAMMA(I)$  is set = to the explosive force. Thus, if any spring in the system cannot transmit tension, its value of  $GAMMA(I)$  should be set to 0.0. Any spring which can transmit tension should have its corresponding  $GAMMA(I)$  set to -1.0 to indicate that tension can be transmitted through the spring. The only exception to this is for a diesel hammer, in which case  $GAMMA(I)$  should be set equal to the explosive pressure as listed in Appendix C. This will then account for the explosive pressure force in the hammer.

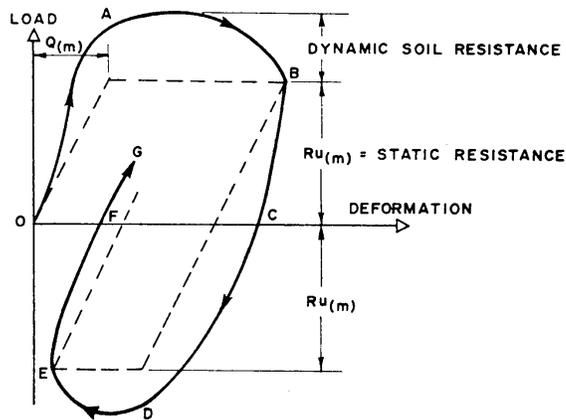
#### Slack in Joints

In the case of certain mandrel driven piles, such as Raymond step-taper piles, some of the pile segments are not rigidly connected, but are connected with loose fitting pins. Thus, the ends of certain pile sections can "open up" a certain distance, known as "slack", before transmitting tension. Any such joint will thus have  $GAMMA(I) = -1.0$  to indicate that it can transmit tension, with its  $SLACK(I)$  set equal to the total slack in the joint, after which tension can be transmitted.

#### Idealization for Soils



(a) STATIC



(b) DYNAMIC

The soil is idealized as a spring in parallel with a dashpot as seen in Figure 22. The soil spring can deform elastically to a limiting deformation,  $Q(I)$ , after which no additional load is required to produce continued deformation (see Figure 27a). The soil resistance corresponding to a deformation  $Q$  is denoted by  $R_u$ . The dashpot is used to include dynamic loading effects in the soil resistance (see Figure 27b).

Each weight of the pile system has a soil spring associated with it. Thus, the distribution of soil resistance along the length of the pile can be specified by proper choice of the constants which describe each individual soil spring. Figure 27(a) shows the assumed static load deformation characteristic for soil springs along the side of the pile and at the tip. For the soil on the side of the pile, path OABCDEF G represents the load-deformation that occurs as the pile moves through the soil. For the soil at the point, only compressive loading can occur, since the point of the pile is free to rebound, and the load deformation path is OABCO.

It can be seen that the characteristics of the spring representing the soil stiffness are

defined by the quantities Q and Ru. Q is the soil quake or maximum elastic deformation corresponding to the maximum elastic force Ru. A load-deformation diagram shown in Figure 27(a) is thus established for each soil spring. The stiffness of a side soil spring is given by:

$$XKIM(m) = Ru(m)/Q(m)$$

where Ru(m) = side soil resistance on segment m (kips)

Q(m) = side soil quake (in).

The dynamic loading effects for the soil are included by assuming that the soil has a damper (dashpot) in parallel with the spring (see Figure 22). The dynamic resistance of the dashpot is assumed directly proportional to the velocity of the associated segment weight during displacement and the total resistance of the soil spring and dashpot during displacement is given by (see Figure 27b):

$$R(m) = [D(m) - D'(m)] XKIM(m) [1.0 + J(m)V(m)] , \text{ from O to A, and}$$

$$R(m) = XKIM(m)[D(m) - D'(m)] + Q(m)J(m)V(m), \text{ after A.}$$

Where R(m) = total resistance, static plus dynamic

D(m) = displacement of WAM(m) into the soil (in)

D'(m) = plastic displacement of weight into soil (in)

XKIM(m) = spring stiffness of soil spring (ksi)

J(m) = damping constant of soil spring (sec/ft)

V(m) = velocity of WAM(m) (ft/sec)

Q(m) = soil quake (in)

This equation will produce a dynamic load-deformation behavior as shown by path OABCDEFG in Figure 27(b) for the side soil and the path OABC for the point soil. The soil dashpot is used to include dynamic loading effects of the soil. The characteristic of a dashpot is its damping constant. Extensive data are not available for the damping characteristics of soils, however, values for sands and clays have been determined and are listed in Appendix C. Should more accurate damping values become available, they should be used instead of the approximate values.

### Soil Quake and Damping

The values of Q (commonly called "quake") and J (the damping constant) for various soils are still being studied. However, most soils have a Q value on the order of 0.1 in, its value is usually considered to be constant for all soils and equal to 0.1 in. More accurate values for Q should be used if available. Until more accurate values are available, the authors recommend use of the values listed in Appendix C. These values have been determined by full scale pile tests wherein the values were varied and those which gave the most accurate correlation with load tests

were selected. Additional information regarding these tests can be found in Reference 31.

## APPENDIX A - COMPUTER PROGRAM INPUT DATA

### Introduction

The following section lists the required information necessary to perform an analysis using the wave equation computer program. A detailed discussion is included that explains the required input parameters. Any number of data sets may be loaded in sequence.

### Program Input Data

#### 1) Card 1 (Required)

NCARDS = Total number of identification cards to be read, including Card 1 (Maximum of 8 cards).

= 1 Read Card 1 only (Read "NCARDS" plus read and print 68 columns of Alphanumeric problem identification).

= 2 Read and print I.D. Cards 1 and 2. (72 columns of information may be punched in Cards 2 thru 8.)

= 3 Etc.

#### 2) Card 101 (Required)

1/DELTEE = 1/Time interval. If left blank, Delta Tcritical/2 will be used. (1/sec) (Normally left blank).

NSTOP = Maximum number of time intervals the program is to run. (See Chapter 4, page 6)

IPRINT = Print frequency. For example, if a print of the solution at every 5th time interval is wanted, set IPRINT = 5.

NSI-NS6 = The element numbers for which solutions vs. time interval will be printed.

.....  
NOP(I) Value      NOP(I) Functions  
.....

NOP(1) Used to specify long or short print-out of solution.

=1 Print out information needed for checking problem solution, and all final answers.

(Normally used).

=2 Print out all variables needed to check program operations using fixed formats. (Dump print).

=3 Print out all variables needed to check program operations using floating formats. (Dump print).

.....  
NOP(2) Used to specify the input method for the segment weights WAM(I)

=1 Read one weight for each segment (card series 200). Note that this number is automatically inserted in the data set for you since no other value is possible.

.....  
NOP(3) Used to specify the input method for the internal spring stiffness. XKAM(I)

=1 Read one stiffness for each internal spring from card series 300.

.....  
NOP(4) Used to specify what soil resistance distribution

acts along the pile. NOTE: RUP is the total point resistance and RUT is the total resistance on the pile. Both are read in on card 103.

=1 Read RUM(I) for each element from card series 400, including the point bearing soil resistance RUM(MP+1). (MP is defined on card 102).

=2 Set all side resistances equal to zero, and set RUM(MP+1)= RUP.

=3 Distribute RUT-RUP uniformly along the side of the pile from segment MO thru MP, and set RUM(MP+1) = RUP. (MO is defined on card 103).

=4 Distribute RUT-RUP triangularly along the pile between segments MO and MP, and set RUM(MP+1) = RUP.

.....  
NOP(5) Used to specify the input method for GAMMA(I).

NOTE: The significance of GAMMA(I) is discussed in the 500 card series.

=1 Read GAMMA1, GAMMA2, and GAMMA3 from card 102 and assign GAMMA1 to internal spring number 1, GAMMA2 to spring number 2, and GAMMA3 to spring number 3. Then set GAMMA(I) of the remaining springs to -1.0. (Normally used).

=2 Read GAMMA(I) for each spring from card series 500.

.....  
NOP(6) Used to specify the input method for EEM(I). (Coefficients of restitution for springs)

=1 Read EEM1, EEM2, and EEM3 from card 102, set EEM(1)= EEM1, EEM(2) = EEM2, and EEM(3) = EEM3. Then set EEM(I) for all other springs equal to 1.0 (perfectly elastic). (Normally used).

=2 Read EEM(I) for each spring from card series 600.

.....  
NOP(7) Used to specify whether program is to run for a full NSTOP iterations, or if program should run only until maximum permanent set of pile has been reached.

=1 Run until permanent set of pile is found. (Normally used).

=2 Run full NSTOP iterations.

.....  
NOP(8) Used to specify input method for VEL(I).  
=1 Read VELMI from card 102 and set VEL(I,t=0) equal to VELMI. Set all other VEL(I,t=0)=0.0. (Normally used).  
=2 Read VEL(I) for each segment from card series 800.

.....  
NOP(9) Used to specify input method for Q(I).  
=1 Read QSIDE and QPOINT from card 103 and set all Q(I) along side of the pile equal to QSIDE. Set Q(MP + 1) under pile tip equal to QPOINT. (Normally used).  
=2 Read Q(I) for each element including Q(MP + 1) from card series 900.

.....  
NOP(10) Used to specify input method for soil damping SJ(I).  
=1 Read SIDEJ and POINTJ from card 103. Set all SJ(I) along side of pile equal to SIDEJ and set SJ(MP + 1) under pile tip equal to POINTJ. (Normally used).  
=2 Read SJ(I) for each element including SJ(MP + 1) from card series 1000.

.....  
NOP(11) Used to specify input method for cross sectional area of pile A(I).  
=1 Read AREA from card 102 and set all A(I) equal to AREA. (Set A(I) = 1000.0 for conversion to kips). (Normally used).  
=2 Read A(I) for each internal spring from card series 1100.

.....  
NOP(12) Used to read in "slack" present in any of the segments.  
=1 No slack present in any of the joints. (Normally used).  
=2 Read in joint slacks for each spring from card series 1200.

.....  
3) Card 102 (Required)

MP = Total number of segments in the system to be analyzed.

MH = Element number of the first pile segment.

VELMI = Initial velocity of the ram. (ft/sec)

AREA = A constant used to convert the output forces into stresses or other more convenient values if desired. Note that you can change pounds, which is the normal computer output unit, to kips by setting AREA = 1000.0. Or you can change pounds to ksi stress by setting AREA = 1000\*area of pile.

EEM1 = Coefficient of Restitution of spring number 1, directly under the ram.

EEM2 = Coefficient of Restitution of spring number 2.

EEM3 = Coefficient of Restitution of spring number 3.

GAMMA1 = The minimum force in the spring between the ram and the anvil, once that force has reached a maximum. (kip) For example, if the diesel hammer explosive pressure causes a 158.7 kip minimum force in this spring, set GAMMA1 = 158.7 kip. If the minimum force the spring can transmit is zero (for example, when no tensile force can exist between the ram and the anvil, and no explosive pressure force is acting, set the corresponding GAMMA(I) = 0.0. If the spring represents a continuous body such as the spring between any two pile segments, that spring can transmit tensile forces between the elements. This is signified by setting GAMMA(I) equal to any negative value, usually -1.0 kip.

GAMMA2 = Same as above, but for spring number 2. Note that GAMMA2 will only be -1 or 0, never positive, since only GAMMA1 will have a diesel explosive pressure.

GAMMA3 = Same as GAMMA2, but for spring number 3.

4) Card 103 (Required)

RUT = The total static soil resistance acting on the pile (kip).

RUP = The total static soil resistance acting beneath the pile point (kip).

MO = Number of the first element upon which soil resistance acts.

QSIDE = Soil quake along the side of the pile (inches). If the soil quake varies along the pile, use input on card series 900, and QSIDE will be ignored.

QPOINT = Soil quake on the point segment (inches).

SIDEJ = Soil damping factor in shear along the side of the pile.(sec/ft)

POINTJ = Soil damping factor in compression beneath the pile point (sec/ft)

DR1 = Increment by which RUT and RUP are to be increased when the problem is re-run.

DR2 = Second increment by which RUT and RUP are to be increased and the problem re-run.

DR3 = Etc. For example, if three levels of resistance were to be run with RUT = 100, 250, 400, 800 kips, with corresponding point resistances of 10, 25, 40 and 80 kips, set RUT = 100, RUP = 10, and set DR1 = 2.5, DR2 = 4.0, and DR3 = 8.0.

5) 200 CARD SERIES (Required)

I = Element number (from top down) (Last value must be MP)

WAM(I) = The weight of element number I (kip). Note that only the last weight of a string of identical weights must be input, if desired. For example, if WAM(1) = 10.0, WAM(2-8) = 5.0, and WAM(9-53) = 2.0, it is sufficient to input:

```
I WAM(I) I WAM(I) I WAM(I) I WAM(I) I WAM(I)
1 10.0 8 5.0 53 2.0
```

The program will understand that WAM(2) thru WAM(8) = 5.0, WAM(9-53) = 2.0. All input data utilizes this method.

6) 300 CARD SERIES (Required)

I = Element number

XKAM(I) = The internal spring rate of spring I (kip/in.)

Similar to card series 200, only the last value of a string of identical values must be input. Values must be input from the top of the system down. Last value must be MP-1.

7) 400 CARD SERIES (Required if NOP(4) = 1)

I = Element number

RUM(I) = The ultimate static soil resistance acting on pile segment I (kip).

- a) If NOP (4) = 1, read MP + 1 ultimate soil resistances, from card series 400.
- b) If NOP(4) = 2, set all side friction = 0.0 and set RUM(MP+1) = RUP.
- c) If NOP(4) = 3, distribute (RUT-RUP) uniformly along the pile starting from segment number MO to number MP, and set RUM(MP+1) = RUP.
- d) If NOP(4) = 4, distribute (RUT-RUP) triangularly between MO and MP, and set RUM(MP+1) = RUP.

8) 500 CARD SERIES (Required when NOP(5) = 2).

I = element number

GAMMA(I) = The minimum force possible in spring I after the peak compressive force has passed, except that any negative GAMMA(I) is construed to mean that spring can transmit a tensile force of any magnitude (kip). Total number of GAMMA(I) values = MP-1 (one for each internal spring.)

9) 600 CARD SERIES (Required when NOP(6) = 2)

I = Element number

EEM(I) = The coefficient of restitution for MP-1 internal springs. This determines the slope of the unloading curve (dimensionless).

10) 700 CARD SERIES (Not Used)

11) 800 CARD SERIES (Required when NOP(8) = 2)

I = Element number

VEL(I) = The initial velocities of each of the MP weights (ft/sec).

12) 900 CARD SERIES (Required when NOP(9) = 2)

I = Element number

Q(I) = The soil "quake" for MP+1 soil springs (in.).

13) 1000 CARD SERIES (Required when NOP(10) = 2)

I = Element number

SJ(I) = The soil damping factor for MP+1 soil springs (sec/ft).

14) 1100 CARD SERIES (Required when NOP(11) = 2)

I = Element number

A(I) = The cross-sectional area of the MP-1 internal springs (in<sup>2</sup>).

15) 1200 CARD SERIES (Required when NOP(12) = 2)

I = Element number

SLACK(I) = The slack or "looseness" in the MP-1 internal springs (in), input for segments which have slack present. For segments which do not have slack, input 0, such that the element will not have slack or looseness.

## APPENDIX B - CODING SHEETS

Coding Sheets - Since EDITWAVE handles the forming of the data sheets, coding sheets are no

longer required. The data is entered in its proper position in ASCII format, and can be viewed with an ASCII editor if desired.

### APPENDIX C - HAMMER, CUSHION, AND SOIL PROPERTIES

The following is a summary for properties of drop and steam hammers, diesel hammers, cushions/capblocks, and soil properties. Figure 28 shows the idealization for commonly used steam and drop hammers, while Table C1 lists their specific values. Figure 29 shows the idealization for diesel hammers, and Table C2 lists their properties for use in the wave equation.

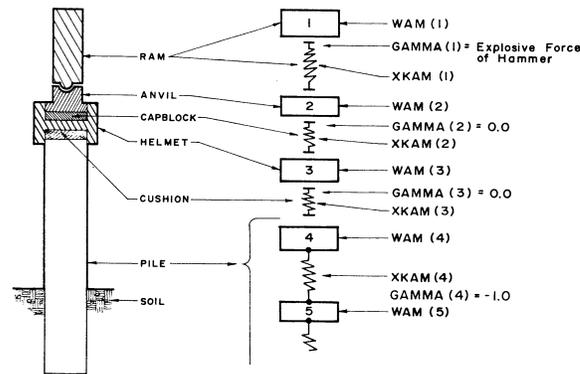


Table C3 gives a summary of various cushion and capblock materials commonly used, and recommended wave equation input values. Table C4 gives a summary of common soil properties.

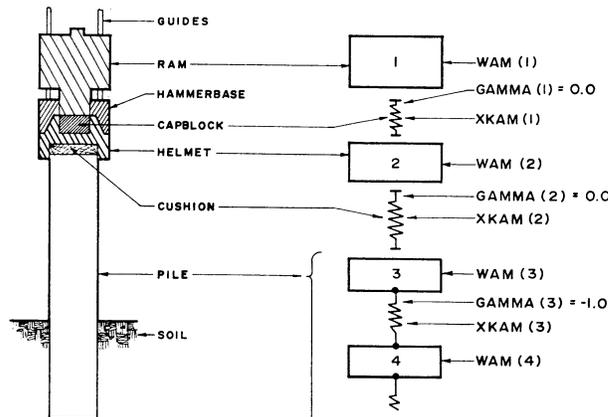


TABLE C1 - Summary of Steam Hammer Properties

Rated	Ram	Maximum Ram	Effi-	Equivalent Ram
-------	-----	-------------	-------	----------------

Hammer	Energy Action	Weight ft-lb	Fall lb	ciency ft	Velocity %	ft/sec
Vulcan 2	Single	7,260	3,000	2.42	66	10.14
" 1	"	15,000	5,000	3.00	66	11.29
" 06	"	19,500	6,500	3.00	66	11.29
" 08	"	26,000	8,000	3.25	66	11.75
" 010	"	32,500	10,000	3.25	66	11.75
" 014	"	42,000	14,000	3.00	66	11.29
" 016	"	48,750	16,250	3.00	66	11.29
" 020	"	60,000	20,000	3.00	66	11.29
" 030	"	90,000	30,000	3.00	66	11.29
" 040	"	120,000	40,000	3.00	66	11.29
" 060	"	180,000	60,000	3.00	66	11.29
Vulcan18c	Differential	3,600	1,800	2.00	66	9.22
" 30c	"	7,260	3,000	2.42	66	10.14
" 50c	"	15,100	5,000	3.01	66	11.31
" 65c	"	19,200	6,500	2.95	66	11.20
" 80c	"	24,450	8,000	3.05	66	11.40
" 140c	"	36,000	14,000	2.57	66	10.45
" 200c	"	50,200	20,000	2.51	66	10.33
" 400c	"	113,488	40,000	2.83	66	10.97
Raymond 1	Single	15,000	5,000	3.00	66	11.29
" 15	"	19,500	6,500	3.00	66	11.29
" 0	"	24,375	7,500	3.25	66	11.75
" 00	"	32,500	10,000	3.25	66	11.75
" 000	"	40,600	12,500	3.25	66	11.75
" 0000	"	48,750	15,000	3.25	66	11.75
" 00000	"	56,875	17,500	3.25	66	11.75
Raymond 15M	Differential	15,060	5,000	3.01	66	11.31
" 65c	"	19,500	6,500	3.00	66	11.29
" 150c	"	48,750	15,000	3.25	66	11.75
MKT C-5	Double	16,000	5,000	3.20	66	11.66
" C-826	"	24,000	8,000	3.00	66	11.29
" 9B3	"	8,750	1,600	5.47	66	15.25
" 10B3	"	13,100	3,000	4.37	66	13.63
" 11B3	"	19,150	5,000	3.83	66	12.76
" S5	Single	16,250	5,000	3.25	66	11.75
" S8	"	26,000	8,000	3.25	66	11.75
" S10	"	32,500	10,000	3.25	66	11.75
" S14	"	37,500	14,000	2.67	66	10.65

" S20 " 60,000 20,000 3.00 66 11.29

TABLE C2 - Summary of Diesel Hammer Properties

Hammer Model (Kips)	Ram Weight (ft-lb)	Energy Output % (ft)	Hammer Efficiency (ft)	Ram Stroke	c
Delmag D-5	1.10	9,100 100	9.64*	0.83	
" D-12	2.75	22,500	100	10.83*	1.08
" D-15	3.30	22,780	100	10.83*	1.10
" D-22	4.85	39,700	100	10.55*	1.08
" D-30	6.60	54,250	100	10.51*	1.25
" D-44	9.50	87,000	100	11.41*	1.19
" D-55	11.86	117,175	100	11.41*	1.64
Kobe K-25	5.51	50,700	100	8.0*	1.46
Link Belt 180	1.72	8,100 100	4.63**	0.64	
" " 312	3.85	515,000	100	3.87**	0.50
" " 440	4.00	18,200	100	4.55**	1.25
" " 520	5.07	26,300	100	5.20**	0.83
MKT DE-20	2.00	18,800	100	8.00*	0.92
" DE-30	2.80	22,400	100	8.00*	1.04
" DE-40	4.00	32,000	100	8.00*	1.17

TABLE C2 - Summary of Diesel Hammer Properties (Continued)

Model(Kips)	Explosive Force (GAMMA1) (ft/sec)	Ram Velocity (kips)	Weight (kips/in)	Anvil K(1)
Delmag D-5	46.3	23.57	0.35	1,850
" D-12	93.7	25.06	0.82	3,150
" D-15	129.2	25.03	0.81	2,646
" D-22	158.7	24.70	1.58	4,970
" D-30	175.0	24.22	1.61	3,976
" D-44	200.0	25.65	2.42	10,600
" D-55	275.0	25.07	2.42	7,810
Kobe K-25	238.1	20.53	1.60	13,464
Link Belt 180	81.0	16.03	0.38	4,450
" " 312	98.0	14.73	1.18	14,250

"	" 440	98.0	14.58	0.71	13,800
"	" 520	98.0	16.78	1.18	10,850
MKT	DE-20	46.3	21.35	0.66	3,120
"	DE-30	98.0	21.17	0.774	3,870
"	DE-40	138.0	20.97	1.35	7,220

\*Maximum stroke. For actual stroke use field observations - may vary from 4.0 to 8.0 ft.

\*\*Maximum stroke. Determine true value in field from bounce chamber pressure ( $h_e = E/Ram$  weight where  $E =$  Indicated Energy).

C - distance from exhaust parts to anvil.

TABLE C3 - Summary of Constants for Commonly Used Cushion and Capblock Materials

Material	Elastic Modulus $E_c$ (Kips/in <sup>2</sup> )*	Coefficient of Restitution EEM
Asbestos	40	0.50
Micarta disks (1"), Aluminum disks (0.5")**	700	0.80
Micarta	450	0.80
Oak, load perpendicular to grain	45	0.50
Fir, plywood load perpendicular to grain	35	0.40
Pine, plywood load perpendicular to grain	25	0.30

\*Values are for used cushion materials.

\*\*1-in. layers of micarta with alternate layers of 0.5-in. aluminum.

TABLE C4 - SOIL PROPERTIES\*

Soil Type	Side Damping (Friction)	Point Damping (Bearing)Quake	
Clay	0.20 sec/ft	0.01 sec/ft	0.1 in
Sand	0.05 sec/ft	0.15 sec/ft	0.1 in

Silt                      0.10 sec/ft                      0.15 sec/ft                      0.1 in

\*After reference 31

## APPENDIX D - SAMPLE PROBLEMS

### Case I

Assume that a 12"x12" prestressed concrete pile 60-feet long is to be driven to a penetration of 30 feet below the mudline with clay at the side and point of the pile, using a standard Vulcan 08 steam hammer.

### Hammer

From Appendix C, the properties of a Vulcan 08 hammer are found to be:

Hammer Stroke = 3.25 feet

Ram Weight (WAM(1)) = 8.0 kips

Efficiency = 66%

Helmet Weight (WAM(2)) = 1.0 kip (assumed)

Note that helmet weights and cushion dimensions are not listed in Appendix C, since they vary from job to job, and with each contractor. They must be individually determined. Values used in all following example cases were selected from previous cases solved by the author.

The ram velocity at impact (VELMI) is computed by:

$$\text{VELMI} = \sqrt{2g(\text{Hammer Stroke})(\text{Efficiency})}$$

$$\text{VELMI} = \sqrt{(64.4)(3.25)(0.66)}$$

$$\text{VELMI} = 11.75 \text{ ft/sec}$$

### Capblock

The properties for this capblock are:

Capblock: OAK (from contractor)

Diameter (from contractor)= 14.0"

Thickness (from contractor)= 1.0"

Modulus of Elasticity (E)= 45 kips/in (Table C3)

Coefficient of Restitution (AIM)= 0.5 (Table C3)

Since this spring is between the ram and the helmet it cannot transmit tension, so  $\text{GAMMA1} = 0$ .  
Spring rate for CAPBLOCK ( $\text{XKAM}(1)$ ) =  $\text{AE/L}$

where A = Area of Capblock

E = Modulus of Elasticity

L = Length or Thickness

$$\begin{aligned}\text{XKAM}(1) &= (\pi)(\text{Diameter})^2(45 \text{ ksi})/(4*1.0") \\ &= 6927 \text{ kips/inch}\end{aligned}$$

Cushion (from contractor) = OAK (see Appendix C)

Size (from contractor) = 12"x12" square (same size as pile)

Thickness (from contractor) = 1.0"

Modulus of Elasticity (E) = 45 ksi

Coefficient of Restitution = (EEM2) = 0.5

$\text{GAMMA2} = 0.0$

Spring rate for cushion  $\text{XKAM}(2)$ :

$$\text{XKAM}(2) = \text{AE/L}$$

$$= (12")(12")(45 \text{ ksi})/1.0"$$

$$= 6480 \text{ kips/inch}$$

Pile

The pile to be driven is a 12"x12" prestressed concrete pile, 60 feet long. Given information is as follows:

Area = 144 in<sup>2</sup>

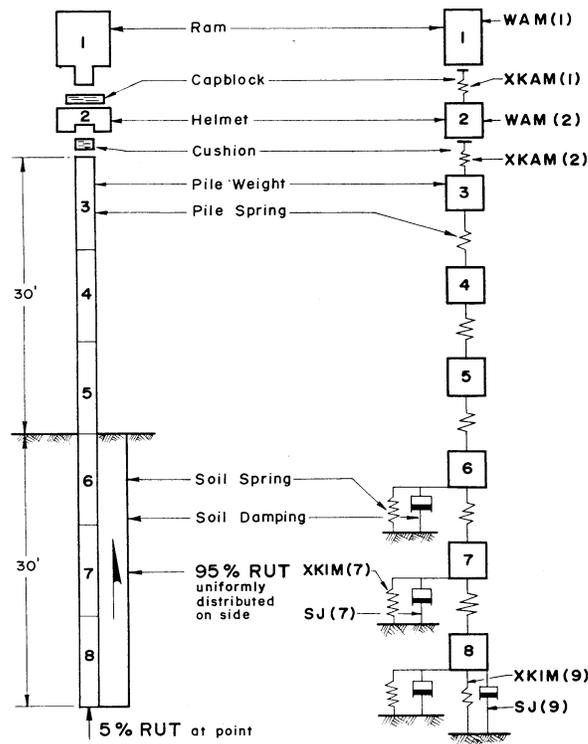
Length = 60 feet

Modulus of Elasticity = 3000 ksi

Prestress = 2000 psi

Maximum allowable compressive stress = 2000 psi above prestress

Maximum allowable tensile stress = 500 psi above prestress



A series of 10-foot pile segments will be used to idealize the pile in this case. Although a slight increase in accuracy would be possible by using shorter segment lengths, this is probably not justified because of the increased solution time required. The idealization for this case is shown in Figure 30.

The segment weights are computed from  $WAM(I) = AL(\text{Density})$

where  $WAM(I)$  = Weight of element I(kips),  $A$  = Cross-sectional area of the pile at element I( $\text{in}^2$ ),  $L$  = Length of element I, (inches), and the density of the material at element I is 0.150 kips/ $\text{ft}^3$ .

Thus,  $WAM(3) = (144 \text{ in}^2)(10\text{ft} \times 12 \text{ in}/\text{ft})(0.150 \text{ kips}/\text{ft}^3) / (1728 \text{ in}^3/\text{ft}^3) = 1.5 \text{ kips}$ . Thus,  $WAM(3)$  through  $WAM(8) = 1.5 \text{ kips}$ .

Note that although there are 8 element weights in the system, there are only 7 internal springs (one between each two adjacent weights). There are also 9 soil springs associated with the 8 weights, since the last weight has a "side" soil spring (side friction) and also a "point" soil spring (point bearing). The top 5 soil springs are not shown on weights 1 through 5 as they are absent for this case.

To compute the spring rates for each of the 10-foot pile segments:

$$\text{XKAM}(3) \text{ through } \text{XKAM}(7) = \text{AE}/\text{L}$$

$$= (12" \times 12")(3000 \text{ ksi}) / (10 \text{ ft} \times 12" / \text{ft})$$

$$= 3600 \text{ kips/inch}$$

Coefficients of restitution for the concrete pile should be set to 1.0, as the damping in the pile is negligible. Also, since each of the pile springs 3 through 7 can transmit tension, GAMMA(3) through GAMMA(7) = -1.0.

## Soil

The soil properties, as determined from soil borings and tests are assumed as follows:

Soil Type: Clay

Soil Resistance: 900 kips total after set up required.

95% distributed uniformly along side of pile in friction

5% point bearing

Set up of soil = 2.0

To obtain a starting value of resistance for use in the wave equation, some value around 5 to 10 times the pile weight is normally selected. This is then increased in increments as desired. Thus for Case I, since the pile weighs 9 kips, the initial total resistance will be assumed as 50 kips. Of this, 95% (47.5 kips) will be distributed uniformly along the side of the pile, and 5% (2.5 kips) will be placed under the pile point. Thus, input data for the program will be: total soil resistance RUT = 50 kips, total point resistance RUP = 2.5 kips.

## Card Input: Case I

Using the values from Case I, the following information is input in EDITWAVE

### 1) Card 1

NCARDS = Total number of identification cards to be read (maximum of 8 cards). For this case, NCARDS = 2, and two lines of identification are entered.

### 2) Card 101

1/Deltee - 1/Time interval. If left blank, Deltee critical/2 will be used. (1/sec). 1/Deltee will be left blank for this case, and the computer will calculate the time interval from the properties of the weights and springs involved in the idealization.

NSTOP = Maximum number of intervals the program is to run. Set at 200 for this case.

IPRINT = Print frequency. For this case, set IPRINT equal to 5, to print every 5th iteration.

NS1-NS6 = The element number for which solution vs. time interval will be printed. For this case,

NS1 = 1 (Ram), NS2 = 2 (Helmet), NS3 = 3 (First Pile Segment), NS4 = 5, NS5 = 7, NS6 = 8 (Last Segment of the Pile).

NOP(1) = 1, to print out normal information needed for checking problem solution, and a summary of all final answers.

NOP(2) = 1, to read the WAM(I) (weights) values for each weight used in the hammer-pile system from card series 200.

NOP(3) = 1, read values of XKAM(I) (spring rates) for each internal spring from card series 300.

NOP(4) = 3, distribute Total Resistance (RUT) minus Point Resistance (RUP) uniformly along the side of the pile from segment MO through MP, and set the point bearing soil resistance = RUP. (MO is defined on card 103).

NOP(5) = 1, read GAMMA(1), GAMMA(2) and GAMMA(3) from card 102. For this case: GAMMA(1) = 0.0, GAMMA(2) = 0.0, and GAMMA(3) = -1.0, meaning that the pile springs can transmit tensile forces. All remaining GAMMA(I) values of the system will then be set to -1.0, indicating that the remaining pile springs can transmit tension.

NOP(6) = 1, read EEM(1), EEM(2), and EEM(3) from card 102. (EEM(1) is discussed on the 102 card.) Thus all remaining EEM(I) will be set equal to 1.0 (no damping).

NOP(7) = 2, run the program for full NSTOP iterations as specified on the 101 card. This is used when you want to make sure that the maximum stresses have been observed in the pile. If you let the computer shut the run down, can only check to see if the pile has reached its maximum penetration and shuts down. The maximum tensile waves may not have yet been recorded.

NOP(8) = 1, read VELMI from card 102. This is the velocity of the ram at impact. All element velocities following the ram are then set equal to 0.0.

NOP(9) = 1, read QSIDE and QPOINT from card 103 and set all Q(I) along the side of the pile equal to QSIDE. Set Q at the pile tip equal to QPOINT. For this case, QSIDE = 0.1 and QPOINT = 0.1.

NOP(10) = 1, read SIDEJ and POINTJ from card 103. Set all SJ(I) along the side of the pile equal to SIDEJ and SJ(MP+1) under pile tip equal to POINTJ.

NOP(11) = 1, read AREA from card 102 and set all A(I) equal to AREA. Note that this is of course incorrect for the hammer area, but since we are not interested in the true stresses in the hammer, we do not care. The stresses in the pile will be accurate. Note also that this in no way affects the solution, even though the areas of some elements are incorrect. The areas are used only after the solution for FORCES in the springs are determined, and only to change that output from pounds to psi or ksi.

NOP(12) = 1, NO SLACK present in any of the joints.

3) Card 102

MP = 8 for this case because the ram and helmet are represented as one weight each, and the pile is 60 feet long, and it is divided into 10-foot segments. (see Figure 30).

MH = 3, the first pile segment (see Figure 30).

VELMI = 11.75 ft/sec as calculated above. AREA = 144 in<sup>2</sup> of concrete for a 12"x12" pile.

EEM1 = 0.5 for an oak capblock (see Appendix C). EEM2 = 0.5 for an oak cushion (see Appendix C). EEM3 = 1.0 for the pile coefficient of restitution.

GAMMA1 = 0.0, minimum spring force between the pile and the helmet (no tension in spring 1).

GAMMA2 = 0.0 (no tension in spring 2).

GAMMA3 = -1.0, the continuous body (pile) can transmit tensile forces (springs 3 through 7).

4) Card 103

RUT = 50 kips = starting value of total static soil resistance acting on the pile.

RUP = 2.5, starting value of static soil resistance acting beneath the pile.

MO = 6, (see Figure 30) first element of the pile upon which soil resistance acts.

QSIDE = 0.1, soil quake along the side of the pile (inches).

QPOINT = 0.1, soil quake at the point segment of the pile (inches).

SIDEJ = 0.2, for clay - soil damping factor in shear along the side of the pile (sec/ft). (See Appendix C).

POINTJ = 0.01, for clay - soil damping factor in compression beneath the pile point (sec/ft). (See Appendix C).

DR1-DR7 = 2.0, 3.0, 4.0, 6.0, etc. These values increase RUT and RUP proportionally to develop points to plot the RUT vs. Blow Count curve (see Figure 22). For example, RUT = 50 and RUP = 2.5, initially, these resistances will then be increased to 100 and 5 kips, 150 and 7.5 kips, etc., respectively.

5) 200 Card Series

WAM(1) = 8.0 kips, ram weight, see Appendix C.

WAM(2) = 1.0 kips, helmet weight, from contractor.

WAM(8) = 1.5 kips, pile weight per 10-foot segment (see Figure 30). Entered on card 200 as

WAM(8) only because the internal program sets WAM(3) through WAM(8) = 1.5 kips, as calculated above.

6) 300 Card Series

XKAM(1) = 6927 kips/inch, spring rate for the capblock as calculated above.

XKAM(2) = 6480 kips/inch, spring rate for the cushion, as calculated above.

XKAM(7) = 3600 kips/inch, spring rate for pile elements as calculated above.

.....

Case II

Assume that a 12"x12" prestressed concrete pile 60 feet long is to be driven to a penetration of 30 feet below the mudline with clay at the side and at the point of the pile, using a standard Vulcan

010 steam hammer. (Same as Case I, except for change in hammer).

Hammer

From the contractor and Appendix C, the properties of a Vulcan 010 hammer are found to be:

Hammer Stroke= 3.25 feet

Ram Weight (WAM(1))= 10.0 kips

Efficiency= 66%

Helmet Weight (WAM(2))= 1.0 kips

The ram velocity at impact (VELMI) is computed by the same equation as in Case I:

$$VELMI = \text{sqrt}[(64.4)(3.25)(0.66)]$$

VELMI = 11.75 ft/sec (Same as Case I)

Capblock and Cushion

From Appendix C, the properties for the capblock and cushion are found to be the same as used in Case I. The dimensions are also assumed to be the same. Thus, the spring rate and all other input parameters for this case are the same as in Case I.

The pile used in this case is the same pile driven in Case I.

Soil

Identical to Case I.

Card Input: Case II

The same input for Case I is used for Case II except the following: 0001 and 0002 cards for problem identification are changed. WAM(1) = 10.0 kips (Ram weight for the Vulcan 010 hammer). All other input data entry for Case II will thus be identical to that used in Case I.

.....

Case III

Assume that a 12"x12" prestressed concrete pile 60 feet long is to be driven to a penetration of 30 feet below the mudline with clay at the side and at the point of the pile, using a standard Delmag D-15 open end diesel hammer. Case III is the same as Case I, except for the hammer and capblock utilized to drive the pile.

Hammer

From the contractor and Appendix C, the properties of a D-15 hammer, which is an open-end diesel hammer, are found to be:

Ram Weight (WAM(1))= 3.3 kips

Total Stroke of Ram (h)= 95 inches (observed in field)

Distance from the Anvil to the Exhaust Ports c = 13.15 in.

Efficiency= 100%

Anvil Weight (WAM(2))= 0.81 kips

Helmet Weight (WAM(3))= 1.0 kips (from contractor)  
The ram velocity at impact (VELMI) is computed by:

$$VELMI = \sqrt{2g(h-c)\text{efficiency}}$$

$$VELMI = \sqrt{64.4(95-13.15)(1.0)/(12\text{in}/\text{ft})}$$

$$VELMI = 21 \text{ ft}/\text{sec}$$

The spring rate for the ram XKAM(1), can be found in Appendix C. It was calculated by AE/L using the dimensions of the solid steel round hammer.

$$XKAM(1) = 2646 \text{ kips}/\text{inch}$$

The coefficient of restitution between the ram and the anvil will be 0.9. Thus, EEM1 = 0.9.

Capblock

From Appendix C, the properties for the capblock are found to be: Capblock: OAK

Diameter= 12.0 in.

Thickness= 1.0 in.<sup>2</sup>

Modulus of Elasticity (E)= 45 ksi

Thus, the spring rate of the capblock is:

$$XKAM(2) = AE/L = \pi(12^2)(45)/(4*1.0")$$

$$= 5089 \text{ kips}/\text{inch}$$

Cushion

From Appendix C, the properties for the cushion are found to be: Cushion: OAK

Size= 12"x12" (assumed)

Thickness= 1.0" (assumed)

45 ksi

EEM2= 0.5

The spring rate for the cushion (XKAM(2)) for this case is:

$$XKAM(3) = (12")^2(45 \text{ ksi})/1"$$

$$XKAM(3) = 6480 \text{ kips}/\text{inch}$$

The GAMMA1 value for a D-15 is found in Appendix C to be 129.2 kips, since this is the explosive pressure force for this hammer.

GAMMA2 and GAMMA3 are 0.0 since these two springs cannot transmit tension. The remaining GAMMA values will be set to -1.0 automatically since tension can be transmitted in the pile.

#### Pile

The pile used in this case is the same pile driven in Cases I and II, except the last pile segment (MP) is 9 because the diesel hammer system has a ram, anvil and a helmet as WAM(1) through WAM(3), whereas the previous stem hammer did not have an anvil.

Thus, WAM(4) through WAM(9) = 1.5 kips.

#### Soil

Identical to Case 1.

#### Card Input: Case III

Card 0201:

WAM(1) = 3.3, ram weight

WAM(2) = 0.81, anvil weight

WAM(3) = 1.0, helmet weight

WAM(9) = 1.5, pile segment weights for segments 4 through 9

Card 0301: XKAM(1) = 2646, ram spring rate XKAM(2) = 5089, capblock spring rate

XKAM(3) = 6480, cushion spring rate

XKAM(8) = 3600, pile segment spring rate for segment 8. The same input for Cases I and II is used, except for the following:

0001 and 0002 cards for problem identification are changed.

Card 0101: NS6 = 9

Card 0102: MP = 9, MH = 4

VELMI = 21.0 ft/sec, EEM1 = 0.9, EEM2 = 0.5, EEM3 = 0.5, GAMMA1 = 129.2 kips

Card 0103: MO = 7

Card 0201:

WAM(1) = 3.3 kips - ram weight

WAM(2) = 0.81 kips - anvil weight

WAM(3) = 1.0 kips - helmet weight

WAM(9) = 1.5 kips, pile segment weights for segments 4 thru 9

Card 0301:

XKAM(1) = 2646 kips/inch, ram spring rate

XKAM(2) = 5089 kips/inch, capblock spring rate

XKAM(3) = 6840 kips/inch, cushion spring rate

XKAM(8) = 3600 kips/inch, pile segment rate (segments 4-9)

.....

#### Case IV

Assume that a 12"x12" prestressed concrete pile 60 feet long is to be driven to a penetration of 30 feet below the mudline with clay at the side and at the point of the pile, using a standard Delmag D-15 open-end diesel hammer. This case is identical to Case III except that a thicker cushion is to be utilized.

Hammer

The input parameters for the hammer are the same as those used in Case III.

Capblock

The same capblock values that were used in Case III are used in Case IV.

Cushion

The same type of cushion is used in this case as in Case III, except the thickness is increased from 1" to 6".

Thus, the spring rate for the cushion (XKAM(3)) for this case is

$$XKAM(3) = (12\text{in}^2)(45 \text{ ksi})/6" = 1080 \text{ kips/inch}$$

The values of GAMMA1 through GAMMA3 are the same as used in Case III.

Pile

The pile used in this case is the same pile driven in Case III.

Soil

Identical to Case III.

Card Input: Case IV

The same input for Case III is used, except for the following: 0001 and 0002 cards for problem identification are changed. Card 0301:

XKAM(3) = 1080, cushion spring rate

.....

Case V

Assume that a 12"x12" prestressed concrete pile 60 feet long is to be driven to a penetration of 30 feet below the mudline with clay at the side and at the point of the pile, using a standard Delmag D-15 open end diesel hammer. This case is identical to Case IV except the cushion thickness is again increased.

Hammer

The input parameters for the hammer are the same as those used in Case IV.

Capblock

The same capblock values that were used in Case IV are used in Case V.

Cushion

The same type of cushion is used in this case as in Case IV, except the thickness is increased from 6" to 12". Thus, the spring rate for the cushion (XKAM(3)) for this case is

$$XKAM(3) = (12in^2)(45 ksi)/12" = 540 kips/inch$$

The values for GAMMA1 through GAMMA3 are the same as used in Case IV.

Pile

The pile used in this case is the same pile as driven in Case IV.

Soil

Identical to Case IV.

Card Input: Case V

The same input as for Case IV is used, except for the following: 0001 and 0002 cards for problem identification are modified. Card 0301: XKAM(3) = 540, cushion spring rate

.....

Case VI

Assume that a 12"x12" prestressed concrete pile 60 feet long is to be driven to a penetration of 30 feet below the mudline with clay at the side and at the point of the pile using a standard Delmag D-15 open-end diesel hammer.

Hammer

The input parameters for the hammer are the same as those used in Case V except the helmet weight is increased from 1 kip to 5 kips.

Thus, WAM(3) = 5.0 kips, helmet weight

Capblock

The same capblock values that were used in Case V are used in Case VI.

Cushion

The same values that were used in Case V are used in Case VI.

The values for GAMMA1 through GAMMA3 are the same.

Pile

The pile used in this case is the same pile driven in Case V.

Soil

identical to Case V.

Card Input: Case VI

The same input for Case V is used, except for the following: Cards 0001 and 0002 for problem identification are modified. Card 0201: WAM(3) = 5.0, helmet weight

.....

### Case VII

Assume that an HP8x36 steel pile 100 feet long is to be driven to a penetration of 80 feet below the mudline with sand at the side and at the point of the pile, using a standard Vulcan 010 steam hammer.

### Hammer

The input parameters for the hammer are the same as those used in Case II.

### Capblock

The same values that were used in Case II are used in Case VII.

The values for GAMMA 1 through GAMMA 3 are the same as used in Case II.

### Cushion

No cushion is used for this case. The helmet sits directly on the pile. Thus the pile spring rates will be brought up above their corresponding weights to supply the necessary spring between the helmet weight and the top pile weight.

### Pile

The pile to be driven is an HP8x36 steel pile, 200 feet long. Given information as follows:

Area = 10.6 in<sup>2</sup>

Length = 100 feet

Modulus of Elasticity = 30000 ksi

The pile will be divided in 10-foot segments. To compute the element weights, since the pile is known to weigh 36 lbs per foot, WAM(I) = (0.036 kips/ft)(10 ft/segment). Thus, WAM(3) through WAM(12) = 0.36 kips.

To compute the spring rates of the pile segments, which are 10-foot segments:

XKAM(2) through XKAM(11) =

$AE/L = (10.6 \text{ in}^2)(30000 \text{ ksi})/10 \text{ ft} \times 12"/\text{ft} = 2650 \text{ kips/inch}$ . Note that on previous cases, the spring rate of the cushion was placed between the helmet and the first pile segment, and the pile springs were placed beneath their corresponding weights. However, in this case, there is no cushion as none was required to reduce the stresses induced in the steel pile. Thus, the spring rate of the first pile segment will be placed between the helmet and the first pile weight, and all remaining pile springs will be placed above their corresponding weights. Coefficients of restitution for the steel pile should be set to 1.0, as damping is negligible. Also, since each of the pile springs 3 through 11 can transmit tension, GAMMA(3) through GAMMA(11) = -1.0.

### Soil

Tests at the site revealed that the soil was sand to a depth of 150 feet. Further lab tests indicated

that 90% of the resistance would be distributed uniformly along the side of the pile, with the remaining 10% of the resistance under the pile tip. The soil has no set up factor (set up = 1.0).

Card Input: Case VII

The same input for Case II is used for Case VII except for the following: 0001 and 0002 cards for problem identification are modified.

Card 0101: NS4 = 8, NS5 = 10, NS6 = 12

NOP(7) = 1,(run problem to determine permanent set only)

Card 0102:

MP = 12, AREA = 10.6, EEM2 = 1.0,

Card 0103:

MO = 5

SIDEJ = 0.05, sand at side of pile (see Appendix C)

POINTJ = 0.15, sand at point of pile (see Appendix C)

DR1-DR4 = 2.5, 3.0, 3.5, 3.75

Card 0201:

WAM(12) = 0.36, weight of each pile segment

Card 0301:

XKAM(11) = 2650, spring rate of pile segment

.....  
Case VIII

Assume that an HP12x53 steel pile 100 feet long is to be driven to a penetration of 80 feet below the mudline with sand at the side and at the point of the pile, using a standard Vulcan 010 steam hammer. This case is identical to Case VII, except the pile is changed from an HP8x36 to an HP 12x53.

Hammer

The input parameters for the hammer are the same as used in Case VII.

Capblock

The same values that were used in Case VII are used in Case VIII.

The values for GAMMA1 through GAMMA3 are the same as used in Case VII.

Cushion

Not used for this case.

Pile

The pile to be driven is an HP12x53 steel pile, 100 feet long.

Given information is as follows:

Area = 15.6 in

Length = 100 feet 2

Modulus of Elasticity = 30000 kips/in

Segment weights 3 through 12 are computed by:

$$\text{WAM(I)} = (0.053 \text{ kips/ft})(10 \text{ ft segment length}) = 0.53 \text{ kips}$$

Thus,

$$\text{WAM(3) through WAM(12)} = 0.53 \text{ kips}$$

Spring rates are computed by:

$$\text{XKAM(I)} = (15.6 \text{ in}^2)(30000 \text{ ksi})/(10 \text{ ft} \times 12 \text{ in/ft})$$

Thus, XKAM(2) through XKAM(11) = 3900 kips/inch.

Coefficients of restitution for the steel pile should be set to

1.0, as the damping is negligible. Also, since each of the pile springs 3 through 11 can transmit tension, GAMMA(3) through GAMMA(11) = -1.0.

Soil

Identical to Case VII.

Card Input: Case VIII

The same input as for Case VII is used except the following:

Cards 0001 and 0002 are modified.

Card 0102:

$$\text{AREA} = 15.6$$

Card 0103:

$$\text{DR1-DR4} = 3.0, 4.0, 4.25, 4.50$$

Card 0201:

$$\text{WAM(12)} = 0.53, \text{ weight of each pile segment}$$

Card 0301:

$$\text{XKAM(11)} = 3900, \text{ spring rate of pile segment}$$

.....

Case IX

Assume that an HP14x102 steel pile 100 feet long is to be driven to a penetration of 80 feet below the mudline with sand at the side and at the point of the pile, using a standard Vulcan 010 hammer. This case is identical to Case VIII except the pile size is increased to an HP14x102.

Hammer

The input parameters for the hammer are the same as those used in Case VIII.

Capblock

The same values that were used in Case VIII are used in Case IX.

The values for GAMMA1 through GAMMA3 are the same as used in Case VIII.

Cushion - Not used for this case.

Pile

The pile to be driven is an HP14x102 steel pile, 100 feet long. Given information as follows:

Area = 30.0 in

Length = 100 feet

Modulus of Elasticity = 30000 kips/in

Segment Weights = (0.102 kips/ft)(10 ft)

Thus, WAM(3) through WAM(12) = 1.02 kips

AE

Spring Rates =  $(30.0 \text{ in}^2)(30000 \text{ ksi}) / (10 \text{ ft} \times 12 \text{ in/ft})$

Thus, XKAM(2) through XKAM(11) = 7500 kips/inch

Coefficients of restitution for the steel pile should be set to 1.0, as the damping is negligible.

Also, since each of the pile springs 3 through 11 can transmit tension, GAMMA(3) through GAMMA(11) = -1.0.

Soil - Identical to Case VIII.

Card Input: Case IX

The same input for Case VII is used for Case IX except the following: 0001 and 0002 cards for problem identification are modified.

Card 0102:

AREA = 30.0

Card 0103: DR1-DR4 = 3.0, 5.5, 6.5, 7.0

Card 0201:

WAM(12) = 1.02, weight of each pile segment

Card 0301:

XKAM(11) = 7500, spring rate of pile segments

.....

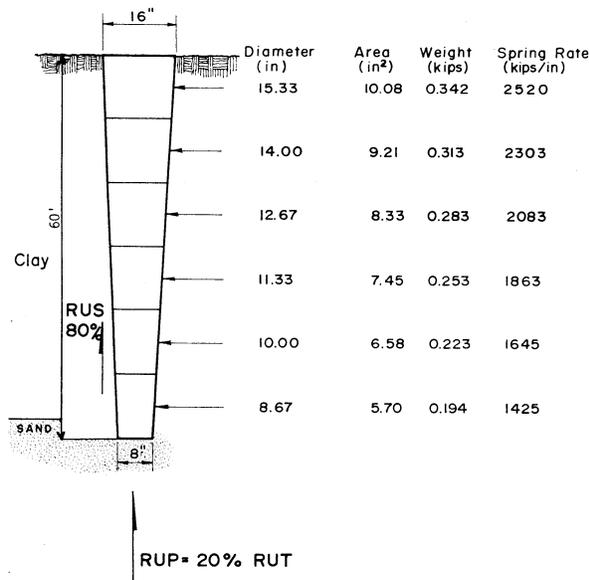
Case X

Assume that a tapered steel pipe 60 feet long is to be driven to full embedment with clay on the side and sand at the point of the pile, using a standard Vulcan 010 steam hammer.

Hammer

The input parameters for the hammer are the same as those used in Case II.

Capblock



The same capblock values that were used in Case II are used in Case X.

Cushion

Not used in this case since it is a steel pile.

Pile

The pile to be driven is a tapered steel pile 60 feet long, as shown in Figure 31. Given information as follows:

- Pile length = 60 feet
- Segment length = 10 feet
- Diameter at top of pile = 16 in.

Diameter at bottom of pile = 8 in.  
Wall thickness = #5 gage (0.2093 in)

The diameters listed in Figure 31 were obtained by proportion. For example, the center of the number 5 element is 7/12 up from the point of the pile. Thus, it has a diameter of 8 inches + (7/12)(16" - 8") = 12.67 inches. Diameters at the centers of each element were similarly obtained and are listed on Figure 31. The average areas listed were computed by multiplying the diameter by  $\pi \cdot D \cdot \text{wall thickness}$ . Thus, the average area of segment 5 is  $(\pi)(12.67 \text{ in})(0.2093 \text{ in}) = 8.33 \text{ in}^2$ . The weight is then computed from:

$$\begin{aligned} \text{WAM}(5) &= \text{AL}(\text{density}) \\ &= (8.33 \text{ in}^2)(10\text{ft} \times 12\text{in}/\text{ft})(0.490\text{k}/\text{ft}^3)/1728\text{in}^3/\text{ft}^3 \end{aligned}$$

= 0.283 kips and its corresponding spring rate, which will be placed above the weight, will be given by

$$\begin{aligned} \text{XKAM}(4) &= \text{AE}/\text{L} = (8.33\text{in}^2)(30000\text{ksi})/(10\text{ft} \times 12\text{in}/\text{ft}) \\ &= 2083 \text{ kips}/\text{inch} \end{aligned}$$

Other weights and spring rates were computed in a similar manner and are tabulated in Figure 31.

Coefficients of restitution for the steel pile were set to 1.0, as the damping is negligible. Also, since each of the pile springs 3 through 7 can transmit tension,  $\text{GAMMA}(3)$  through  $\text{GAMMA}(7) = -1.0$ .

## Soil

The soil properties, as determined from soil borings and tests are assumed as follows:

Soil Types: 57 ft of clay on side of pile  
Pile tipped in sand

Soil Resistance: 80% distributed uniformly along side of pile in friction, 20% point bearing  
Set up of soil = 2.0

Card Input: Case X

The same input for Case II is used except the following:  
Cards 0001 and 0002 for problem identification.

Card 0102:

AREA = 1000.0

EEM2 = 1.0, since there is no cushion used for this case

Card 0103: RUT = 100, RUP = 20

MO = 3, pile is driven to full embedment (see Figure 31) POINTJ = 0.15, sand at the point  
DR1-DR2 = 2.5, 3.0

Card 0201 and 0202:

WAM(3) = .342

WAM(4) = .313

WAM(5) = .283

WAM(6) = .253

WAM(7) = .223

WAM(8) = .194

Card 0301:

XKAM(2) = 2520

XKAM(3) = 2303

XKAM(4) = 2083

XKAM(5) = 1863

XKAM(6) = 1645

XKAM(7) = 1425

.....

## Case XI

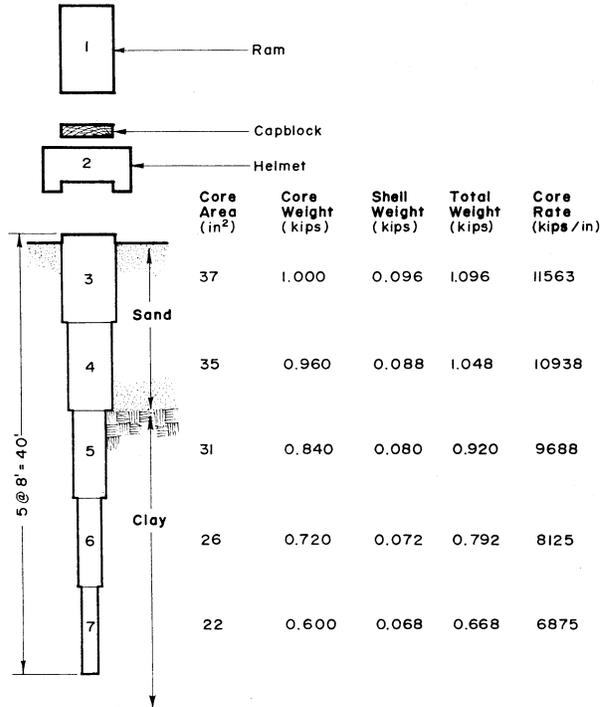
Assume that a Raymond Step-Tapered mandrel driven pile 40 feet long is to be driven to full embedment with sand and clay at the side and clay at the point of the pile, using a standard Vulcan 010 steam hammer. (See Figure 32). This case is for initial driving of the pile, when the soil is completely remolded. See Case XII for re-driving the pile after the soil has set up.

### Hammer

The input parameters for the hammer are the same as used in Case II.

### Capblock

The same values that were used in Case II are used in Case XI.



The values for GAMMA1 through GAMMA3 are the same as used in Case II.

Cushion: None, thus the spring rate of the pile segments will be placed above their corresponding weights.

### Pile

The pile to be driven is a Raymond Step-Tapered mandrel driven pile, 40 feet long. Cross-sectional areas and weights were determined from the manufacturer, as listed by Chellis (30). The pile is divided into 8-foot segments since the mandrel lengths are manufactured 8 feet long. Note that the cross-sectional area of the core is listed by the manufacturer, as is the weight of the 8-foot core section. This core fits into an 8-foot corrugated shell section, whose weight is also listed. For example, for segment 5, the cross-sectional area of the core is 31 inches<sup>2</sup>. It thus has a spring rate of

$$\begin{aligned}
 XKAM(4) &= AE/L \\
 &= (31.0\text{in}^2)(30000 \text{ ksi})/(8\text{ft} \times 12\text{in}/\text{ft}) = 9688 \text{ kips}/\text{inch} \text{ and a weight of } WAM(5) \\
 &= (31.0 \text{ in}^2)(8 \text{ ft} \times 12 \text{ in}/\text{ft})(0.490 \text{ kips}/\text{ft}^3)/(1728 \text{ in}^3/\text{ft}^3)
 \end{aligned}$$

$$= 0.84 \text{ kips (agrees with manufacturer)}$$

This weight is increased by 0.080 kips due to the weight of the shell. Thus,  $WAM(5) = 0.84 + 0.08 = 0.92 \text{ kips}$ .

However, because the shell is corrugated it has practically no stiffness, thus the  $XKAM(4)$  value

is not increased.

The core sections are pin-connected at each end, with a loose-fitting pin, such that there is a 1.125 inch space of 'SLACK' between each section. Thus, these sections can open up 1.125 inches before tension will be transmitted between adjacent sections. Thus, values for SLACK(3) through SLACK(6) will be input as 1.125 inches. Since the values for GAMMA(1) and (2) have been input 0.0, indicating that tension can never be transmitted through these springs, the values of SLACK(1) and (2) are meaningless, and are input as 100.0.

Coefficients of restitution for the steel pile should be set to 1.0, as the damping is negligible. Also, since each of the pile springs 3 through 6 can transmit tension, GAMMA(3) through GAMMA(6) = -1.0.

Card Input: Case XI

The same input for Case II is used except the following:

Cards 0001 and 0002 for problem identification are modified.

Card 0101: NS1 = 1, NS2 = 2, NS3 = 3, NS4 = 4, NS5 = 6, NS6 = 7 NOP(4) = 1, read RUM(1) for each element from card series 400 (long form)

NOP(7) = 1, run only until permanent set of pile is found

NOP(10) = 2, read SJ(I) from card series 1100 (long form) NOP(12) = 1, read in joint slacks from card series 1200

Card 0102:

MP = 7, AREA = 1000.0, EEM2 = 1.0

Card 0103:

WAM(3) = 1.096, WAM(4) = 1.048, WAM(5) = 0.920, WAM(6) = 0.792 WAM(7) = 0.668

Card 0301:

XKAM(2) = 11563, XKAM(3) = 10938, XKAM(4) = 9688

XKAM(5) = 8125, XKAM(6) = 6875

Card 0401: soil resistance (see Figure 7 for soil resistance distribution)

RUM(2) = 0.0, RUM(4) = 70.0, RUM(7) = 100.0, RUM(8) = 40.0

The value of RUM(4) = 70.0 because the 140 kips resistance is spread equally over 2 elements of the pile. (See Figure 7). The total resistance on the two upper elements equals 140 kips, thus RUM(3) and RUM(4) = 140.0 kips/2 = 70.0 kips each. Also, RUM(5) through RUM(7) = 300 kips/3 = 100.0 kips each since the resistance equals a total of 300 kips which is equally distributed over those 3 segments of the pile.

Card 1101:

SJ(2) = 0.0

SJ(4) = 0.05

SJ(7) = 0.20

$$SJ(8) = 0.01$$

Note that the first two soil damping values, for the ram and helmet are set to zero, although any value would do since there is no RU on them. The next two SJ values are for side friction in sand, the next 3 are for side friction in clay, and finally the point value is for point bearing damping in clay.

Card 1201:

$$SLACK(2) = 100.0$$

SLACK(6) = 1.125 The values of SLACK in the pile springs are input long form to the program when NOP(12) = 2 for each internal spring in the pile. Last spring slack is MP-1.

.....

## Case XII

Assume that the Raymond Step-Taper pile of Case XI is to be driven to full embedment with sand and clay at the side and clay at the point of the pile, using a standard Vulcan 010 steam hammer. This case is for FINAL driving of the pile in case XI, i.e., the pile is to be redriven several days after the pile was originally installed, after the soil is allowed to set up. (See Figure 7 for soil resistances and distribution).

### Hammer

The input parameters for the hammer are the same as used in Case XI.

### Capblock

The same values that were used in Case XI are used in Case XII. The values for GAMMA1 through GAMMA3 are the same as used in Case XI.

### Cushion

None used.

### Pile

The pile to be driven is the same mandrel pile, 40 feet long, as driven in Case XI.

The computed weights and spring rates for the pile were shown on Figure 32.

Coefficients of restitution for the steel pile should be set to 1.0, as the damping is negligible. Also, since each of the pile springs 3 through 6 can transmit tension, GAMMA(3) through

GAMMA(6) = -1.0, and SLACK values are the same as for Case XI.

Card Input: Case XII

The same input for Case XI is used except the following:

Cards 0001 and 0002 for problem identification.

Card 0401: RUM(2)=0.0, RUM(4)=70.0, RUM(7)=150.0, RUM(8)=40.0

Note from Figure 7, "Long-Term Capacity", that there is no soil resistance on elements 1 or 2, thus RUM(2) = 0.0. On the next two segments, there is 140 kips/2, thus RUM(4) = 70.0, etc.

.....

Case XIII

Assume that a 12-inch O.D. pipe pile with a 0.25-inch wall, 60 feet long is to be driven to 40 feet below the mudline with clay at the side and at the point of the pile, using a standard KOBE K-25 diesel hammer.

Hammer

From Appendix C, the properties of a KOBE K-25 hammer are found to be:

Hammer Energy = 50,700 ft-lb

Ram Weight (WAM(1)) = 5.51 kips

Efficiency = 100% Observed

Total Stroke of Ram (h) = 8.0 ft

Distance from the Anvil to the Exhaust Ports = 1.46 ft

Anvil Weight (WAM(2)) = 1.6 kips

Helmet Weight (WAM(3)) = 1.5 kips (assumed)

VELMI (Velocity of Ram at Impact)=

$$\text{sqrt}[(64.4)(8.0 - 1.46)(1.00)] = 20.53 \text{ ft/sec}$$

XKAM(1) = 13464 kips/inch (See Appendix C)

Cushion Not used for this case.

Capblock

From Appendix C, the properties for this capblock are found to be:

Capblock: ASBESTOS

Size = 21 inches diameter(assumed)

Thickness = 2 inches (assumed)

Modulus of Elasticity = 40 ksi

Coefficient of Restitution = 0.5

GAMMA2 = 0.0

$$\begin{aligned} \text{Spring Rate (XKAM(2))} &= \pi(21\text{in})^2(40\text{ksi})/(4 \times 2") \\ &= 6927 \text{ kips/inch Pile} \end{aligned}$$

The pile to be driven is a 12-inch O.D. pipe pile, with a 0.25-inch wall, 60 feet long.

The computed weights and spring rates for the pile segments are as follows:

$$\begin{aligned} \text{WAM(I)} &= (9.23\text{in}^2)(10\text{ft} \times 12\text{in}/\text{ft})(490\text{lb}/\text{ft}^3)/1728\text{in}^3/\text{ft}^3 \\ &= 0.314 \text{ kips} \end{aligned}$$

$$\text{WAM(4) through WAM(9)} = 0.314 \text{ kips}$$

$$\text{XKAM(I)} = (9.23\text{in}^2)(30000\text{ksi})/(10\text{ft} \times 12\text{in}/\text{ft}) = 2312 \text{ kips/inch}$$
 So XKAM(3) through

$$\text{XKAM(8)} = 2312 \text{ kips/inch}$$

Soil

The soil is assumed to act uniformly along the side of the pile only, with no point bearing beneath the pile tip.

Card Input: Case XIII

Using the values from Case XIII, the following information is input. The input for this case will be input "long form" throughout, even if not required, to demonstrate use of these options.

Cards 0001 and 0002: problem identification.

Card 0101:

1/Deltee = (Left Blank)

NSTOP = 200, IPRINT = 5, NS1 = 1, NS2 = 2, NS3 = 3, NS4 = 4, NS5 = 6, NS6 = 9,

NOP(1) = 1, standard printout

NOP(2) = 1, read WAM(I) from card series 200

NOP(3) = 1, read XKAM(I) from card series 300

NOP(4) = 1, read resistance from card series 400

NOP(5) = 2, read GAMMAs from card series 500

NOP(6) = 2, read EEM(I) from card series 600

NOP(7) = 1, run program until permanent set of pile is found

NOP(8) = 2, read VEL(I) from card series 800

NOP(9) = 2, read Q(I) from card series 900

NOP(10) = 2, read SJ(I) from card series 1000

NOP(11) = 2, read A(I) from card series 1100

NOP(12) = 1, no slack is present in any of the joints

Note that long form input is being checked out here. The short form would have obviously been okay, also.

Card 0102:

MP = 9, last pile segment

MH = 4, first pile segment

Card 0103:

MO = 6, segment of pile at the mudline

DRI = 2.5, DR2 = 3.0, DR3 = 3.5, DR4 = 4.0

DR5 = 5.0, DR6 = 6.0

Card 0201:

WAM(1) = 5.51, ram weight WAM(2) = 1.6, anvil weight, WAM(3) = 1.5, helmet weight, WAM(9) = 0.314, weight of pile segment

Card 0301:

XKAM(1) = 13464, ram spring rate, XKAM(2) = 6927, capblock spring rate, XKAM(8) = 2312, pile spring rate

Card 0401:

RUM(5) = 0.0, no resistance on ram, anvil, or helmet

RUM(9) = 30.0, resistance along the side of the pile for each pile segment 4 through 9.

RUM(10) = 0.0, no resistance under the point of the pile

Card 0501:

GAMMA1 = 238.1, explosive force of the ram

GAMMA3 = 0.0

GAMMA8 = -1.0

Card 0601:

EEM(1) = 0.5

EEM(8) = 1.0

Card 0801:

VEL(1) = 20.53, velocity of the ram at impact

VEL(9) = 0.0, velocity of remaining elements

Card 0901:

Q(10) = 0.1

Card 1001:

SJ(5) = 0.0

SJ(9) = 0.2 (side, clay, see Appendix C)

SJ(10) = 0.01 (point, clay, see Appendix C)

Card 1101: A(1) = 1000.0 (convert force in lbs to kips), A(8) = 9.25, area of each pile segment

.....

#### Case XIV

Assume that a pipe pile 60 feet long is to be driven to 40 feet below the mudline with rock at the point of the pile (all point bearing), using a standard Delmag D-44 diesel hammer.

#### Hammer

From Appendix C, the properties of a Delmag D-44 hammer are found to be:

Ram Weight (WAM(1)) = 9.5 kips

Efficiency = 100%

Observed Total Stroke of Ram = 8.0 ft

Distance from the Anvil to the Exhaust Ports (c)= 1.19 ft

Anvil Weight (WAM(2)) = 2.42 kips

Helmet Weight (WAM(3)) = 1.6 kips (assumed)

VELMI (Velocity of the Ram at Impact)

$$= \sqrt{(64.4)(8 - 1.19)(1.0)} = 20.94 \text{ ft/sec}$$

XKAM(1) = 10,600 kips/inch (Spring rate of hammer)

Capblock

The same values that were used in Case XIII are used in Case XIV.

Cushion

Not used for this case.

Pile

The same values that were used in Case XIII are used in Case XIV.

Soil

The soil is assumed to act at the point of the pile only, with no resistance at the side.

Card Input: Case XIV

The same input for Case XIII is used except the following:

Cards 0001 and 0002 are modified.

Card 0101:

NOP(7) = 2, run problem full NSTOP iterations

Card 0103:

DR1 = 2.0, DR2 = 3.0, DR3 = 4.0, DR4 = 5.0, DR5 = 6.0,

DR6 = 7.0, DR7 = 8.0

Card 0201:

WAM(1) = 9.5

WAM(2) = 2.42

WAM(3) = 1.6

Card 0301:

XKAM(1) = 10,600

Card 0401:

RUM(9) = 0.0, no resistance on the side of the pile

RUM(10) = 100.0, all point bearing pile

Card 0501: GAMMA1 = 200, explosive force of the ram

Card 0801: VEL(1) = 20.94, velocity of the ram at impact

Card 1001:

SJ(9) = 0.0, no soil on side of pile

SJ(10) = .15, rock at the point of the pile

.....

Case XV

Assume that a 10"x10" prestressed concrete pile 60 feet long is to be driven to a penetration of 30

feet below the mudline with clay at the side and at the point of the pile, using a standard Vulcan 30c hammer.

### Hammer

From Appendix C, the properties of a Vulcan 30c hammer are found to be: Hammer Stroke = 2.42 ft Ram Weight

(WAM(1)) = 3.0 kips

Efficiency = 66% Helmet Weight

(WAM(2)) = 1.0 kips (assumed)

Note that helmet weights and cushion dimensions are not listed in Appendix C, since they vary from job to job, and with each contractor.

The ram velocity at impact (VELMI) is computed by:

$$\text{VELMI} = \text{sqrt}[(64.4)(2.42)(0.66)] = 10.14 \text{ ft/sec}$$

### Capblock and Cushion

From Appendix C, the properties for the capblock and cushion are found to be the same as used in Case I. The dimensions are also assumed to be the same. Thus, the spring rate and all other input parameters for this case are the same as in Case I.

### Pile

The pile to be driven is a 10"x10" prestressed concrete pile, 60 feet long. Given information is as follows:

Area = 100 in<sup>2</sup>

Length = 60 feet

Modulus of Elasticity = 3000 kips/in

The pile segment weights are computed from:

WAM(I) = AL(density) =

WAM(3) = (100in<sup>2</sup>)(10ftx12in/ft)(0.150kips/ft<sup>3</sup>)/1728in<sup>3</sup>/ft<sup>3</sup> WAM(3) = 1.04 kips Thus,

WAM(3) through WAM(8) = 1.04 kips

To compute the spring rate of the 10-foot pile segments:

XKAM(3) through XKAM(7) = AE/L

= (10"x10")(3000ksi)/(10ftx12in/ft) = 2500 kips/inch

Coefficients of restitution for the concrete pile should be set to 1.0, as the damping is negligible. Also, since each of the pile springs 3 through 7 can transmit tension,  $GAMMA(3)$  through  $GAMMA(7) = -1.0$ .

Soil

Identical to Case I.

Card Input: Case XV

The same input for Case I is used except for the following: 0001 and 0002 cards for problem identification are changed. Card 0101:  $NS4 = 7$ ,  $NS5 = 10$ ,  $NS6 = 13$

$NOP(7) = 1$  Card 0102:

$VELMI = 10.14$

$AREA = 100$

Card 0103:

$RUP = 0.0$ , no resistance beneath the point of the pile

$DR1 = 2.0$ ,  $DR2 = 2.5$ ,  $DR3 = 3.0$ ,  $DR4 = 3.25$

Card 0201:

$WAM(1) = 3.0$ , ram weight

$WAM(8) = 1.04$ , pile segment weight

Card 0301:

$XKAM(7) = 2500$

.....

Case XVI

Assume that a 12"x12" prestressed concrete pile 60 feet long is to be driven to a penetration of 30 feet below the mudline, clay at the side and at the point of the pile, using a standard Link Belt 312 open-end diesel hammer. Case XVI is the same as Case III except for the hammer utilized to drive the pile.

Hammer

From Appendix C, the properties of a Link Belt 312 hammer, which is an open-end diesel hammer, are found to be:

Ram Weight ( $WAM(1)$ ) = 3.855 kips

Maximum Stroke ( $h$ ) = 3.87 ft

Distance from Anvil to Exhaust Ports ( $c$ ) = 0.5 ft

Efficiency = 100% Anvil Weight

( $WAM(2)$ ) = 1.188 kips

Helmet Weight ( $WAM(3)$ ) = 1.381 kips (assumed)

The ram velocity at impact (VELMI) is computed by:

$$\text{VELMI} = \text{sqrt}[2g(h - c)*\text{efficiency}]$$
$$\text{VELMI} = \text{sqrt}[(64.4)(3.87 - 0.5)(1.00)] = 14.73 \text{ ft/sec}$$

The spring rate for the ram:

The value for XKAM(1), the spring rate for the ram, can be found in Appendix C, in Table C2.  
XKAM(1) = 14,250 kips/inch

The assumed coefficient of restitution between the ram and the anvil will be 0.9. EEM1 = 0.9

### Capblock and Cushion

From Appendix C, the properties for the capblock and cushion are found to be the same as those used in Case III. The dimensions are also assumed to be the same. Thus, the spring rate and all other input parameters are the same as in Case III.

### Pile

The pile used in this case is the same pile driven in Case III.

### Soil

Identical to Case III.

### Card Input: Case XVI

0001 and 0002 for problem identification are changed.

Card 0101:

NOP(7) = 1

Card 0102:

VELMI = 14.73, GAMMA1 = 98.0

Card 0103: RUT = 100, total resistance

RUP = 5, resistance beneath the point of the pile

DR2 = 2.5, DR3 = 3.0, DR4 = 3.25

Card 0201:

WAM(1) = 3.855, ram weight

WAM(2) = 1.188, anvil weight

WAM(3) = 1.381, helmet weight

Card 0301:

XKAM(1) = 14,250, spring rate of the ram

.....

## Case XVII

Assume that an HP8x36 steel pile 100 feet long is to be driven to a penetration of 80 feet below the mudline with sand at the side and at the point of the pile, using a standard MKT DE-30 open-end diesel hammer.

### Hammer

From Appendix C, the properties of a MKT DE-30 hammer are found to be

Ram Weight (WAM(1)) = 2.8 kips

Observed Total Stroke of Ram = 8 ft (observed in field)

Distance from Anvil to Exhaust Ports (c) = 1.04 ft

Efficiency = 100%

Anvil Weight (WAM(2)) = 0.774

Helmet Weight (WAM(3)) = 1.0 kips (assumed)

Note that the helmet weights and cushion dimensions are not listed in Appendix C, since they vary from job to job and with each contractor. They must be individually determined.

The ram velocity at impact (VELMI) is computed by:

$$\text{VELMI} = \sqrt{2g(h - c)\text{efficiency}}$$

$$\text{VELMI} = \sqrt{(64.4)(8.0 - 1.04) (1.00)}$$

$$\text{VELMI} = 21.17 \text{ ft/sec}$$

Cushion

From Appendix C:

Cushion: OAK

Size (assumed) = 12"x12"

Thickness (assumed) = 6.0"

Modulus of Elasticity (E) = 45 kips/in<sup>2</sup>

Coefficient of Restitution (EEM2) = 0.5

GAMMA2 = 0.0

Spring rate for cushion XKAM(2)

$$= (12" \times 12")(45 \text{ ksi})/6" = 1080 \text{ kips/inch}$$

Capblock: Not used.

### Pile

The pile to be driven is an HP8x36 steel pile, 100 feet long. Given information is as follows:

Area = 10.6 in<sup>2</sup>  
Length = 100 feet  
Modulus of Elasticity = 30000 kips/in<sup>2</sup>

The pile segment lengths are 10-foot each, for 10 elements.

The segment weights are computed by:

WAM(I) = AL(gamma) =  
WAM(4) = (10.6 in<sup>2</sup>)(10ftx12in/ft)(490kips/ft<sup>3</sup>)1728in/ft  
= 0.36 kips Thus, WAM(4) through WAM(13) = 0.36 kips

To compute the spring rates of the 10-foot pile segments:

XKAM(3) through XKAM(12) = AE/L  
= (10.6in<sup>2</sup>)(30000 ksi)/(10 ft x 12 in/ft) = 2650 kips/inch.

Soil

The soil properties, as determined from soil borings and tests are assumed as follows:

Soil Type: Sand

Soil Resistance: 90% distributed uniformly along side of pile in friction, 10% point bearing  
Set up of soil = 1.0

Card Input: Case XVII

Using the values from Case XVII, the following cards are necessary to run the program.

Cards 0001 and 0002:

Problem identification cards

Card 0101:

NSTOP = 200, IPRINT = 5, NS1 = 1, NS2 = 2, NS3 = 3, NS4 = 7  
NS5 = 10, NS6 = 13, NOP(1) = 1, NOP(2) = 1, NOP(3) = 1  
NOP(4) = 3, NOP(5) = 1, NOP(6) = 1, NOP(7) = 1  
NOP(8) = 1, NOP(9) = 1, NOP(10) = 1, NOP(11) = 1, NOP(12) = 1

Card 0102:

MP = 13, last pile segment

MH = 4, first pile segment  
 VELMI = 21.17, initial velocity of the ram at impact  
 AREA = 10.6, area of pile  
 EEMI = 0.9  
 EEM2 = 0.5  
 EEM3 = 1.0  
 GAMMA1 = 98.0, explosive force of ram  
 GAMMA2 = 0.0  
 GAMMA3 = 0.0  
 Card 0103:  
 RUT = 100, total soil resistance  
 RUP = 10, resistance beneath the point of the pile  
 MO = 6, first segment of pile beneath the mudline  
 QSIDE = 0.1  
 QPOINT = 0.1  
 SIDEJ = 0.05, sand damping at the side of the pile  
 POINTJ = 0.15, sand damping beneath the point of the pile  
 DR1 = 2.0  
 DR2 = 2.5  
 DR3 = 3.0  
 Card 0201:  
 WAM(1) = 2.8, ram weight  
 WAM(2) = 0.774, anvil weight  
 WAM(3) = 1.0, helmet weight  
 WAM(13) = 0.36, pile segment weights for 4 through 13  
 Card 0301  
 XKAM(1) = 3870, spring rate of ram  
 XKAM(2) = 1080, spring rate of cushion  
 XKAM(12) = 2650, spring rate of pile segments 4 through 12 - entered as XKAM(12) because the last spring for the pile is placed above the last pile segment.

## APPENDIX F - LIST OF SELECTED REFERENCES

### SELECTED REFERENCES

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APPENDIX G - MICROWAVE/EDITWAVE

USER'S MANUAL FOR  
BUILDING AND CHECKING  
WAVE EQUATION ANALYSIS DATA  
and  
RUNNING THE WAVE EQUATION

For technical assistance, contact:  
Dr. Lee L. Lowery, Jr., P.E.  
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College Station, Texas 77843-3136  
409-845-4395  
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## Introduction - MICROWAVE

MICROWAVE consists of two main programs:

1) EDITWAVE - used to build new data sets or to modify old data sets, and for general file handling necessary in building data sets for use in the wave equation. Examples include displaying files on disk, deleting old files no longer needed to make room for new files, renaming data files with more current or more applicable names, copying a file to provide a second or backup copy under a new name, merging two or more data sets to be run at the same time, and to print resulting answers from the wave equation on paper.

2) MW88 or MW87 - The program MICROWAVE has the name MW88 or MW87 on the disk, and is used to study pile driving by the wave equation. This program is the actual wave equation solution used to run data generated by EDITWAVE. If your computer has a high-speed math co-processor you should run MW87, as it uses the high speed math coprocessor, and will run much more quickly. If a co-processor is not installed, you must run MW88.

NOTE - 1994: These programs were originally written to accommodate numerous kinds of computers, and as such the instructions may well ask you to do some goofy things, like "hit control C to boot in your drives". Please just ignore such things if you have a IBM or compatible which doesn't require such nonsense, but follow those instructions to the letter if you have an Osborne, or CPM type computer. Also, since some computers require the entry of data in upper case only, EDITWAVE and MICROWAVE REQUIRE that you turn on the caps lock key. They won't take data any other way. Furthermore, much of the information below assumes that you do not have a hard drive - probably a poor assumption in 1994. If you do have a hard drive, simply copy everything to a subdirectory of your choice, and run everything from there.

### Program Operation

#### EDITWAVE

To build data sets, put the program disk marked EDITWAVE in drive A:, and a blank formatted disk in Drive B:, for use as your data disk. On some micros it is necessary to hit Control C to "boot" in the drives so that the data disk can be written. The program disk, new in drive A:, can now be used to generate data which will be written to the data disk in Drive B:. For hard disk operation, simply copy all program files on both distribution disks to a subdirectory on your computer, and run everything from there.

To invoke the program, put the caps lock key on and type: EDITWAVE. The computer will read the program from the disk and will display a "MAIN MENU" similar to the following:

```
<<< M A I N  M E N U >>>
l> DISPLAY FILES ON DISK
```

- 2> DELETE A FILE FROM DISK
- 3> RENAME A FILE ON DISK
- 4> COPY A FILE
- 5> LOAD A FILE FROM DISK
- 6> EDIT PRESENT FILE
- 7> CHECK PRESENT FILE
- 8> SAVE PRESENT FILE
- 9> BUILD A NEW FILE
- 10> MERGE TWO OR MORE DATA FILES
- 11> PRINT A FILE ON THE LINE PRINTER
- 12> EXIT TO SYSTEM

Note that throughout this users guide, the actual text shown for your computer may vary from that listed above. This is due to changes made necessary by the number of lines and columns available on each computer. For example, on the apple using 40 column screens, the above text has had to be severely shortened to permit the text to fit on the screen.

Option 1) DISPLAY FILES ON DISK - To see what files are already on the disk, respond to the question WHICH DRIVE? It is, normally best to put only one set of data on a blank disk, thereby leaving a maximum of room for the wave equation to put answers on the same disk. We normally label the disk with the client's name and job ID, and after running the wave equation, file the disk with the other job information for future reference. If you have several other files on the disk, be sure that you have enough room for answers to be written on the disk - use STAT or CHKDSK or whatever your computer uses to determine how much room is left on the disk.

Option 2) DELETE A FILE FROM DISK - To delete an unwanted file from the disk, simply answer the prompts as they appear. Be sure to copy any good files onto another disk before deleting them from the present disk or they Will be lost.

Option 3) RENAME A FILE ON DISK - This option is used to rename an existing file on the disk to some new name.

Option 4) COPY A FILE - This option is used to make a backup copy of an existing file either using a new name on the disk, or putting a copy of the file on another disk.

Option 5) LOAD A FILE FROM DISK - If you have previously built a data set on the disk and wish to either check or modify the data, use this option. You will be asked which drive the data set is on, and then what name the data set has. For example, if the data set has the name JUNK.DAT, you should respond only with the name JUNK since the program asks for the three letter extension separately. Thus you would respond with JUNK and hit return, then respond with DAT and hit return when asked for the extension. If you change your mind after getting into Option 5, and do not wish to load a file after all, simply hit RETURN instead of giving the file name.

Option 6) EDIT PRESENT FILE - If you wish to make changes to an existing data file, use Option 6. Note that you MUST have previously built the data file you intend to edit, and that you MUST have loaded it into memory before it can be edited. Thus, you must have used Option 9 (discussion follows) to first build the data file and save it on disk, then use Option 5 to load that data file from the disk back into memory where you can then use Option 6 to edit it.

Thus the general procedure is as follows:

- a) Use Option 9 to build the data set and load it on disk. If the data set is ready to run, run it using MICROWAVE.
- b) Should any changes in the original data set be desired, use Option 5 to load the data set from disk back into memory.
- c) Use Option 6 to make any desired changes in the data set. Note that once the data set is loaded into memory and modified, it need not be saved under the same name unless you so desire. You may bring in the data set with the name JUNK.DAT and modify it into a new data set without losing the old data set JUNK.DAT. Simply give it a new name when you save the data set.

Option 7) CHECK PRESENT FILE - Option 7 is used to check a data set which has been loaded from disk and modified. Note that Option 7 is not needed the first time a data set is constructed and saved on disk. In this case, the data set is automatically checked and saved. Option 7 is useful when you have previously built a data set and wish to modify it into a different although similar set of data. Also, if you make a mistake when building the original data set, but cannot get back to correct the mistake, do not abandon it and start over. Simply finish and save the data set, then load it again using Option 5, then correct your mistake using Option 6, then check it using Option 7, and finally, save it using Option 8.

Option 8) SAVE PRESENT FILE - Option 8 is used to save any files which have been loaded from disk and modified. It is not used when the data file is initially built, since those files are automatically checked and saved.

Option 9) BUILD A NEW DATA FILE - Option 9 is the first option used, when running the wave equation. It is the basic means by which data files are built. The other options will probably be used more often, since many data files are simply modifications of previous runs. However, a truly brand new data set must be built using Option 9.

Option 10) MERGE TWO OR MORE DATA FILES - Option 10 is used to combine two or more data sets to be run at the same time. Note that when you run several data sets at once, you obviously need more space on the data disk to store the answers. Thus you need to be more careful as to how much blank space there is on the data disk for answers. A second consideration is that the data editor (Option 6) and the data checker (Option 7) can only be used on a single set of data. Thus if you wish to merge three or four data sets together to all be run at once, you can do so, but you cannot then modify the data sets, nor can you check them. This is really not much

of a restriction, since the data sets must have been checked before you could save them originally. However, to prevent merged data sets from accidentally being loaded and then erroneously edited or checked, they are forcibly given the three letter extension MRG. Thus, if you say you want to get three separate files, and merge them under a new name called STUFF, the file will actually end up with the name STUFF.MRG and you must use this name whenever you want to run the data in MICROWAVE.

Option 11) PRINT A FILE - If you wish to see the final input data set you have generated, as required for input to the wave equation, you can use Option 11. Note that the format will appear similar (though not identical) to sample problem data sets appearing in the user's manual. The most obvious changes will be the addition of card numbers at the end of each card, as required by MICROWAVE. These card numbers are generated by EDITWAVE - you need not enter them. Also, some widening of the data fields was done to improve the capabilities of the program.

Option 12) EXIT TO SYSTEM - When you are through either generating, loading, modifying, or merging data files and are ready to run them, you then exit back to the operating system, out of the EDITWAVE program, and run the MICROWAVE program. Be sure to save your data before exiting to the system or you will lose it.

## MICROWAVE

To run data sets previously generated by EDITWAVE, put the program disk marked MICROWAVE in Drive A:, and the data disk in Drive B:. On some computers it will be necessary to hit Control C to boot in the drives. On computers with a hard disk, you can simply copy everything off of the distribution disks onto the hard disk and run your problems from there.

Once the disks have been loaded and "booted in", type either MW88 (if your computer has no high-speed math co-processor) or MW87 (if you have a co-processor.) If you do not know if your computer has a math co-processor, try running MW87 first, and if it runs, you have one and the runs will go much faster. If you get an error stating something like "no co-processor found", then use MW88 as your program.

After you invoke the program with either MW88 or MW87, you will be asked to give the name of the data set to be run. Give a complete description of the data set name, including the path, if necessary. Be sure to use the three letter extension MRG if the data to be run is a merged data set. You will also be asked if you wish to save all of the answers in a single answer file, including both the stress results and the blow count summary, as well as the force-time results, or if you wish to split the stress/blow count summaries and force-time results into two files.

To further explain this option, look at one of the sample problem output tables. Note that the output consists of a summary of the input data, then a summary of the force-time values which occurred during the hammer blow, then a summary of the maximum tensile and compressive

forces (or stresses) and the blow count observed under one hammer blow. Although the force-time values are often of interest, they are not usually desired in a final report, and must often be cut out, or the stress/blow count summary must be retyped into the final report. By allowing the user to put the force-time results in one file for inspection, while putting the report summary values in a second file, this problem is overcome.

Assume for example that you are going to run a data set named JUNK.MRG. If you decide to place both the force-time answers and the summary answers in a single file, the answers will be placed in a file named JUNK.ANS which stands for ANSWERS. However, if you run this same data set and request that the answers be placed in separate files, your summary answers will be placed on the disk under the name JUNK.ANS and the force-time answers will be placed on the disk under the name JUNK.LNG, where LNG is an abbreviation for LONG. In any case, you can get a printout of either of the files using EDITWAVE, Option 12.

If you would like to preview the answers on the screen, you may use any normal word processor, or you may use your computer's version of "TYPE". For example, assuming that you are currently on drive A (the default drive is A), and your answers are on drive B. To view the summary file, type: TYPE B:JUNK.ANS |MORE To view the long file (force vs. time summary) you would type: TYPE B:JUNK.LNG |MORE

### Sample Computer Session

The following cases present an typical session with the computer. The program disk EDITWAVE was in Drive A:, and a blank formatted disk was in Drive B:. The disks had been booted in using Control C, and the prompt A> was shown on the screen. The items which should be typed in by the user have been enclosed by the symbols [ ] <--- to distinguish them from the text generated by the computer. In each case the ENTER key was pressed after the given keystrokes were made. Do not type the [ ] <--- symbols, only what is inside plus the ENTER key. In the case where only the ENTER key is pressed (i.e. no data is to be input), the symbol [CR for carriage return is shown. Note that all of the options on the main menu were utilized, but only to show how they work. {Notes in braces are comments and discussion about the data being entered.}

A> [EDITWAVE] <--- {This means type EDITWAVE and the ENTER key}

Editwave/Readwave 9.12 23-May-94  
Copyright (c) 1994 Pile Dynamics, Inc.

```
<<< M A I N   M E N U >>>
1> DISPLAY FILES ON DISK
2> DELETE A FILE FROM DISK
3> RENAME A FILE ON DISK
4> COPY A FILE
5> LOAD A FILE FROM DISK
```

- 6> EDIT PRESENT FILE
- 7> CHECK PRESENT FILE
- 8> SAVE PRESENT FILE
- 9> BUILD A NEW FILE
- 10> MERGE TWO OR MORE DATA FILES
- 11> PRINT A FILE ON THE LINE PRINTER
- 12> EXIT TO SYSTEM

ENTER YOUR SELECTION [1] <---

WHICH DRIVE? [A] <---

Directory of Disk A:

JUMPFIL CHKWAVE.COM LOADWAVE.COM  
WRITWAVE.COM PRNTWAVE.COM UTILWAVE.COM  
INSTWAVE.COM TINYWAVE.COM CASEXII  
EDITWAVE.COM MERGWAVE.COM CASEIII  
READWAVE.COM CASEVII CASEVIII  
CASEXIII CASEXIV CASEXVI  
CASEXVII BRUN.COM MAINPARM.DAT  
EDWAV100.OVR EWMAINMU.OVR EDWAVMNU.OVR  
EDWAV200.OVR

HIT RETURN TO GO BACK TO MAIN MENU [CR] <---

<<< M A I N M E N U >>>

- 1> DISPLAY FILES ON DISK
- 2> DELETE A FILE FROM DISK
- 3> RENAME A FILE ON DISK
- 4> COPY A FILE
- S> LOAD A FILE FROM DISK
- 6> EDIT PRESENT FILE
- 7> CHECK PRESENT FILE
- 8> SAVE PRESENT FILE
- 9> BUILD A NEW FILE
- 10> MERGE TWO OR MORE DATA FILES
- 11> PRINT A FILE ON THE LINE PRINTER
- 12> EXIT TO SYSTEM

ENTER YOUR SELECTION [4] <---

DRIVE TO COPY FROM? (A or B) [A] <---

Directory of Disk A:

JUMPFIL CHEKWAVE.COM LOADWAVE.COM  
WRITWAVE.COM PRNTWAVE.COM UTILWAVE.COM  
INSTWAVE.COM TINYWAVE.COM CASEXII  
EDITWAVE.COM MERGWAVE.COM CASEIII  
READWAVE.COM CASEVII CASEVIII  
CASEXIII CASEXIV CASEXVI  
CASEXVII BRUN.COM MAINPARM.DAT  
EDWAV100.OVR EWMAINMU.OVR EDWAVMNU.OVR  
EDWAV200.OVR

NAME OF FILE TO COPY FROM? (1 to 8 characters)

OR HIT RETURN TO GO BACK TO MAIN MENU [CASEXII] <---

3 LETTER ATTRIBUTE? (If necessary) [CR] <---

COPYING FROM FILE A:CASEXII.

DRIVE TO COPY TO? (A or B) [A] <---

Directory of Disk A:

JUMPFIL CHEKWAVE.COM LOADWAVE.COM  
WRITWAVE.COM PRNTWAVE.COM UTILWAVE.COM  
INSTWAVE.COM TINYWAVE.COM CASEXII  
EDITWAVE.COM MERGWAVE.COM CASEIII  
READWAVE.COM CASEVII CASEVIII  
CASEXIII CASEXIV CASEXVI  
CASEXVII BRUN.COM MAINPARM.DAT  
EDWAV100.OVR EWMAINMU.OVR EDWAVMNU.OVR  
EDWAV200.OVR

NAME OF FILE TO COPY TO? (1 to 8 characters)

OR HIT RETURN TO GO BACK TO MAIN MENU [JUMPFIL] <---

3 LETTER EXTENSION? (If desired) [CR] <---

\*\*\*\* FILE A:JUMPFIL. ALREADY EXISTS...

REPLACE?? (Y/N) [Y] <---

PLEASE WAIT

COPYING FILE A:CASEXII. TO FILE A:JUMPFIL.E.

COPY OF FILE A:CASEXII. TO FILE A:JUMPFIL.E. IS COMPLETE

DO YOU WANT TO COPY ANOTHER FILE? (Y/N) [N] <---

<<< M A I N M E N U >>>

- 1> DISPLAY FILES ON DISK
- 2> DELETE A FILE FROM DISK
- 3> RENAME A FILE ON DISK
- 4> COPY A FILE
- 5> LOAD A FILE FROM DISK
- 6> EDIT PRESENT FILE
- 7> CHECK PRESENT FILE
- 8> SAVE PRESENT FILE
- 9> BUILD A NEW FILE
- 18> MERGE TWO OR MORE DATA FILES
- 11> PRINT A FILE ON THE LINE PRINTER
- 12> EXIT TO SYSTEM

ENTER YOUR SELECTION [3] <---

WHICH DRIVE IS THE FILE ON? (A or B) [A] <---

Directory of Disk A:

JUMPFIL.E CHEKWAVE.COM LOADWAVE.COM  
WRITWAVE.COM PRNTWAVE.COM UTILWAVE.COM  
INSTWAVE.COM TINYWAVE.COM CASEXII  
EDITWAVE.COM MERGWAVE.COM CASEIII  
READWAVE.COM CASEVII CASEVIII  
CASEXIII CASEXIV CASEXVI  
CASEXVII BRUN .COM MAINPARM.DAT  
EDWAV100.OVR EWMAINMU.OVR EDWAVMNU.OVR  
EDWAV200.OVR

ENTER OLD FILENAME (1 to 8 characters)  
OR HIT RETURN TO GO BACK TO MAIN MENU [JUMPFIL.E] <---

3 LETTER EXTENSION (If necessary) [CR] <---

OLD NAME = A:JUMPFIL.E.  
ENTER NEW FILENAME (1 to 8 characters)  
OR HIT RETURN TO GO TO MAIN MENU [JUNKFILE] <---

ENTER 3 LETTER EXTENSION (If necessary) [DAT] <---

RENAMING FILE A:JUMPFIL.E. AS A:JUNKFILE.DAT

FILE A:JUMPFIL.E. HAS BEEN RENAMED AS A:JUNKFILE.DAT

DO YOU WANT TO RENAME MORE FILES ? (Y/N) [N] <---

<<< M A I N M E N U >>>

- 1> DISPLAY FILES ON DISK
- 2> DELETE A FILE FROM DISK
- 3> RENAME A FILE ON DISK
- 4> COPY A FILE
- S> LOAD A FILE FROM DISK
- 6> EDIT PRESENT FILE
- 7> CHECK PRESENT FILE
- 8> SAVE PRESENT FILE
- 9> BUILD A NEW FILE
- 18> MERGE TWO OR MORE DATA FILES
- 11> PRINT A FILE ON THE LINE PRINTER
- 12> EXIT TO SYSTEM

ENTER YOUR SELECTION [2] <---

WHICH DRIVE IS THE FILE ON? (A or B) [A] <---

Directory of Disk A:

JUNKFILE CHEKWAVE.COM LOADWAVE.COM  
WRITWAVE.COM PRNTWAVE.COM UTILWAVE.COM  
INSTWAVE.COM TINYWAVE.COM CASEXII  
EDITWAVE.COM MERGWAVE.COM CASEIII  
READWAVE.COM CASEVII CASEVIII  
CASEXIII CASEXIV CASEXVI  
CASEXVII BRUN .COM MAINPARM.DAT  
EDWAV100.OVR EWMAINMU.OVR EDWAVMNU.OVR  
EDWAV200.OVR

ENTER NAME OF FILE TO DELETE (1 to 8 characters)  
OR HIT RETURN TO GO TO MAIN MENU [JUNKDAT] <---

3 LETTER EXTENSION (If necessary)

\*\*\*\* FILE A:JUNKDAT. DOES NOT EXIST...  
HIT RETURN [CR] <---  
{WHOOOPS - MISSPELLED IT}

WHICH DRIVE IS THE FILE ON? (A or B) [A] <---

Directory of Disk A:

JUNKFILE CHEKWAVE.COM LOADWAVE.COM  
WRITWAVE.COM PRNTWAVE.COM UTILWAVE.COM  
INSTWAVE.COM TINYWAVE.COM CASEXII  
EDITWAVE.COM MERGWAVE.COM CASEIII  
READWAVE.COM CASEVII CASEVIII  
CASEXIII CASEXIV CASEXVI  
CASEXVII BRUN .COM MAINPARM.DAT  
EDWAV100.OVR EWMAINMU.OVR EDWAVMNU.OVR  
EDWAV200.OVR

ENTER NAME OF FILE TO DELETE (1 to 8 characters)  
OR HIT RETURN TO GO TO MAIN MENU [JUNKFILE] <---

3 LETTER EXTENSION (If necessary) [DAT] <---

THIS IS IT. I'M ABOUT TO DELETE FILE A:JUNKFILE.DAT  
AND IT WILL BE GONE FOR GOOD.....  
SHALL I PROCEED WITH THE DELETION?? (Y/N) [Y] <---

DELETING FILE A:JUNKFILE.DAT

FILE A:JUNKFILE.DAT HAS BEEN DELETED

DO YOU WANT TO DELETE MORE FILES? (Y/N) [N] <---

<<< M A I N M E N U >>>

- 1> DISPLAY FILES ON DISK
- 2> DELETE A FILE FROM DISK
- 3> RENAME A FILE ON DISK

- 4> COPY A FILE
- 5> LOAD A FILE FROM DISK
- 6> EDIT PRESENT FILE
- 7> CHECK PRESENT FILE
- 8> SAVE PRESENT FILE
- 9> BUILD A NEW FILE
- 10> MERGE TWO OR MORE DATA FILES
- 11> PRINT A FILE ON THE LINE PRINTER
- 12> EXIT TO SYSTEM

ENTER YOUR SELECTION [9] <---

WRITE DATA TO WHICH DISK (A or B) [A] <---

Directory of Disk A:

CHEKWAVE.COM LOADWAVE.COM WRITWAVE.COM  
 PRNTWAVE.COM UTILWAVE.COM INSTWAVE.COM  
 TINYWAVE.COM CASEXII EDITWAVE.COM  
 MERGWAVE.COM CASEIII READWAVE.COM  
 CASEVII CASEVIII CASEXIII  
 CASEXIV CASEXVI CASEXVII  
 BRUN .COM MAINPARM.DAT EDWAV100.OVR  
 EWMAINMU.OVR EDWAVMNU.OVR EDWAV200.OVR

ENTER NAME OF DATASET (1 to 8 characters)  
 OR HIT RETURN TO GO BACK TO MAIN MENU [CASEI] <---

3 LETTER ATTRIBUTE (IF DESIRED): ? [CR] <---

INPUT FOR CARD SERIES 001 \*\*\*\*\*

INPUT NUMBER OF COMMENT CARDS (8 MAX):? [2] <---

INPUT LINE OF COMMENTS

? VULCAN-08 DRIVING 12X12 INCH PRESTRESSED CONC PILE, 60 FT LONG

INPUT LINE OF COMMENTS

? CASEI USING A 1 INCH OAK CAPBLOCK AND CUSHION {SEE CASEI EXAMPLE}

INPUT DATA FOR CARD 101 \*\*\*\*\*

INPUT 1/DELTEE (1/SECONDS):  
HIT RETURN IF YOU WOULD LIKE  
PROGRAM TO COMPUTE VALUE: ? [CR] <---

INPUT MAXIMUM NUMBER OF ITERATIONS  
YOU WISH PROGRAM TO RUN: ? [200] <---

PROGRAM WILL PRINT FORCES (OR STRESSES)  
AND DISPLACEMENTS AFTER EVERY 'IPRINT'  
ITERATION. PLEASE ENTER IPRINT: ? [5] <---

PROGRAM WILL PRINT INTERMEDIATE ANSWERS  
FOR 6 ELEMENTS OF YOUR CHOICE. PLEASE  
INPUT 6 ELEMENTS ALONG THE PILE

FIRST ELEMENT: ? [1] <---  
SECOND ELEMENT: ? [2] <---  
THIRD ELEMENT: ? [3] <---  
FOURTH ELEMENT: ? [5] <---  
FIFTH ELEMENT: ? [7] <---  
SIXTH ELEMENT: ? [8] <---

THE FOLLOWING IS OPTION INPUT. FOR MORE  
DETAILED INFORMATION, SEE USERS MANUAL

OPTION BRIEF POSSIBLE  
NUMBER DESCRIPTION VALUES INPUT?

1	PRINT	1-3	[1] <---
2	WEIGHTS	1	1
3	SPRINGS	1	1
4	SOIL R'S	1-4	[3] <---
5	GAMMAS	1-2	[1] <---
6	EEMS	1-2	[1] <---
7	RUN FULL NSTOP?	1-2	[2] <---
8	VELOCITIES	1-2	[1] <---
9	SOIL QS	1-2	[1] <---
10	SOIL JS	1-2	[1] <---
11	AREAS	1-2	[1] <---
12	SLACKS	1-2	[1] <---

INPUT FOR CARD 102 \*\*\*\*\*

INPUT TOTAL NUMBER OF MASSES IN SYSTEM: ? [8] <---

INPUT MASS NUMBER OF FIRST PILE ELEMENT: ? [3] <---

INPUT INITIAL RAM VELOCITY FT/SEC): ? [11.75] <---

INPUT AREA TO BE USED IN COMPUTING STRESSES (SQ IN):

INPUT 1000 TO CHANGE FROM POUNDS TO KIPS: ? [144] <---

INPUT FIRST THREE COEFFICIENTS OF RESTITUTION:

INPUT EEM(1): ? [.5] <---

INPUT EEM(2): ? [.5] <---

INPUT EEM(3): ? [1] <---

INPUT FIRST THREE GAMMA(I) VALUES KIPS):

INPUT GAMMA(1): ? [0] <---

INPUT GAMMA(2): ? [0] <---

INPUT GAMMA(3): ? [-1] <---

INPUT FOR CARD 103 \*\*\*\*\*

INPUT TOTAL SOIL RESISTANCE ON PILE (KIPS): ? [50] <---

INPUT SOIL RESISTANCE UNDER TIP OF PILE (KIPS): ? [2.5] <---

INPUT FIRST MASS NUMBER EMBEDDED IN SOIL: ? [6] <---

INPUT QSIDE FOR SOIL ON SIDE OF PILE (INCHES): ? [.1] <---

INPUT QPOINT FOR SOIL AT PILE POINT (INCHES): ? [.1] <---

INPUT SOIL DAMPING FOR SIDE OF PILE (SEC/FT): ? [.2] <---

INPUT SOIL DAMPING FOR POINT OF PILE (SEC/FT): ? [.01] <---

TO RUN UP TO 9 MULTIPLES OF THE ABOVE  
SOIL RESISTANCE VALUES, ENTER THE FOLLOWING  
DELTA R VALUES. ENTER VALUES FROM 0 TO  
9.99 ONLY:

INPUT DELR( 1 ): ? [2] <---

INPUT DELR( 2 ): ? [3] <---

INPUT DELR( 3 ): ? [4] <---  
INPUT DELR( 4 ): ? [6] <---  
INPUT DELR( 5 ): ? [8] <---  
INPUT DELR( 6 ): ? [10] <---

\*\* DELR VALUE OVER 9.99, RE-INPUT VALUE

INPUT DELR( 6 ): ? [9] <---  
INPUT DELR( 7 ): ? [CR] <---  
INPUT DELR( 8 ): ? [CR] <---  
INPUT DELR( 9 ): ? [CR] <---

INPUT DATA FOR ELEMENT WEIGHT (KIPS) \*\*\*\*\*

INPUT ELEMENT NUMBER, THEN CORRESPONDING  
WEIGHT (KIPS), IN PAIRS, UNTIL ALL  
DATA HAS BEEN ENTERED. LAST ELEMENT  
NUMBER MUST BE = 8 FOR THIS SERIES.

ELEMENT NUMBER: ? [1] <---  
WEIGHT (KIPS): ? [8] <---

ELEMENT NUMBER: ? [2] <---  
WEIGHT (KIPS): ? [1] <---

ELEMENT NUMBER: ? [8] <---  
WEIGHT (KIPS): ? [1.5] <---

INPUT DATA FOR ELEMENT SPRING RATES (KIPS/IN) \*\*\*\*\*

INPUT ELEMENT NUMBER, THEN CORRESPONDING  
SPRING RATES (KIPS/IN), IN PAIRS, UNTIL ALL  
DATA HAS BEEN ENTERED. LAST ELEMENT  
NUMBER MUST BE = 7 FOR THIS SERIES.

ELEMENT NUMBER: ? [1] <---

SPRING RATES (KIPS/IN): ? [6927] <---

ELEMENT NUMBER: ? [2] <---

SPRING RATES (KIPS/IN): ? [6480] <---

ELEMENT NUMBER: ? [7] <---

SPRING RATES (KIPS/IN): ? [3600] <---

NEW DATA SET A:CASE1. IS COMPLETE  
DO YOU WANT TO BUILD ANOTHER? (Y/N) [N] <---

{NOTE: WHEN A DATA SET IS FIRST BUILT, IT IS AUTOMATICALLY CHECKED AND SAVED TO DISK. THUS IT CANNOT BE CHECKED USING OPTION 7, SINCE IT'S GONE! (TO DISK) ANY FILES THAT ARE MODIFIED, HOWEVER, MUST BE CHECKED USING OPTION 7 BEFORE YOU CAN SAVE THE FILE TO DISK.}

<<< M A I N M E N U >>

- 1> DISPLAY FILES ON DISK
- 2> DELETE A FILE FROM DISK
- 3> RENAME A FILE ON DISK
- 4> COPY A FILE
- 5> LOAD A FILE FROM DISK
- 6> EDIT PRESENT FILE
- 7> CHECK PRESENT FILE
- 8> SAVE PRESENT FILE
- 9> BUILD A NEW FILE
- 10> MERGE TWO OR MORE DATA FILES
- 11> PRINT A FILE ON THE LINE PRINTER
- 12> EXIT TO SYSTEM

ENTER YOUR SELECTION [7] <---

\*\*\*\* NO FILE PRESENT - USE OPTION 5 ON MAIN MENU TO LOAD DATA  
HIT RETURN [CR] <---

{SEE? I TOLD YOU SO - FILE IS GONE!}

<<< M A I N M E N U >>>

- 1> DISPLAY FILES ON DISK
- 2> DELETE A FILE FROM DISK
- 3> RENAME A FILE ON DISK
- 4> COPY A FILE
- 5> LOAD A FILE FROM DISK
- 6> EDIT PRESENT FILE
- 7> CHECK PRESENT FILE
- 8> SAVE PRESENT FILE
- 9> BUILD A NEW FILE

- 10> MERGE TWO OR MORE DATA FILES
- 11> PRINT A FILE ON THE LINE PRINTER
- 12> EXIT TO SYSTEM

ENTER YOUR SELECTION [5] <---

WHICH DRIVE IS THE DATA SET ON (A or B)? [A] <---

Directory of Disk A:

CASE1 CHEKWAVE.COM LOADWAVE.COM  
WRITWAVE.COM PRNTWAVE.COM UTILWAVE.COM  
INSTWAVE.COM TINYWAVE.COM CASEXII  
EDITWAVE.COM MERGWAVE.COM CASEIII  
READWAVE.COM CASEVII CASEVIII  
CASEXIII CASEXIV CASEXVI  
CASEXVII BRUN .COM MAINPARM.DAT  
EDWAV100.OVR EWMAINMU.OVR EDWAVMNU.OVR  
EDWAV200.OVR

NAME OF DATA SET? (1 to 8 characters)  
OR HIT RETURN TO GO BACK TO MAIN MENU [CASEI] <---

3 LETTER ATTRIBUTE (IF DESIRED)? [CR] <---

PLEASE WAIT  
LOADING FILE A:CASEI.  
INTERPRETING DATA  
FILE A:CASEI. HAS BEEN LOADED AND INTERPRETED  
HIT RETURN [CR] <---

- <<< M A I N M E N U >>>
- 1> DISPLAY FILES ON DISK
  - 2> DELETE A FILE FROM DISK
  - 3> RENAME A FILE ON DISK
  - 4> COPY A FILE
  - 5> LOAD A FILE FROM DISK
  - 6> EDIT PRESENT FILE
  - 7> CHECK PRESENT FILE
  - 8> SAVE PRESENT FILE
  - 9> BUILD A NEW FILE
  - 10> MERGE TWO OR MORE DATA FILES
  - 11> PRINT A FILE ON THE LINE PRINTER

12> EXIT TO SYSTEM  
ENTER YOUR SELECTION [6] <---

{NOW I WOULD LIKE TO BUILD A MODIFICATION OF CASEI, BUT NOT LOSE  
CASEI:}

EDITING FILE A:CASEI. <<< E D I T M E N U >>>

0> 1 SERIES - PROBLEM TITLE CARDS  
1> 100 SERIES - CARDS 101,102, AND 103  
2> 200 SERIES - ELEMENT WEIGHTS (WAM)  
3> 300 SERIES - ELEMENT SPRING RATES (XKAM)  
4> 400 SERIES - STATIC SIDE RESISTANCES (RUM)  
5> 500 SERIES - MINIMUM SPRING FORCES (GAMMA)I  
6> 600 SERIES - COEFFICIENTS OF RESTITUTION (EEM)  
7> 700 SERIES - NOT USED  
8> 800 SERIES - INITIAL VELOCITIES (VEL)  
9> 900 SERIES - SOIL 'QUAKE' (Q)  
10> 1000 SERIES - SOIL DAMPING FACTORS (SJ)  
11> 1100 SERIES - CROSS-SECTIONAL AREAS (A)  
12> 1200 SERIES - INTERNAL SPRING 'SLACKS' (SLACK)  
ENTER THE NUMBER(S) 0-12 OR 'ALL' ... M=MAIN MENU  
INPUT NUMBER(S)? [0] <---

CURRENT TITLE CARD(S) ARE:

#1 VULCAN-08 DRIVING 12X12 INCH PRESTRESSED CONC PILE, 60 FT LONG  
#2 CASEI USING A 1 INCH OAK CAPBLOCK AND CUSHION {SEE CASEI EXAMPLE}  
#3  
#4  
#5  
#6  
#7  
#8

INPUT THE CARD NUMBERS THAT YOU WANT TO CHANGE/ADD  
OR RETURN TO CONTINUE

INPUT CARD NUMBER(S)? [3] <---  
CARD # 3 [THIS WILL BE SAME AS CASE I BUT ADD 20 FEET TO THE PILE] <---

CURRENT TITLE CARD(S) ARE:

#1 VULCAN-08 DRIVING 12X12 INCH PRESTRESSED CONC PILE, 60 FT LONG

#2 CASEI USING A 1 INCH OAK CAPBLOCK AND CUSHION {SEE CASEI SAMPLE}  
#3 THIS WILL BE SAME AS CASE I BUT ADD 20 FEET TO THE PILE

INPUT THE CARD NUMBERS THAT YOU WANT TO CHANGE/ADD OR RETURN TO  
CONTINUE

INPUT CARD NUMBER(S)? [4] <---  
CARD # 4 [THUS, ADD TWO WEIGHTS AND SPRINGS TO THE PILE] <---

CURRENT TITLE CARD(S) ARE:

#1 VULCAN-08 DRIVING 12X12 INCH PRESTRESSED CONC PILE, 60 FT LONG  
#2 CASEI USING A 1 INCH OAK CAPBLOCK AND CUSHION {SEE CASEI SAMPLE}  
#3 THIS WILL BE SAME AS CASE I BUT ADD 20 FEET TO THE PILE  
#4 THUS, ADD TWO WEIGHTS AND SPRINGS TO THE PILE  
#5  
#6  
#7  
#8

INPUT THE CARD NUMBERS THAT YOU WANT TO CHANGE/ADD OR RETURN TO  
CONTINUE

INPUT CARD NUMBER(S)? [CR] <---

EDITING FILE A:CASEI. <<<EDITMENU>>>  
0> 1 SERIES - PROBLEM TITLE CARDS  
1> 100 SERIES - CARDS 101,102, AND 103  
2> 200 SERIES - ELEMENT WEIGHTS (WAM)  
3> 300 SERIES - ELEMENT SPRING RATES (XKAM)  
4> 400 SERIES - STATIC SIDE RESISTANCES (RUM)  
5> 500 SERIES - MINIMUM SPRING FORCES (GAMMA)  
6> 600 SERIES - COEFFICIENTS OF RESTITUTION (EEM)  
7> 700 SERIES - NOT USED  
8> 800 SERIES - INITIAL VELOCITIES (VEL)  
9> 900 SERIES - SOIL 'QUAKE' (Q)  
10> 1000 SERIES - SOIL DAMPING FACTORS (SJ)  
11> 1100 SERIES - CROSS-SECTIONAL AREAS (A)  
12> 1200 SERIES - INTERNAL SPRING 'SLACKS' (SLACK)  
ENTER THE NUMBER(S) 0-12 OR 'ALL' .... M=MAIN MENU  
INPUT NUMBER(S)? [1-4] <---

{Note that the 1-4 entry means edit 1,2,3&4}

CARD #101

#	NAME	VALUE	#	NAME	VALUE
1	1/DELTEE	0	12	NOP(3)	1
2	NSTOP	200	13	NOP(4)	3
3	IPRINT	5	14	NOP(5)	1
4	NS1	1	15	NOP(6)	1
5	NS2	2	16	NOP(7)	2
6	NS3	3	17	NOP(8)	1
7	NS4	5	18	NOP(9)	1
8	NS5	7	19	NOP(10)	1
9	NS6	8	20	NOP(11)	1
10	NOP(1)	1	21	NOP(12)	1
11	NOP(2)	1	22	NOT USED	0

N=NEXT CARD,M=EDIT MENU

INPUT THE NUMBER NEXT TO THE PARAMETER TO CHANGE [9] <---

{O.K. Here you have 3 choices. You can either type N to go to the next card, M to return to the EDITMENU, or any number from 1 to 22 to change the corresponding value on this screen. I picked 9 to change the point of the pile print-out. Program now asks me for new NS6 value.}

INPUT NEW VALUE FOR N56? [10] <---

{Program now repeats the data and lets me change other data or move on to the next card.}

CARD #101

#	NAME	VALUE	#	NAME	VALUE
1	1/DELTEE	0	12	NOP(3)	1
2	NSTOP	200	13	NOP(4)	3
3	IPRINT	5	14	NOP(5)	1
4	NS1	1	15	NOP(6)	1
5	NS2	2	16	NOP(7)	2
6	NS3	3	17	NOP(8)	1
7	NS4	5	18	NOP(9)	1
8	NS5	7	19	NOP(10)	1
9	NS6	10	20	NOP(11)	1
10	NOP(1)	1	21	NOP(12)	1
11	NOP(2)	1	22	NOT USED	0

N=NEXT CARD,M=EDIT MENU

INPUT THE NUMBER NEXT TO THE PARAMETER TO CHANGE [N] <---

CARD #102

#	NAME	VALUE	#	NAME	VALUE
---	------	-------	---	------	-------

23	MP	8	28	EEM2	.5
24	MH	3	29	EEM3	1
25	VELMI	11.75	30	GAMMA1	0
26	AREA	144	31	GAMMA2	0
27	EEM1	.5	32	GAMMA3	-1

N=NEXT CARD,M=EDIT MENU

INPUT THE NUMBER NEXT TO THE PARAMETER TO CHANGE [23] <---  
WARNING: IF YOU ALTER DATA IN THE 100 SERIES, YOU MUST CHECK TO SEE  
THAT THE DATA ON THE 200-1200 SERIES OF CARDS ARE COMPATIBLE  
INPUT NEW VALUE FOR MP? [10] <---

{Here we are changing the number of elements from 8 to 10}

CARD #102

#	NAME	VALUE	#	NAME	VALUE
---	------	-------	---	------	-------

23	MP	10	28	EEM2	.5
24	MH	3	29	EEM3	1
25	VELMI	11.75	30	GAMMA1	0
26	AREA	144	31	GAMMA2	0
27	EEM1	.5	32	GAMMA3	-1

N=NEXT CARD,M=EDIT MENU

INPUT THE NUMBER NEXT TO THE PARAMETER TO CHANGE [N] <---

CARD #103

#	NAME	VALUE	#	NAME	VALUE
---	------	-------	---	------	-------

33	RUT	58	41	DELR(2)	4
34	RUP	2.5	42	DELR(3)	6

35 MO 6 43 DELR(4) 8  
36 QSIDE .1 44 DELR(5) 9  
37 QPOINT .1 45 DELR(6) 0  
38 SIDEJ .2 46 DELR(7) 0  
39 POINTJ .01 47 DELR(8) 0  
40 DELR(1) 3 48 DELR(9) 0  
N=NEXT CARD,M=EDIT MENU

INPUT THE NUMBER NEXT TO THE PARAMETER TO CHANGE [35] <---  
INPUT NEW VALUE FOR MO? [8]

{Here I moved the soil down the pile to element number 8, so that the pile would be embedded in the ground the same distance as before - i.e. the extra 20 feet of pile is above the ground level.}

CARD #103

#	NAME	VALUE	#	NAME	VALUE
33	RUT	58	41	DELR(2)	4
34	RUP	2.5	42	DELR(3)	6
35	MO	8	43	DELR(4)	8
36	QSIDE	.1	44	DELR(5)	9
37	QPOINT	.1	45	DELR(6)	0
38	SIDEJ	.2	46	DELR(7)	0
39	POINTJ	.01	47	DELR(8)	0
40	DELR(1)	3	48	DELR(9)	0

N=NEXT CARD,M=EDIT MENU

INPUT THE NUMBER NEXT TO THE PARAMETER TO CHANGE [N] <---

CARD SERIES 200

ELEMENT WAM

1 8.000  
2 1.000  
8 1.500

RETURN=NEXT SCREEN,P=PREVIOUS SCREEN,N=NEXT SERIES,M=EDIT MENU

INPUT ELEMENT NUMBER(S) TO BE ALTERED? [10] <---

C=CHANGE,D=DELETE,A=ADD [C] <---

\*\*\*\* ELEMENT 10 DOES NOT CURRENTLY EXIST

HIT RETURN

{Wow! An explanation is in order. First note that there are sometimes so many pile elements in the system that they will not fit on the screen. Hence the P to go back to a previous screen, and the RETURN to advance to the next screen of weights. Next, note that I tried to "Change" mass number 10's weight, and he says phooey on you - there is no weight number 10 - they currently only go to 8. Try again! What I must do is ADD a couple of weights to the bottom of the pile.}

CARD SERIES 200

ELEMENT WAM

1 8.000  
2 1.000  
8 1.500

RETURN=NEXT SCREEN,P=PREVIOUS SCREEN,N=NEXT SERIES,M=EDIT MENU

INPUT ELEMENT NUMBER(S) TO BE ALTERED? [10] <---

C=CHANGE,D=DELETE,A=ADD [A] <---

FOR ELEMENT NUMBER(S) 10

INPUT WAM? [1.5] <---

CARD SERIES 200

ELEMENT WAM

1 8.000  
2 1.000  
8 1.500  
10 1.500

RETURN=NEXT SCREEN,P=PREVIOUS SCREEN,N=NEXT SERIES,M=EDIT MENU

INPUT ELEMENT NUMBER(S) TO BE ALTERED? [8] <---

C=CHANGE,D=DELETE,A=ADD [D] <---

{Not that it mattered, but giving both elements 8 and 10 the same weight seemed redundant, so I deleted weight 8.}

CARD SERIES 200

ELEMENT WAM

1 8.000  
2 1.000  
10 1.500

{ Thus we now have weight 1 = the ram = 8 kips, the helmet = weight 2 = 1 kip, and weights 3 through 10 = 1.5 kips each. }

RETURN=NEXT SCREEN,P=PREVIOUS SCREEN,N=NEXT SERIES,M=EDIT MENU  
INPUT ELEMENT NUMBER(S) TO BE ALTERED? [N] <---

CARD SERIES 300

ELEMENT XKAM

1 6927  
2 6480  
7 3600

RETURN=NEXT SCREEN,P=PREVIOUS SCREEN,N=NEXT SERIES,M=EDIT MENU  
INPUT ELEMENT NUMBER(S) TO BE ALTERED? [7] <---  
C=CHANGE,D=DELETE,A=ADD [D] <---

CARD SERIES 300

ELEMENT XKAM

1 6927  
2 6480

RETURN=NEXT SCREEN,P=PREVIOUS SCREEN,N=NEXT SERIES,M=EDIT MENU  
INPUT ELEMENT NUMBER(S) TO BE ALTERED? [9] <---  
C=CHANGE,D=DELETE,A=ADD [A] <---

FOR ELEMENT NUMBER(S) [9] <---

INPUT XKAM? [3600]

CARD SERIES 300

ELEMENT XKAM

1 6927  
2 6480  
9 3600

RETURN=NEXT SCREEN,P=PREVIOUS SCREEN,N=NEXT SERIES,M=EDIT MENU  
INPUT ELEMENT NUMBER(S) TO BE ALTERED? [N] <---

\*\*\*\* NO RUM's ENTERED - CHECK NOP VALUES ON CARD #101

{Since I asked for changes to card series 1-4, and since no 400 card series were present, I am warned that I cannot change that data - it must be changed on CARD #101.}

HIT RETURN TO CONTINUE... {CR} <---

EDITING FILE A:CASE1. <<< E D I T M E N U >>>

0> 1 SERIES - PROBLEM TITLE CARDS  
1> 100 SERIES - CARDS 101,102, AND 103  
2> 200 SERIES - ELEMENT WEIGHTS (WAM)  
3> 300 SERIES - ELEMENT SPRING RATES (XKAM)  
4> 400 SERIES - STATIC SIDE RESISTANCES (RUM)  
5> 500 SERIES - MINIMUM SPRING FORCES (GAMMA)  
6> 600 SERIES - COEFFICIENTS OF RESTITUTION (EEM)  
7> 700 SERIES - NOT USED  
8> 800 SERIES - INITIAL VELOCITIES (VEL)  
9> 900 SERIES - SOIL 'QUAKE' (Q)  
10> 1000 SERIES - SOIL DAMPING FACTORS (SJ)  
11> 1100 SERIES - CROSS-SECTIONAL AREAS (A)  
12> 1200 SERIES - INTERNAL SPRING 'SLACKS' (SLACK)  
ENTER THE NUMBER(S) 0-12 OR 'ALL' .... M=MAIN MENU  
INPUT NUMBER(S)? [M] <---

{So now we are going back to the main menu.}

<<< M A I N M E N U >>>

1> DISPLAY FILES ON DISK  
2> DELETE A FILE FROM DISK  
3> RENAME A FILE ON DISK  
4> COPY A FILE  
5> LOAD A FILE FROM DISK  
6> EDIT PRESENT FILE  
7> CHECK PRESENT FILE  
8> SAVE PRESENT FILE  
9> BUILD A NEW FILE  
10> MERGE TWO OR MORE DATA FILES  
11> PRINT A FILE ON THE LINE PRINTER  
12> EXIT TO system

ENTER YOUR SELECTION [8] <---

\*\*\*\* YOUR DATA HAS NOT BEEN CHECKED

USE OPTION 7 ON MAIN MENU TO CHECK YOUR DATA  
HIT RETURN [CR] <---

<<< M A I N M E N U >>>  
1> DISPLAY FILES ON DISK  
2> DELETE A FILE FROM DISK  
3> RENAME A FILE ON DISK  
4> COPY A FILE  
5> LOAD A FILE FROM DISK  
6> EDIT PRESENT FILE  
7> CHECK PRESENT FILE  
8> SAVE PRESENT FILE  
9> BUILD A NEW FILE  
10> MERGE TWO OR MORE DATA FILES  
11> PRINT A FILE ON THE LINE PRINTER  
12> EXIT TO SYSTEM

ENTER YOUR SELECTION [7] <---

PLEASE WAIT  
CHECKING FILE A:CASE1.

Check Complete

00000 Error(s)

HIT RETURN TO GO BACK TO MAIN MENU [CR] <---

<<< M A I N M E N U >>>  
1> DISPLAY FILES ON DISK  
2> DELETE A FILE FROM DISK  
3> RENAME A FILE ON DISK  
4> COPY A FILE  
5> LOAD A FILE FROM DISK  
6> EDIT PRESENT FILE  
7> CHECK PRESENT FILE  
8> SAVE PRESENT FILE  
9> BUILD A NEW FILE  
10> MERGE TWO OR MORE DATA FILES  
11> PRINT A FILE ON THE LINE PRINTER  
12> EXIT TO SYSTEM

ENTER YOUR SELECTION [8] <---

CURRENT FILE IS A:CASEI.

SAVE DATA ON WHICH DRIVE (A or B)? [A] <---

Directory of Disk A:

CASE1 CHEKWAVE.COM LOADWAVE.COM  
WRITWAVE.COM PRNTWAVE.COM UTILWAVE.COM  
INSTWAVE.COM TINYWAVE.COM CASEXII  
EDITWAVE.COM MERGWAVE.COM CASEIII  
READWAVE.COM CASEVII CASEVIII  
CASEXIII CASEXIV CASEXVI  
CASEXVII BRUN .COM MAINPARM.DAT  
EDWAV100.OVR EWMAINMU.OVR EDWAVMNU.OVR  
EDWAV200.OVR

NAME TO SAVE DATA UNDER (1 to 8 characters)  
OR HIT RETURN FOR CURRENT FILE AS SHOWN ABOVE [MODCASEI] <---

3 LETTER ATTRIBUTE (IF DESIRED)? [CR] <---

PLEASE WAIT  
SAVING FILE A:MODCASEI.

<<< M A I N M E N U >>>

- 1> DISPLAY FILES ON DISK
- 2> DELETE A FILE FROM DISK
- 3> RENAME A FILE ON DISK
- 4> COPY A FILE
- 5> LOAD A FILE FROM DISK
- 6> EDIT PRESENT FILE
- 7> CHECK PRESENT FILE
- 8> SAVE PRESENT FILE
- 9> BUILD A NEW FILE
- 10> MERGE TWO OR MORE DATA FILES
- 11> PRINT A FILE ON THE LINE PRINTER
- 12> EXIT TO SYSTEM

ENTER YOUR SELECTION [10] <---

{Note: Now we are going to merge two data sets to run at the same time. However, once they are merged they can no longer be edited or checked, so make sure they are good before you

merge them.}

NOTE... ANY FILE WHICH IS CREATED BY MERGING WILL HAVE THE  
EXTENSION .MRG AND CANNOT BE LOADED BY THE EDITOR

MERGE DATA TO WHICH DRIVE ? [A] <---

Directory of Disk A:

CASEI CHEKWAVE.COM LOADWAVE.COM  
WRITWAVE.COM PRNTWAVE.COM UTILWAVE.COM  
INSTWAVE.COM TINYWAVE.COM CASEXII  
EDITWAVE.COM MERGWAVE.COM CASEIII  
READWAVE.COM MODCASEI CASEVII  
CASEVIII CASEXIII CASEXIV  
CASEXVI CASEXVII BRUN .COM  
MAINPARM.DAT EDWAV100.OVR EWMAINMU.OVR  
EDWAVMNU.OVR EDWAV200.OVR

NAME TO SAVE MERGED FILES UNDER (1 to 8 characters)

OR HIT RETURN TO GO BACK TO MAIN MENU [RUNBOTH] <---

MERGING TO FILE A:RUNBOTH.MRG

ADD FILE FROM WHICH DRIVE (A or B)

OR RETURN TO GO TO MAIN MENU [A] <---

Directory of Disk A:

CASEI CHEKWAVE.COM LOADWAVE.COM  
WRITWAVE.COM PRNTWAVE.COM UTILWAVE.COM  
INSTWAVE.COM TINYWAVE.COM CASEXII  
EDITWAVE.COM MERGWAVE.COM CASEIII  
READWAVE.COM MODCASEI RUNBOTH .MRG  
CASEVII CASEVIII CASEXIII  
CASEXIV CASEXVI CASEXVII  
BRUN .COM MAINPARM.DAT EDWAV100.OVR  
EWMAINMU.OVR EDWAVMNU.OVR EDWAV200.OVR

INPUT NAME OF FILE YOU WANT TO MERGE (1 to 8 characters)

OR RETURN FOR NONE [CASEI] <---

3 LETTER ATTRIBUTE (IF NECESSARY) [CR] <---

ADDING FILE A:CASEI.  
MERGE OF FILE A:CASEI. TO FILE A:RUNBOTH.MRG IS COMPLETE

ADD ANOTHER DATASET TO FILE A:RUNBOTH.MRG? (Y/N) [Y] <---

MERGING TO FILE A:RUNBOTH.MRG

ADD FILE FROM WHICH DRIVE (A or B)  
OR RETURN TO GO TO MAIN MENU

Directory of Disk A:

CASEI    CHEKWAVE.COM LOADWAVE.COM  
WRITWAVE.COM PRNTWAVE.COM UTILWAVE.COM  
INSTWAVE.COM TINYWAVE.COM CASEXII  
EDITWAVE.COM MERGWAVE.COM CASEIII  
READWAVE.COM MODCASEI    RUNBOTH .MRG  
CASEVII    CASEVIII    CASEXIII  
CASEXIV    CASEXVI    CASEXVII  
BRUN .COM MAINPARM.DAT EDWAV100.OVR  
EWMMAINMU.OVR EDWAVMNU.OVR EDWAV200.OVR

INPUT NAME OF FILE TO MERGE (1 to 8 characters)  
OR RETURN FOR NONE            [MODCASEI] <---

3 LETTER ATTRIBUTE (IF NECESSARY)    [CR] <---

ADDING FILE A:MODCASEI.  
MERGE OF FILE A:MODCASEI. TO FILE A:RUNBOTH.MRG IS COMPLETE

DO YOU WANT TO ADD ANOTHER DATASET TO FILE A:RUNBOTH.MRG? (Y/N)

<<< M A I N   M E N U >>>

- 1> DISPLAY FILES ON DISK
- 2> DELETE A FILE FROM DISK
- 3> RENAME A FILE ON DISK
- 4> COPY A FILE
- 5> LOAD A FILE FROM DISK
- 6> EDIT PRESENT FILE
- 7> CHECK PRESENT FILE
- 8> SAVE PRESENT FILE
- 9> BUILD A NEW FILE
- 10> MERGE TWO OR MORE DATA FILES

11> PRINT A FILE ON THE LINE PRINTER  
12> EXIT TO SYSTEM

ENTER YOUR SELECTION [11] <---

{Let's see what CASEI looks like:}

WHICH DRIVE IS THE DATA ON (A or B) [A] <---

Directory of Disk A:

CASEI CHEKWAVE.COM LOADWAVE.COM  
WRITWAVE.COM PRNTWAVE.COM UTILWAVE.COM  
INSTWAVE.COM TINYWAVE.COM CASEXII  
EDITWAVE.COM MERGWAVE.COM CASEIII  
READWAVE.COM MODCASEI RUNBOTH.MRG  
CASEVII CASEVIII CASEXIII  
CASEXIV CASEXVI CASEXVII  
BRUN.COM MAINPARAM.DAT EDWAV100.OVR  
EWMMAINMU.OVR EDWAVMNU.OVR EDWAV200.OVR

NAME OF THE FILE TO BE PRINTED (1 to 8 characters)  
OR RETURN TO GO BACK TO MAIN MENU [CASEI] <---

3 LETTER EXTENSION (If necessary) [CR] <---

\*\*\* READY PRINTER AND HIT RETURN

PRINTING FILE A:CASEI.

HIT SPACE BAR TO STOP PRINT

2VULCAN-08 DRIVING 12X12 INCH PRESTRESSED CONC PILE, 60 FT LONG  
CASE I USING A 1 INCH OAK CAPBLOCK AND CUSHION

0	200	5	1	2	3	5	7	8	1113112111110					
8	3	11.75	144.0	0.50	0.50	1.00	0.0	0.0	-1.0					
50.00	2.50	60.1000	1.000	2.000	0.010	2.003	0.004	0.006	0.008	0.009	0.990	0.000	0.000	0.00
1	8.000	2	1.000	8	1.500	0	0.000	0	0.000	0	0.000	0	0.000	0
1	6927	2	6480	7	3600	0	0	0	0	0	0	0	0	0

PRINT OF FILE A:CASEI. IS COMPLETE

HIT RETURN

<<< M A I N M E N U >>>

- 1> DISPLAY FILES ON DISK
- 2> DELETE A FILE FROM DISK
- 3> RENAME A FILE ON DISK
- 4> COPY A FILE
- 5> LOAD A FILE FROM DISK
- 6> EDIT PRESENT FILE
- 7> CHECK PRESENT FILE
- 8> SAVE PRESENT FILE
- 9> BUILD A NEW FILE
- 10> MERGE TWO OR MORE DATA FILES
- 11> PRINT A FILE ON THE LINE PRINTER
- 12> EXIT TO SYSTEM

ENTER YOUR SELECTION [12] <---

End Run - Editwave/Readwave Ver 9.12 23-May-93  
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To run the data using MICROWAVE

A> [MW87] <---

WAVE EQUATION ANALYSIS OF PILES

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PROGRAM SERIAL #Freeware

ENTER YOUR DATA FILE NAME <DRIVE:FILENAME.EXT> [CASEI] <---

YOU HAVE CHOSEN FILE: CASEI

IS THIS CORRECT? <Y/N> [Y] <---

ENTER FILE NAME FOR ANSWER FILE <DRV:NAME.EXT>: [CASEI.OUT] <---

YOU HAVE CHOSEN FILE: CASEI.OUT

IS THIS CORRECT? <Y/N> [Y] <---

DO YOU WANT THE FORCE/TIME OUTPUT

IN THE SAME FILE AS THE ANSWER FILE SUMMARY? <Y/N>: [Y] <---  
EXECUTING FILE: CASEI

CALCULATING FOR TIME INTERVAL 1  
CALCULATING FOR TIME INTERVAL 2  
CALCULATING FOR TIME INTERVAL 3  
CALCULATING FOR TIME INTERVAL 4  
ETC.  
ETC.  
ETC.  
CALCULATING FOR TIME INTERVAL 198  
CALCULATING FOR TIME INTERVAL 199  
CALCULATING FOR TIME INTERVAL 200

MAXIMUM COMPRESSIVE AND TENSILE FORCES OVER AREAS IN SEGMENTS

SEGMENT	TIME	COMP	TIME	TENS	TIME	D MAX
1	7	4164.7	200	0.0	200	1.1572
2	11	4358.4	200	0.0	200	1.4577
3	20	3053.7	93	-1704.8	200	1.5984
4	28	3049.4	84	-978.5	200	1.5555
5	37	3086.3	173	-763.0	200	1.5069
6	44	2864.4	76	-954.2	200	1.5074
7	49	2091.6	156	-1349.2	198	1.4955
8					200	1.4902

TOTAL SOIL RESISTANCE = 50.000 KIPS  
PERMANENT SET OF PILE = 1.390 INCHES  
NUMBER OF BLOWS PER INCH = .719  
NUMBER OF BLOWS PER FOOT = 8.632  
PILE WEIGHT (KIPS) = 9.000

CALCULATING FOR TIME INTERVAL 1 {Next resistance running}  
CALCULATING FOR TIME INTERVAL 2  
ETC.  
ETC

{Answers are on drive A: and are named CASEI.ANS - Enjoy}