D-MOD2000
A Computer Program for Seismic Response Analysis of Horizontally Layered Soil Deposits, Earthfill Dams and Solid Waste Landfills

Quick Tutorial

Neven Matasović
Gustavo A. Ordóñez
D-MOD2000

A Computer Program for Seismic Response Analysis of Horizontally Layered Soil Deposits, Earthfill Dams and Solid Waste Landfills

By

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Gustavo A. Ordóñez
GeoMotions, LLC

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D-MOD2000

Quick Tutorial
D-MOD2000 Quick Tutorial

by:

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GeoMotions, LLC
Lacey, Washington
USA

October 2011

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Double-click on the D-MOD2000 icon to execute D-MOD2000
Help on each form is obtained by clicking on the “Help” command button.
Nonlinear Earthquake Response Analysis

This is the Main Menu form for D-MOD2000. It has three main uses: 1) to create the input file for D-MOD_2, 2) to process the master and auxiliary output files created by D-MOD_2, and 3) to allow the user access to plotting and other engineering analyses features of the program.

In this section, we will first explain the main working file in D-MOD2000. This file is identified by the extension *.EDT. This file is a database file that stores the data for the different options for D-MOD_2. You can have any number of sets of data for each option, i.e., 8 sets of option 1 data, 6 sets of option 2, etc. D-MOD2000 creates this database file for all the files that are created and used in D-MOD2000. However, once

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Command button to create a new option

Command buttons to open, save or to edit an existing database file
Command buttons to create input file and edit the list of options

Command buttons to execute D-MOD_2 and to process the output files
Text box to enter name of Master Output File

Text box to enter the label used to name the files generated from processing of the Master Output File

Text box to enter the number of the layer for which output will be generated by the program
Options to create, view and print input data

Plotting options
Option for other analysis and utilities
Options to automatically save data, check data before conducting the analysis, and to switch between SI and English units.
Window where list of options in the database file is shown

Window where list of options to be included in the input file is shown
EDT and Input Data Files

- An EDT file is a database file that stores the data for the different D-MOD_2 options. These options are used by D-MOD2000 to create an input file.
- A maximum of 32,000 options can be saved in the EDT file.
- The options are saved sequentially.
- Listing of the options used in the input file are saved in the EDT file.
- The input file stores the different options that will be executed by D-MOD_2.
- The EDT file is not an input file for D-MOD_2.
D-MOD2000 EDT & Input Files

EDT Options

Option 1 - Master Control Card - Wildlife Site - D-MOD2000 Tutorial
Option 2 - Wildlife Site - Analytical Soil Profile
Option 4 - Wildlife Site - Material Properties - Case SH-A
Option 4 - Wildlife Site - Material Properties - Case SH-B
Option 4 - Wildlife Site - Material Properties - Case SH-C
Option 5 - Visco-Elastic Half-Space Properties
Option 6 - Wildlife Site - D-MOD2000 Tutorial - Dynamic Analysis Solution
Option 7 - Input Motion: Wildlife Liquefaction Array, 7.5 M Downhole

Input File Options

Option 1 - Master Control Card - Wildlife Site - D-MOD2000 Tutorial
Option 2 - Wildlife Site - Analytical Soil Profile
Option 4 - Wildlife Site - Material Properties - Case SH-B
Option 6 - Wildlife Site - D-MOD2000 Tutorial - Dynamic Analysis Solution
Option 7 - Input Motion: Wildlife Liquefaction Array, 7.5 M Downhole
Output Files

- D-MOD creates a master output file and a series of auxiliary output files for a specific layer.

- The master output file echoes the input information, provides information on the initial stress state in the profile, lists the peak values of time-dependent variables (for all layers in the profile), and defines contents (file names, variables and units) of the auxiliary output files.

- The auxiliary output files contain time-dependent variables calculated for a specific layer in the profile.

- A summary of the master output file, which includes the input data and the table of maximum values is saved to a file.
Output Files

- When processing the master output file, a series of files are created to save the data used by other options of D-MOD2000:
  
  - *ACC* Acceleration time histories
  - *DPL* Displacement time histories
  - *MAX* Maximum values
  - *NTS* Normalized shear stress time histories
  - *PWP* Pore water pressure ratio time histories
  - *STN* Strain time histories
  - *STS* Stress time histories
  - *VEL* Velocity time histories
  - *A#L#.VAR* Time dependent variables for a specific layer

- Files are text files
The first step in our analysis is to estimate viscous damping by calibrating the D-MOD analysis against an equivalent-linear, i.e. SHAKE, analysis that has a constant value of viscous damping at all frequencies. There are two approaches that can be used to evaluate the Rayleigh Damping coefficients, n and \( \xi \), using an iterative procedure based on comparing how well the SHAKE and D-MOD surface response spectra and peak acceleration & shear strain vs. depth compare to each other:

1. Develop a SHAKE column and perform an equivalent-linear SHAKE analysis to obtain the acceleration time history at the surface level. Limit PGA to \( \leq 0.4 \) g and Shear Strain to \( < 0.5\% \).

2. Develop a SHAKE column and perform a small strain, linear SHAKE analysis to obtain the acceleration time history at the surface level. Use \( G_{\text{max}} \) and 5% damping for all layers (i.e., use “zero” type soils in Option 2). More detailed information about this approach is provided by Stewart et al. (2008).
The first approach involves evaluation of the Rayleigh Damping coefficients, $n$ and $\xi$, using an iterative procedure as follows:

1. Develop a SHAKE column and perform the SHAKE analysis to obtain the response spectrum at the surface level. Limit PGA to $\leq 0.4$ g and Shear Strain to $< 0.5\%$.
2. Develop the D-MOD column to match the SHAKE column as close as possible and use $n = 0$ and $\xi = 0.5$ for first iteration.
3. Perform a total-stress nonlinear analysis with D-MOD.
4. Compare the surface response spectrum from SHAKE to the response spectrum from D-MOD.
5. Adjust $n$ and $\xi$ and repeat from step 3 until a “satisfactory” match between the SHAKE and D-MOD spectra is obtained. Also, compare the shear strain vs. depth plot from both SHAKE and D-MOD.
Create *.EDT Database File Options

1. Click on “Import SHAKE2000 Input” to select it.

2. Click on “Ok”.

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Import Data from SHAKE2000 Input File

1. Switch folders until you change to "GeoMotions\ ShortCourse\ D-MOD" folder

2. Click on "SHAKEShortCourse.in" to select it

3. Click on "Open"
Create *.EDT Database File Options

1. Click on "Yes"
Sample Problem

SHAKE Column

D-MOD Column

\[ f_{\text{max}} = 25 \text{ Hz} \Rightarrow h < \sqrt{v/100} \]
Create *.EDT Database File Options

1. Click on "Save"
Create *.EDT Database File Options

1. Switch folders until you change to "GeoMotions\ ShortCourse\ D-MOD" folder

2. Enter "ShortCourse.edt" in File name

3. Click on "Save"
Create *.EDT Database File Options

| Option 1 - Total Stress/Nonlinear 13 Layers & 13 Materials |
| Option 2 - Soil Profile No. 1: Column 1 - Short Course |
| Option 3 - Soil Profile No. 2: Column 2 - Long Course |

1. Click on "Option 2 - Soil Profile No. 1: Column 1 - Short Course" to select it

2. Click on "Edit"
Create *.EDT Database File Options
Option 2 – Soil Profile – Check Settings

Above GWT = 1
Below GWT = 0

Layer No. 5, top saturated layer

PWP = 1 ⇒ Sand
PWP = 2 ⇒ Clay
Create *.EDT Database File Options
Option 2 – Soil Profile

1. Enter “1” for layers 2 through 4
2. Scroll down to show bottom layers
Create *EDT Database File Options
Option 2 – Soil Profile

1. Click on “Ok”

Layer 13, bottom saturated soil layer
Create *.EDT Database File Options

1. Click on "Option 1 - Total Stress\Nonlinear..." to select it

2. Click on "Edit"
Create *.EDT Database File Options
Option 1 – Master Control Card – Total Stress Analysis

1. Enter “5” for Number of the top saturated layer
2. Click on “Ok”

- Total Stress Analysis
- Half-space is visco-elastic ⇒ outcrop motion
- Nonlinear Analysis
Create *.EDT Database File Options

1. Click on “Option 4 - Material Properties: Dynamic Soil Properties Set No. 1” to select it

2. Click on “Edit”
Create *.EDT Database File Options
Option 4 – Material Properties: MKZ Model

\[
\tau^* = f'(\gamma) = \frac{\delta_G G_{mo} \gamma}{1 + \beta \left(\frac{\delta_G G_{mo} \gamma}{\tau_{mo}}\right)^s}
\]

\[
G_{mo} = \frac{G_{mo}}{\sigma_{vc}}
\]

\[
\tau_{mo} = \frac{\tau_{mo}}{\sigma_{vc}}
\]

\[
\delta_{\tau} = 1 - \left(\mu^*\right) \quad \delta_G = \sqrt{1 - \mu^*}
\]

<table>
<thead>
<tr>
<th>Set No.</th>
<th>Material Description - Set Identification</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Material Properties: Dynamic Soil Properties Set No. 1</td>
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<table>
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<tr>
<th>No. Materials</th>
<th>Material</th>
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<td>No. 1 - 5 and Upper</td>
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<table>
<thead>
<tr>
<th>( G_{mo} ) (psf)</th>
<th>( \tau_{mo} ) (psf)</th>
<th>( \beta )</th>
<th>( s )</th>
<th>( v )</th>
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<th>( \gamma_s ) (ft/sec)</th>
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<th>( K_2 )</th>
<th>( m )</th>
<th>( n )</th>
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<td>572.76</td>
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<td>0.62</td>
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<th>( \gamma_{sat} ) (pcf)</th>
<th>( \gamma_{wet} ) (pcf)</th>
<th>( k ) (ft/sec)</th>
<th>( \alpha_R ) or ( c )</th>
<th>( \beta_R )</th>
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<th>( P )</th>
<th>( t )</th>
<th>( \gamma_{fV} ) (%)</th>
<th>OCR</th>
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<td>2</td>
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<td>1.7</td>
<td></td>
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</table>
Create *.EDT Database File Options

Differential equations of the simultaneous generation, dissipation and redistribution of PWP within a deposit

\[ \frac{\partial u}{\partial t} = \frac{E_r}{\gamma_w} \frac{k}{\gamma_w} \left( \frac{\partial^2 u}{\partial z^2} \right)_{st} + \left( \frac{\partial u}{\partial r} \right)_{cy} \]

\[ E_r = \frac{(\sigma'_v)^{1-m}}{m K_2 \left( \sigma'_{vo} \right)^{n-m}} \]  
(Martinet et al., 1975)
Create *.EDT Database File Options
Pore Water Pressure Model for Sand

\[ \mu_N = \frac{p f F N (\gamma_c - \gamma_{\text{wp}})}{1 + p f F N (\gamma_c - \gamma_{\text{wp}})} \]

(Dobry et al., 1985)
Create *.EDT Database File Options
Cyclic Degradation & Pore Water Pressure Model for Clay

1. Click on down arrow and select “No. 8 - Clay PI = 35”

2. Click on “MKZ”

\[ \mu_N^* = AN^{-3s(\gamma_c - \gamma,np)} + BN^{-2s(\gamma_c - \gamma,np)} + CN^{-s(\gamma_c - \gamma,np)} + D \]

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Create *.EDT Database File Options

Option 4 – Material Properties: MKZ Model & Viscous Damping

\[
\tau^* = f''(\gamma) = \frac{\delta G G^{*}_{mo} \gamma}{1 + \beta \left( \frac{\delta G G^{*}_{mo}}{\delta \tau \tau^{*}_{mo}} \right)^n}
\]

\[
G^{*}_{mo} = \frac{G_{mo}}{\sigma_{vc}} \quad \tau^{*}_{mo} = \frac{\tau_{mo}}{\sigma_{vc}}
\]

\[
c = \alpha_R m x \beta_R k
\]

\[
\alpha_R = \frac{\varepsilon_{sir}}{T} \left( \frac{n}{n+1} \right)
\]

\[
\beta_R = \frac{\varepsilon_{sir} T}{\pi (1+n)}
\]
Create *.EDT Database File Options

Option 4 – Material Properties

1. Click on up/down arrows for $\beta$
2. Click on up/down arrows for $s$
3. Click on “Update $\beta$ & $s$ for material type”
4. Click on “Ok”

1st iteration use default values for $n$ and $\xi$
Create *.EDT Database File Options
Option 4 – Material Properties

1. Click on “graph” icon
Create *.EDT Database File Options
Option 4 - Material Properties

1. Click on down arrow, scroll down and select "Generic Clay (Pl=30)"

2. Click on “Update all similar materials”

3. Click on “Choose”
Create *.EDT Database File Options
Option 4 – Material Properties

1. Click on down arrow and select “No. 5 - EPRI 21-50”

2. Click on “Sand”

<table>
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<tr>
<th>Set No.:</th>
<th>Material Description - Set Identification:</th>
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<th>No. Materials</th>
<th>Material</th>
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<th>$\beta$</th>
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<th>$\gamma_{wet}$ (pcf)</th>
<th>$k$ (ft/sec)</th>
<th>$\alpha_R$ or $c$</th>
<th>$\beta_R$</th>
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<th>$P$</th>
<th>$F$</th>
<th>$s$</th>
<th>$\gamma_{tv}$ (%)</th>
<th>OCR</th>
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<td>2</td>
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<th>$A$</th>
<th>$B$</th>
<th>$C$</th>
<th>$D$</th>
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</table>
Create *.EDT Database File Options
Option 4 – Material Properties

1. Enter "0.4" & "100" for particle size and percent finer.

The new curve is drawn.
Create *.EDT Database File Options
Option 4 – Material Properties

User’ Sand

<table>
<thead>
<tr>
<th>Particle Size</th>
<th>Percent Finer</th>
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<tbody>
<tr>
<td>0.2</td>
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<tr>
<td>0.1</td>
<td>60</td>
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<tr>
<td>0.03</td>
<td>5</td>
</tr>
</tbody>
</table>
Create *.EDT Database File Options
Option 4 – Material Properties

1. Enter “Short Course” for Curve ID

2. Click a symbol of WSB Sand to this as the matching curve

3. Click on “Ok”
Create *.EDT Database File Options
Option 4 – Material Properties

1. Click on “Fit”

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<table>
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<th>β</th>
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<th>m</th>
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<tr>
<th>γsat (pcf)</th>
<th>γwet (pcf)</th>
<th>k (ft/sec)</th>
<th>αR or c</th>
<th>βr</th>
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<td></td>
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</table>

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Create *.EDT Database File Options

Option 4 – Material Properties: MKZ Parameters

1. Click on "ALDO"

2. Click on "Ok"
Create *.EDT Database File Options
Option 4 – Material Properties

1. Click on “Ok”
Create *.EDT Database File Options

1. Click on "Option 5 - Properties of Visco-Elastic ...." to select it

2. Click on "Edit"
Create *.EDT Database File Options
Option 5 – Properties of Visco-Elastic Half-Space

1. Click on “Ok”
Create *.EDT Database File Options

1. Scroll down
2. Click on "Option 6 - AND_FP D-MOD Calibration" to select it
3. Click on "Edit"
Create *.EDT Database File Options
Option 6 – Dynamic Analysis Solution Control
NCPR = 100 ⇒ Print results every 100th time step

1. Enter “100” in NCPR

2. Click on “Ok”
Interval for Printing Results to Output File in Option 6

Layer 1 - DS-1 Site
Time: 40.96 (sec)

Response Spectrum for Layer 1 - DS-1 Site

NCPR = 1 ⇒ save data every 0.02 sec - time to process ≈ 1 to 10 minutes

Layer 1 - DS-1 Site
Time: 40 (sec)

Response Spectrum for Layer 1 - DS-1 Site

NCPR = 100 ⇒ save data every 2 sec - time to process ≈ 10-20 seconds
Create *.EDT Database File Options

1. Scroll down

2. Select “Option 7 - AND_FP D-MOD Calibration”

3. Click on “Edit”
Create *.EDT Database File Options

Option 7 – Earthquake Record Control
Check Path to Ground Motion File

1. Click on “Plot”
Create *.EDT Database File Options

Plot of Input Ground Motion

1. Click on "Close"
Create *.EDT Database File Options

Option 7 – Earthquake Record Control

1. Click on “Ok”

```
<table>
<thead>
<tr>
<th>Set No.</th>
<th>Earthquake Record Control - Set Identification:</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>AND_FP D-MOD Calibration</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>NCARD</th>
<th>NREC</th>
<th>NFTS</th>
<th>RCRF</th>
<th>Time Step</th>
<th>New Option 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>990</td>
<td>8</td>
<td>0</td>
<td>0.938</td>
<td>0.005</td>
<td></td>
</tr>
</tbody>
</table>

FINPEQ

C:\ Geotechnical\GeoMotions\Quakes\739AND_FP.eq

NHEAD 8
```
Create Input File – First Iteration

SHAKE Calibration – Evaluation of Rayleigh Damping Coefficients

1. Scroll up

2. Click on “Option 1 – Total Stress\Nonlinear”

3. Click on “Add”

Option 1 has been added to the list of options in input file
### Create Input File – First Iteration

1. Select Options 2 and click on “Add”. Do the same for options 4, 5, last set of options 6 and 7 (i.e., AND_FP D-MOD) to add them to the list of input options.

Options 2, 4, 5, 6 and 7 have been added to the list of options in input file.

#### Options available in EDT file:

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
<th>Scaling Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Option 2</td>
<td>Motion: ROCK[href] - Scaling Factor: 2.0153</td>
<td></td>
</tr>
<tr>
<td>Option 3</td>
<td>Motion: ROCK[href] - Scaling Factor: 1.972</td>
<td></td>
</tr>
<tr>
<td>Option 4</td>
<td>Motion: ROCK[href] - Scaling Factor: 1.3272</td>
<td></td>
</tr>
<tr>
<td>Option 5</td>
<td>Motion: ROCK[href] - Scaling Factor: 1.3272</td>
<td></td>
</tr>
<tr>
<td>Option 6</td>
<td>Motion: ROCK[href] - Scaling Factor: 1.3272</td>
<td></td>
</tr>
<tr>
<td>Option 7</td>
<td>Motion: ROCK[href] - Scaling Factor: 1.3272</td>
<td></td>
</tr>
<tr>
<td>Option 8</td>
<td>Motion: ROCK[href] - Scaling Factor: 1.3272</td>
<td></td>
</tr>
</tbody>
</table>

#### Options saved in input file:

<table>
<thead>
<tr>
<th>Input Set No.</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Option 1 - Soil Profile No. 1: Short Course</td>
</tr>
<tr>
<td></td>
<td>Option 2 - Soil Profile No. 1: Short Course</td>
</tr>
<tr>
<td></td>
<td>Option 4 - Material Properties: Dynamic Soil Properties Set No. 1</td>
</tr>
<tr>
<td></td>
<td>Option 5 - Properties of Visco-Elastic Half-Space - Layer: 14</td>
</tr>
<tr>
<td></td>
<td>Option 6 - AND_FP D-MOD Calibration</td>
</tr>
<tr>
<td></td>
<td>Option 7 - AND_FP D-MOD Calibration</td>
</tr>
</tbody>
</table>

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D-MOD2000 Quick Tutorial - Page No. 56
1. Switch folders until you change to “GeoMotions\ShortCourse\D-MOD” folder

2. Enter “AND_FPcal.inp” in File name

3. Click on “Save”
Save EDT Database File

1. Click on "Save"

2. Click on "Yes"

1. Click on "Save"
1. Enter “AND_FP SHAKE Calibration” for Input Set Description

2. Click on folder icon
1. Double click on "GeoMotions" folder icon

2. Scroll down to display the "ShortCourse" folder

3. Double click on "ShortCourse" folder icon

4. Double click on "D-MOD" folder

5. Click on "Ok"
Output & Auxiliary Files and Output Layer

1. Enter “AND_FPcal.out” for Master Output File

2. Enter “AND_FPcal” for Name of Plot Files
SHAKE Calibration – Evaluation of Rayleigh Damping

Simplified Rayleigh Damping ($n = 0$ & $\xi = 0.5-5.5$)

1. Click on “Calibrate with Frequency…..” to select it

2. Click on “D-MOD”

\[
\alpha_R = \xi_{\text{tar}} \left( \frac{4\pi n}{T} \right) \left[ \frac{n}{n+1} \right] = \xi_{\text{tar}} \left( \frac{4\pi}{T} \right) \left[ \frac{0}{0+1} \right] = 0
\]

\[
\beta_R = \frac{\xi_{\text{tar}} T}{\pi (1+n)} = \xi_{\text{tar}} \frac{T}{\pi (1+0)} = \xi_{\text{tar}} \frac{T}{\pi}
\]
Execute D-MOD – 1st Iteration

1. Click on “Save”
Execute D-MOD – 1st Iteration

D-MOD2000 Quick Tutorial - Page No. 64
1st Iteration – Process Output Files

1. Click on “Process”
Results are provided in rows and columns every certain number of time steps as defined in Option 6.
Master Output File

For plotting, this file will need to be read every time, which may be time consuming depending on the size of the file, e.g., this file has 271,154 lines.
If we used 200 layers and 30,400 values for the acceleration time history, the output file would have 13,000,000 (! 13 million!) lines of data. It would take about 30 minutes to process.
Output & Plot Files Generated by Processing

Files created from processing of D-MOD’s output files

Output files created by D-MOD
1st Iteration – Process Output Files
Open Acceleration Time History File for Layer 1

1. If necessary, change to the “GeoMotions\ShortCourse\D-MOD” folder

2. Click on “AND_FPCalA1L1.var” file to select it

3. Click on “Open”
1st Iteration – Process Output Files
Open SHAKE Calibration File – PGA & Shear Strain vs. Depth

1. If necessary, change to the GeoMotions\ShortCourse\SHAKE” folder
2. Click on “Short-A15-AND_FP.cal” to select it
3. Click on “Open”
Display & Plot Results for Layer 1
Compare to Frequency Domain Spectrum & Shear Strain vs. Depth

1. Click on “Graph”
Display & Plot Results for Layer 1
Compare to Frequency Domain Spectrum

<table>
<thead>
<tr>
<th>ACC File:</th>
<th>C:\Geotechnical\GeoMotions\ShortCourse\D-MOD\AND_FPcalA1L1.var</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project:</td>
<td>Total Stress:Nonlinear Analysis * Dt: 0.005</td>
</tr>
<tr>
<td>Profile:</td>
<td>Total Stress:Nonlinear Analysis * Dt: 0.005</td>
</tr>
<tr>
<td>Layer No.:</td>
<td>1</td>
</tr>
<tr>
<td>Earthquake:</td>
<td>C:\Geotechnical\GeoMotions\Quakes\739AND_FP.eq</td>
</tr>
</tbody>
</table>

Damping Values:
- **Response spectrum for 5% damping**

Type of Response Spectrum:
- **Absolute Acceleration**
- Pseudo-Absolute Acceleration
- Relative Displacement
- Relative Velocity
- Pseudo-Relative Velocity

1. Click on **"Response Spectrum for 5% damping"**
2. Click on **"Absolute Acceleration"**
3. Click on **"Other"**
Display & Plot Results for Layer 1
Compare to Frequency Domain Spectrum

1. Click on “Other”
Display & Plot Results for Layer 1
Open File for Layer 1 from SHAKE Analysis

1. Switch folders until you change to “GeoMotions\ShortCourse\SHAKE” folder

2. Scroll

3. Select the “Short-L1A15D1-99-Column 1-AND_FP.ahl” file

4. Click on “Open”
Display & Plot Results for Layer 1
Compute Spectrum from SHAKE Analysis

1. Click on "Spectra"

2. Click on "Ok"
Display & Plot Results for Layer 1
Compare to Frequency Domain Spectrum

1. Click on “Ok”
Display & Plot Results for Layer 1
Compare to Frequency Domain Spectrum & Shear Strain vs. Depth

1. Click on “Close”
2nd Iteration – Evaluation of Rayleigh Damping
Full Rayleigh Damping \( (n = 1, 3, 5, 7\ldots \& \xi = 0.5-5.5) \)

1. Enter "5" for \( n \)

2. Click on "D-MOD"
Execute D-MOD – 2nd Iteration

1. Click on “Save”
2nd Iteration – Evaluation of Rayleigh Damping

1. Click on “Process”
2nd Iteration - Display & Plot Results for Layer 1
Compare to Frequency Domain Spectrum & Shear Strain vs. Depth

1. Click on "Close"
3rd Iteration – Evaluation of Rayleigh Damping

Full Rayleigh Damping \( (n = 1, 3, 5, 7, \ldots \) \& \( \xi = 0.5-5.5 \) )

1. Enter “1” for \( n \) and “5” for \( \xi \)

2. Click on “D-MOD” & “Save”

3. Click on “Process”
3rd Iteration - Display & Plot Results for Layer 1
Compare to Frequency Domain Spectrum & Shear Strain vs. Depth

1. Click on “Close”
Nonlinear and Effective-Stress Analysis
Better match ⇒ Use $n = 1$ and $\xi = 5$

1. Select “Option 7” from input list

2. Click on “Clear”

3. Click on “No”
Nonlinear and Effective-Stress Analysis

Use $n = 1$ and $\zeta = 5$

1. Click on "Maximum Values"

2. Click on second set of Option 1, i.e., Nonlinear

3. Click on "Edit"
Nonlinear and Effective-Stress Analysis

2. Click on “Ok”

<table>
<thead>
<tr>
<th>D-MOD2000 Option 1: Master Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>D-MOD - Identification for Input Data Set:</td>
</tr>
<tr>
<td>Nonlinear Effective-Stress: 13 Layers &amp; 13 Materials</td>
</tr>
<tr>
<td>Title:</td>
</tr>
<tr>
<td>Nonlinear Effective-Stress Analysis</td>
</tr>
<tr>
<td>Analysis type control number:</td>
</tr>
<tr>
<td>Number of material layers in the profile:</td>
</tr>
<tr>
<td>Number of material property sets specified:</td>
</tr>
<tr>
<td>Half-space control number:</td>
</tr>
<tr>
<td>System of units to be used:</td>
</tr>
<tr>
<td>Stress-Strain model control number:</td>
</tr>
<tr>
<td>Viscous damping control number:</td>
</tr>
<tr>
<td>Top hydraulic boundary condition control number:</td>
</tr>
<tr>
<td>Bottom hydraulic boundary condition control number:</td>
</tr>
<tr>
<td>&quot;Irregular stress-strain behavior&quot; accuracy control No. 1:</td>
</tr>
<tr>
<td>&quot;Irregular stress-strain behavior&quot; accuracy control No. 2:</td>
</tr>
<tr>
<td>Number of the top saturated soil layer:</td>
</tr>
<tr>
<td>Number of the bottom saturated soil layer:</td>
</tr>
</tbody>
</table>

1. Enter “5” for top saturated layer
1. Enter “AND_FPeff.out” for Master Output File
2. Enter “AND_FPeff” for Name of Plot Files
3. Enter “6” for Output Generated for Layer
4. Enter “AND_FP Nonlinear” for description
Create Input File – Nonlinear Analysis

1. Select SECOND set of Option 1 and click on “Add”, then add Options 2, 4, 5, and SIXTH sets of options 6 and 7

Options 1, 2, 4, 5, 6 and 7 have been added to the list of options in input file

2. Click on “Save”
1. Switch folders until you change to “GeoMotions\ShortCourse\D-MOD” folder

2. Enter “AND_FPeff.inp” in File name

3. Click on “Save”
Save EDT Database File

1. Click on "Save"
2. Click on "Yes"

1. Click on "Save"
Nonlinear and Effective-Stress Analysis

1. Scroll up
2. Select “Option 6 - Motion: P.AND_FP....”
3. Click on “Edit”
Nonlinear and Effective-Stress Analysis
Option 6 – Dynamic Analysis Solution Control

NCPR = 1 ⇒ Print results every time step

1. Enter "1" for NCPR

2. Click on "Ok"
Nonlinear and Effective-Stress Analysis

1. Click on "D-MOD"

2. Click on "Save"
Nonlinear and Effective-Stress Analysis

1. Click on "Process"

2. Click on "Ok"

Process time about 2+ minutes
Nonlinear and Effective-Stress Analysis
Display/Plot Results

1. Click on "Maximum Values"

2. Click on "Plot"
Nonlinear and Effective-Stress Analysis
PGA Profile

1. Click on a symbol

Acceleration & Depth values

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Nonlinear and Effective-Stress Analysis
Pore Water Pressure Ratio

1. Click on "Show Layers" option
2. Click on "PWP Ratio" option
3. Click on "Close"
1. Click on “Partial Results at Uniform Time Step” to select it

2. Click on “Plot”
Nonlinear and Effective-Stress Analysis
Acceleration vs. Depth Time History

1. Click on the scroll-bar and hold down
Nonlinear and Effective-Stress Analysis
Create PWP Ratio vs. Depth Time History Movie

1. Click on “PWP Ratio”

2. Click on “Record Movie”

3. Scroll down and select “Microsoft Video 1”

4. Click on Camcorder
Nonlinear and Effective-Stress Analysis
Create PWP Ratio vs. Depth Time History Movie

1. Click on Cross Camcorder to stop movie
2. Click “Cancel”
3. Click on “Close”
1. Click on “Time Dependent Variables for Layer” to select it.

2. Click on “Plot”.

Nonlinear and Effective-Stress Analysis
Display/Plot Results
Nonlinear and Effective-Stress Analysis
Open File for Layer No. 6

1. Switch folders until you change to “GeoMotions\ShortCourse\D-MOD” folder

2. Click on “AND_FPeffA1L6.var” to select it

3. Click on “Open”
Nonlinear and Effective-Stress Analysis
Display/Plot Results – Layer 6

1. Click on “Stress-Strain Loops” to select it.
Nonlinear and Effective-Stress Analysis
Display/Plot Results – Layer 6

1. Click on “Plot Input Motion” to select it
2. Click on Fixed Axis” to select it
Nonlinear and Effective-Stress Analysis
Display/Plot Results – Layer 6

1. Drag scroll-bar

2. Click on “Normalized PWP”
Nonlinear and Effective-Stress Analysis
Display/Plot Results – Layer 6

1. Click on "Close"
Nonlinear and Effective-Stress Analysis
Compare Results from Several Analyses

1. Click on “Compare Results of Several Analyses”

2. Click on “Ok”
Nonlinear and Effective-Stress Analysis
Compare Results from Several Analyses

1. Click on “Open”
Nonlinear and Effective-Stress Analysis
Compare Results from Several Analyses

2. Click on “AND_FPeffaux.max” to select it

3. Use ctrl+click to select “G06_FPeffaux.max”

4. Use ctrl+click to select “GIL_FPeffaux.max”

5. Use ctrl+click to select “HOW_FPeffaux.max”

6. Click on “Ok”
Nonlinear and Effective-Stress Analysis
Compare Results from Several Analyses

1. Click on "Read"

2. Click on "Ok"
Nonlinear and Effective-Stress Analysis
Compare Results from Several Analyses

1. Enter “AND_FP” in Description text box for first file
2. Enter “G06_FP”, “GIL_FP” & “HOW_FP” for other files
3. Click on “Plot”
Nonlinear and Effective-Stress Analysis
Compare Results from Several Analyses

1. Click on “Show Layers”
2. Click on “PWP Ratio”
Nonlinear and Effective-Stress Analysis
Compare Results from Several Analyses

1. Click on "Close"
Nonlinear and Effective-Stress Analysis
Compare Results from Several Analyses

1. Click on "Response Spectrum"
2. Click on "Yes"

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Nonlinear and Effective-Stress Analysis

Compare Results from Several Analyses

1. Click on "Open"
Nonlinear and Effective-Stress Analysis
Compare Results from Several Analyses

1. Switch folders until you change to “GeoMotions\ShortCourse\D-MOD”

2. Click on “AND_FPeffaux.acc” to select it

3. Use ctrl+click to select “G06_FPeffaux.acc”

4. Use ctrl+click to select “GIL_FPeffaux.acc”

5. Use ctrl+click to select “HOW_FPeffaux.acc”

6. Click on “Ok”
Nonlinear and Effective-Stress Analysis

Compare Results from Several Analyses

1. Click on “Read”

2. Click on “Ok”
Nonlinear and Effective-Stress Analysis
Compare Results from Several Analyses

2. Click on “Plot”

1. Enter the names for the spectra plots
Nonlinear and Effective-Stress Analysis

Compare Results from Several Analyses

1. Click on “Close”
Nonlinear and Effective-Stress Analysis
Compare Results from Several Analyses

1. Click on "Close"
Nonlinear and Effective-Stress Analysis

1. Click on "Play AVI Movies"

2. Click on "Play"

Options available in EDT file:
- Option 1 - Nonlinear Effective Stress: 13 Layers & 13 Materials
- Option 2 - Soil Profile No. 1: Column 1 - Short Course
- Option 4 - Material Properties: Dynamic Soil Properties Set No. 1
- Option 5 - Properties of Visco-Elastic Half-Space: Layer 14
- Option 6 - Motion: PAND, FP - Scaling Factor: 1.3272

Options saved in input file:
- Input File Description: AND_FP Nonlinear

Input & Output File Options:
- Create new EDT file using default data
- Use Excel: 25 Hz
- Calibrate with Frequency Domain Analysis
- T = 4.27, n = 1, & = 5
- Print Summary of Master Output File
- Print EDT File
- Print Input File

Plotting Options:
- Maximum Values
- Partial Results at Uniform Time Step
- Response Spectrum
- Time Histories
- Compare Results of Several Analyses
- Time Dependant Variables for Layer

Utility Analysis & Utilities Options:
- Automatically save EDT & Input Files
- Earthquake Engineering Analyses & Utilities
- Create Excel CSV Files
- Plot

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Nonlinear and Effective-Stress Analysis

1. Click on open folder icon
Nonlinear and Effective-Stress Analysis
Open AVI Movie File

1. Switch folders until you change to "GeoMotions\ ShortCourse\ D-MOD"

2. Click on "Motion.avi" file to select it

3. Click on "Open"
Nonlinear and Effective-Stress Analysis

1. Click on open folder icon
Nonlinear and Effective-Stress Analysis
Open AVI Movie File

1. Switch folders until you change to “GeoMotions\ ShortCourse\ D-MOD”

2. Click on “PWP.avi” file to select it

3. Click on “Open”
Nonlinear and Effective-Stress Analysis

1. Click on “>”

2. Click to close
A second approach to estimate viscous damping parameters is by calibrating the D-MOD analysis against a linear SHAKE analysis for small strain conditions (i.e., use $G_{\text{max}}$ and a constant value of 5% damping for all soil layers). More detailed information on this procedure is presented by Stewart et al (2008).

1. Develop a SHAKE column and perform a small strain linear SHAKE analysis to obtain the acceleration time history at the surface level. Use $G_{\text{max}}$ and 5% damping for all soil layers (i.e., use “zero” type soils in Option 2).

2. Develop the D-MOD column to match the SHAKE column as close as possible; use $n = 0$ and $\xi = 5$ for first iteration.

3. Perform a Total-Stress/Linear-Elastic analysis with D-MOD.

4. Compare the surface response spectrum from SHAKE to the response spectrum from D-MOD.

5. Adjust $n$ and $\xi$ and repeat from step 3 until a match between the SHAKE and D-MOD spectra is obtained within a reasonable degree of tolerance. Also, compare peak acceleration & Shear Strain vs. depth obtained from SHAKE and D-MOD.

1. Select “Option 7” from input list

2. Click on “Clear”

3. Click on “No”
SHAKE Small Strain Calibration

2. Click on "Edit"

1. Click on third set of Option 1, i.e., Linear Elastic
2. Click on “Ok”

1. Enter “5” for top saturated layer

0 ⇒ Linear-Elastic Analysis
1. Enter “AND_FPsmall.out” for Master Output File

2. Enter “AND_FPsmall” for Name of Plot Files

3. Enter “1” for Output Generated for Layer

4. Enter “AND_FP Small Strain Calibration” for description
Create Input File – SHAKE Small Strain Calibration

1. Select THIRD set of Option 1 and click on “Add”, then add Options 2, 4, 5, and SIXTH sets of options 6 and 7

2. Click on “Save”

Options 1, 2, 4, 5, 6 and 7 have been added to the list of options in input file.
1. Switch folders until you change to “GeoMotions\ShortCourse\D-MOD” folder

2. Enter “AND_FPSmall.inp” in File name

3. Click on “Save”
Save EDT Database File

1. Click on "Save"
2. Click on "Yes"
Create Input File – SHAKE Small Strain Calibration

1. Scroll up

2. Select “Option 6 - Motion: P.AND_FP....”

3. Click on “Edit”
Create Input File – SHAKE Small Strain Calibration
Option 6 – Dynamic Analysis Solution Control
NCPR = 100 ⇒ Print results every 100th time step

1. Enter “100” for NCPR

2. Click on “Ok”
1st Iteration – Evaluation of Rayleigh Damping
Full Rayleigh Damping (n = 1, 3, 5, 7... & ξ = 0.5–5.5)

2. Click on “D-MOD”

1. Click on “Calibrate with Frequency.....” to select it
Execute D-MOD – 1st Iteration

1. Click on “Save”
1st Iteration – Process Output Files

1. Click on "Process"
1st Iteration – Process Output Files
Open Acceleration Time History File for Layer 1

1. If necessary, change to the “GeoMotions\ShortCourse\D-MOD” folder

2. Click on “AND_FPsmallA1L1.var” file to select it

3. Click on “Open”
1st Iteration – Process Output Files
Open SHAKE Calibration File – PGA & Shear Strain vs. Depth

1. If necessary, change to the "GeoMotions\ShortCourse\SHAKE" folder
2. Click on "AND_FPsmallA1-P.AND_FP.cal" file to select it
3. Click on "Open"
Display & Plot Results for Layer 1
Compare to Frequency Domain Spectrum, PGA/Shear Strain vs. Depth

1. Click on “Graph”
Display & Plot Results for Layer 1
Compare to Frequency Domain Spectrum

1. Click on “Response Spectrum for 5% damping”
2. Click on “Absolute Acceleration”
3. Click on “Other”
Display & Plot Results for Layer 1
Compare to Frequency Domain Spectrum

1. Click on “Other”
Display & Plot Results for Layer 1
Open File for Layer 1 from SHAKE Analysis

1. Switch folders until you change to “GeoMotions\ ShortCourse\ SHAKE” folder

2. Select the “AND_FPsmall-L1A1D2-1-Column 1-P.AND_FP.ahl” file

4. Click on “Open”
Display & Plot Results for Layer 1
Compute Spectrum from SHAKE Analysis

1. Click on "Spectra"

2. Click on "Ok"
1. Click on “Ok”
Display & Plot Results for Layer 1
Compare to Frequency Domain Spectrum, PGA/Shear Strain vs. Depth

1. Click on “Close”
2nd, 3rd, 4th Iterations – Evaluation of Rayleigh Damping

1. Repeat for \( n \) equal to 0, 3 & 5
SHAKE Small Strain Calibration
Better Match ⇒ Use $n = 1$ & $\zeta = 5$ for Nonlinear Analysis
1. Click on "Exit"