APPENDIX A

FINITE ELEMENT ANALYSIS

Figure A.1: Basic project properties
Figure A.2: Selecting basic units and maximum coordinates of the model
Figure A.3: Creating model geometry of a half-space with an open trench
Figure A.4: Assigning loads and model boundaries
Figure A.5: Creating material data set for half-space soil
Appendix A: Finite element analysis

Figure A.6: Assigning elastic parameters to half-space soil
Figure A.7: Mesh generation
Appendix A: Finite element analysis

Figure A.8: Calculation program
Figure A.9: Defining parameters for dynamic analysis
Appendix A: Finite element analysis

Figure A.10: Defining dynamic load parameters in calculation program
Appendix A: Finite element analysis

Figure A.11: Node selection for displacement-time histories
Appendix A: Finite element analysis

Figure A.12: Starting calculation phase
Figure A.13: End of calculation phase
Figure A.14: Deformed mesh
Appendix A: Finite element analysis

Figure A.15: Contour map showing vertical displacement components
Figure A.16: Contour map showing horizontal displacement components
Figure A.17: Curve generation at a preselected node
Figure A.18: Displacement-time curve for vertical component of surface displacement at the desired node
Figure A.19: Displacement-time curve for horizontal component of surface displacement at the desired node
APPENDIX B
ESTIMATING AMPLITUDE REDUCTION

Amplitude reduction factor \( (A_R) \) at a certain point is the ratio of peak surface displacement amplitudes with and without barrier. The average amplitude reduction factor \( (A_{my} \text{ or } A_{mx} \text{ depending on the component of vibration under consideration}) \) is the weighted average of \( A_R \) values over the range of study. The method is explained with reference to vertical vibration isolation in active case \((L=1)\) by an open trench of dimension, \( D=1 \) and \( W=0.2 \) as follows. Variation of peak surface displacement amplitudes with and without barrier against normalized distances from barrier is depicted in Figure B.1. \( A_R \) values obtained at different distances are shown in Figure B.2.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure_b_1.png}
\caption{Peak surface displacement amplitudes with and without barrier measured at different points beyond barrier}
\end{figure}

\[
A_{my} = \frac{1}{S} \int_{s}^{e} A_R(x)dx \tag{B.1}
\]
Appendix B: Estimating amplitude reduction

\[ \int_{0}^{s} A_{R}(x)dx = \text{Area bounded by } A_{R} \text{ curve and X-axis} \]

\[ s = \text{Length of zone of study} \]

Figure B.2: Amplitude reduction factors versus normalized distances from barrier

The distance between the 1\textsuperscript{st} two observations is \(0.4L_{R} = \text{(1.5}L_{R}-1.1L_{R})\) and all other observations are taken in intervals of \(0.5L_{R}\). Applying trapezoidal rule,

\[
\text{Area} = 0.4L_{R} \left( \frac{0.34 + 0.27}{2} \right) + 0.5L_{R} \left[ \frac{(0.27 + 0.35)}{2} + 2 \left( \frac{0.30 + 0.21 + 0.18 + 0.26 + 0.32 + 0.28 + 0.30 + 0.31 + 0.28 + 0.35 + 0.39 + 0.37 + 0.32}{2} \right) \right] = 2.592L_{R}
\]

\[ s = 10L_{R}-1.1L_{R} = 8.9L_{R} \]

\[ A_{my} = \frac{2.592L_{R}}{8.9L_{R}} = 0.29 \]

Hence, in case of an open trench of \(D=1\) and \(W=0.2\) in active case \((L=1)\), average amplitude reduction factor for vertical vibration component \((A_{my})\) is 0.29.
APPENDIX C

SIMPLIFIED REGRESSION MODELS

The method adopted in formulating simplified design models of open trenches is discussed in this section with reference to the simplified regression model developed for estimating $A_{my}$ in passive case ($L=5$). Against a given value of depth, $D$ of an open trench, $A_{my}/A_{mx}$ marginally differs depending on the barrier width, $W$. For fitting regression curves, overall amplitude reduction factors can be averaged as shown in Table C.1.

Table C.1: Estimating average $A_{my}$ against $D$

<table>
<thead>
<tr>
<th>$D$</th>
<th>$W$=0.2</th>
<th>$W$=0.4</th>
<th>$W$=0.6</th>
<th>Average $A_{my}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.3</td>
<td>0.62</td>
<td>0.57</td>
<td>0.54</td>
<td>0.576667</td>
</tr>
<tr>
<td>0.4</td>
<td>0.48</td>
<td>0.43</td>
<td>0.4</td>
<td>0.436667</td>
</tr>
<tr>
<td>0.6</td>
<td>0.33</td>
<td>0.3</td>
<td>0.27</td>
<td>0.3</td>
</tr>
<tr>
<td>0.8</td>
<td>0.25</td>
<td>0.22</td>
<td>0.21</td>
<td>0.226667</td>
</tr>
<tr>
<td>1.0</td>
<td>0.19</td>
<td>0.17</td>
<td>0.16</td>
<td>0.173333</td>
</tr>
<tr>
<td>1.2</td>
<td>0.17</td>
<td>0.15</td>
<td>0.14</td>
<td>0.153333</td>
</tr>
<tr>
<td>1.5</td>
<td>0.14</td>
<td>0.13</td>
<td>0.12</td>
<td>0.13</td>
</tr>
</tbody>
</table>

The trend of variation of $A_{my}$ versus $D$ (values shown in last and first columns of Table C.1) follows a power law. The equation of which is given by:

$$y = Ax^B$$  \hspace{1cm} (C.1a)

For the values shown in Table C.1, $x$ represents normalized depth, $D$ and $y$ signifies the corresponding values of $A_{my}$. The coefficients $A$ and $B$ can be obtained by least square fitting method as:
Appendix C: Simplified regression models

\[ b = \frac{n \sum \ln x \ln y - \sum \ln x \sum \ln y}{n \sum (\ln x)^2 - (\sum \ln x)^2} \]  
(C.1b)

\[ a = \frac{\sum \ln y - b \sum \ln x}{n} \]  
(C.1c)

Where, \( B = b \) and \( A = e^a \)

There exists a coefficient of determination \((R^2)\) which can be obtained as follows:

\[ R^2 = \frac{\left[ \sum \ln x \ln y - \frac{1}{n} \sum \ln x \sum \ln y \right]^2}{\sum (\ln x)^2 - \frac{1}{n} \left( \sum \ln x \right)^2 \left[ \sum (\ln y)^2 - \frac{1}{n} \left( \sum \ln y \right)^2 \right]} \]  
(C.1d)

<table>
<thead>
<tr>
<th>( x )</th>
<th>( y )</th>
<th>( \ln x )</th>
<th>( \ln y )</th>
<th>( \ln x \ln y )</th>
<th>( (\ln x)^2 )</th>
<th>( (\ln y)^2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.3</td>
<td>0.57666</td>
<td>-1.20397</td>
<td>-0.5505</td>
<td>0.66279</td>
<td>1.449551</td>
<td>0.303053</td>
</tr>
<tr>
<td>0.4</td>
<td>0.43666</td>
<td>-0.91629</td>
<td>-0.8286</td>
<td>0.759239</td>
<td>0.839589</td>
<td>0.686579</td>
</tr>
<tr>
<td>0.6</td>
<td>0.3</td>
<td>-0.51083</td>
<td>-1.20397</td>
<td>0.61502</td>
<td>0.260943</td>
<td>1.449551</td>
</tr>
<tr>
<td>0.8</td>
<td>0.22666</td>
<td>-0.22314</td>
<td>-1.4843</td>
<td>0.331213</td>
<td>0.049793</td>
<td>2.203159</td>
</tr>
<tr>
<td>1.0</td>
<td>0.17333</td>
<td>0</td>
<td>-1.75256</td>
<td>0</td>
<td>0</td>
<td>3.071459</td>
</tr>
<tr>
<td>1.2</td>
<td>0.15333</td>
<td>0.182322</td>
<td>-1.87516</td>
<td>-0.34188</td>
<td>0.033241</td>
<td>3.516236</td>
</tr>
<tr>
<td>1.5</td>
<td>0.13</td>
<td>0.405465</td>
<td>-2.04022</td>
<td>-0.82724</td>
<td>0.164402</td>
<td>4.162501</td>
</tr>
<tr>
<td>( \sum = )</td>
<td>-2.26645</td>
<td>-9.73532</td>
<td>1.199141</td>
<td>2.797518</td>
<td>15.39254</td>
<td></td>
</tr>
</tbody>
</table>

\[ b = \frac{7 \times 1.1999141 - (-2.26645)(-9.73532)}{7 \times 2.797518 - (-2.26645)^2} = -0.9463 \]

\[ a = \frac{(-9.73532) - (-0.9463)(-2.26645)}{7} = -1.69716 \]
Appendix C: Simplified regression models

Coefficients of Equation (3.1a) are computed as; \(B=b=-0.9463\) and \(A = e^a = 0.183203\).

The coefficient of determination \(R^2\) can be obtained as:

\[
R^2 = \frac{\left(1.199141 - \frac{1}{7} \times (-2.26645)(-9.73532)\right)^2}{2.797518 - \frac{1}{7} \times (-2.26645)^2 \left[15.39254 - \frac{1}{7} \times (-9.73532)^2\right]} = 0.997353
\]

Replacing \(x\) by \(D\) and \(y\) by \(A_{my}\), Equation (C.1a) correct up to two decimal places can be written as:

\[
A_{my} = 0.18D^{(-0.95)} \quad (C.2)
\]

Equation (C.2) represents the expression of the simplified model for estimating \(A_{my}\) in passive case \((L=5)\). The other regression models are obtained in a similar way.