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APPENDIX A

FINITE ELEMENT ANALYSIS

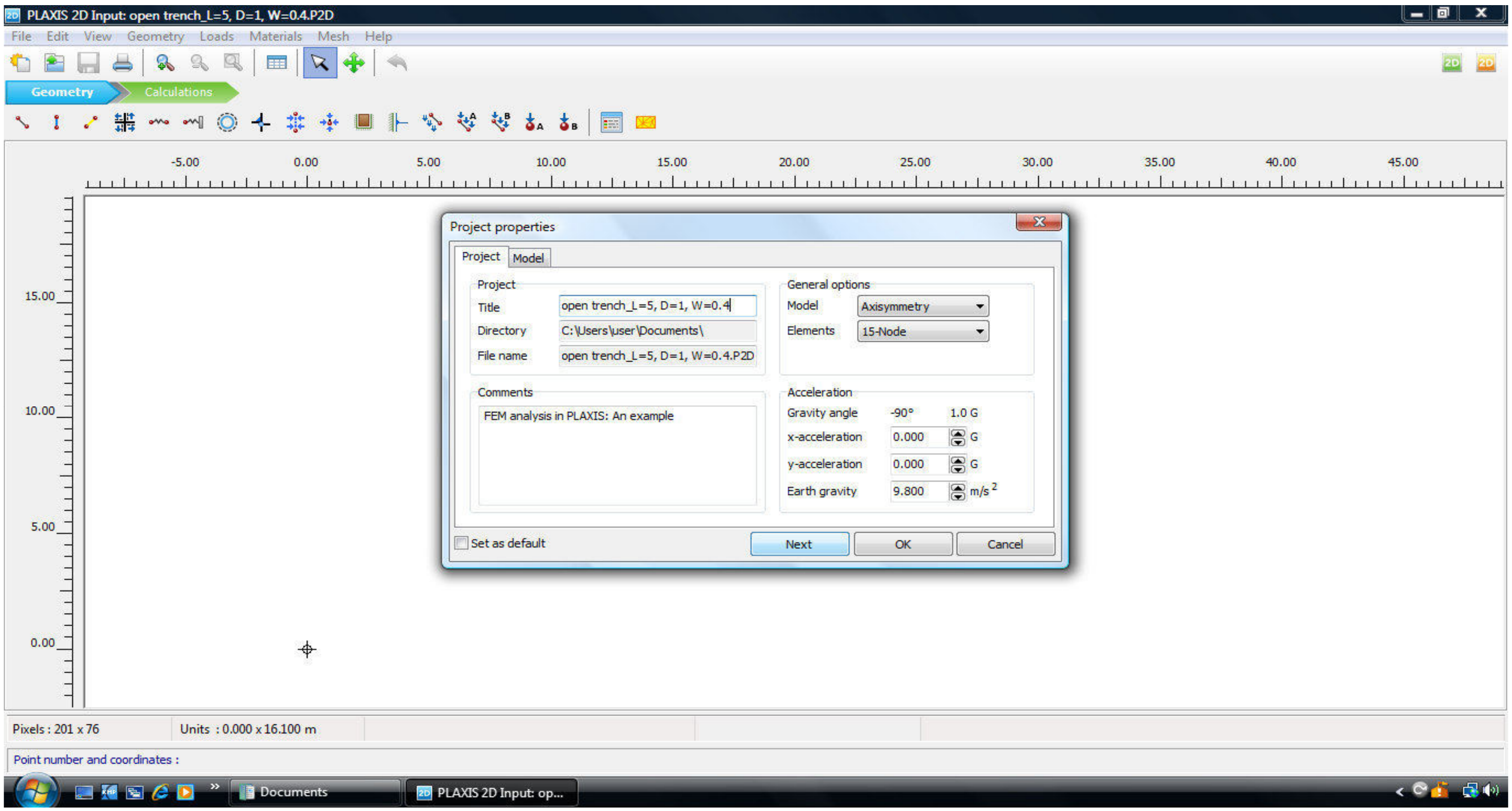

Figure A.1: Basic project properties

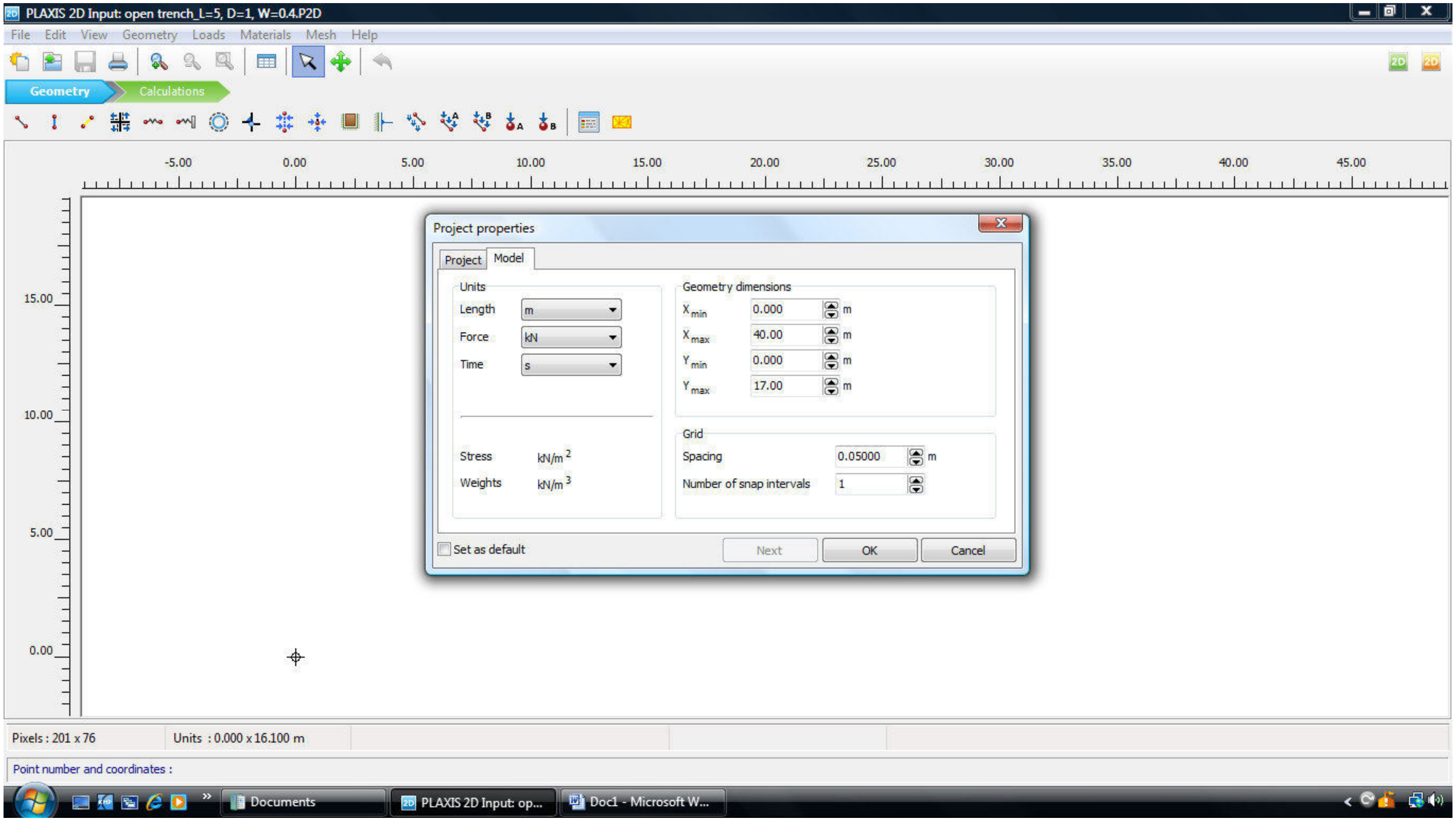

Figure A.2: Selecting basic units and maximum coordinates of the model

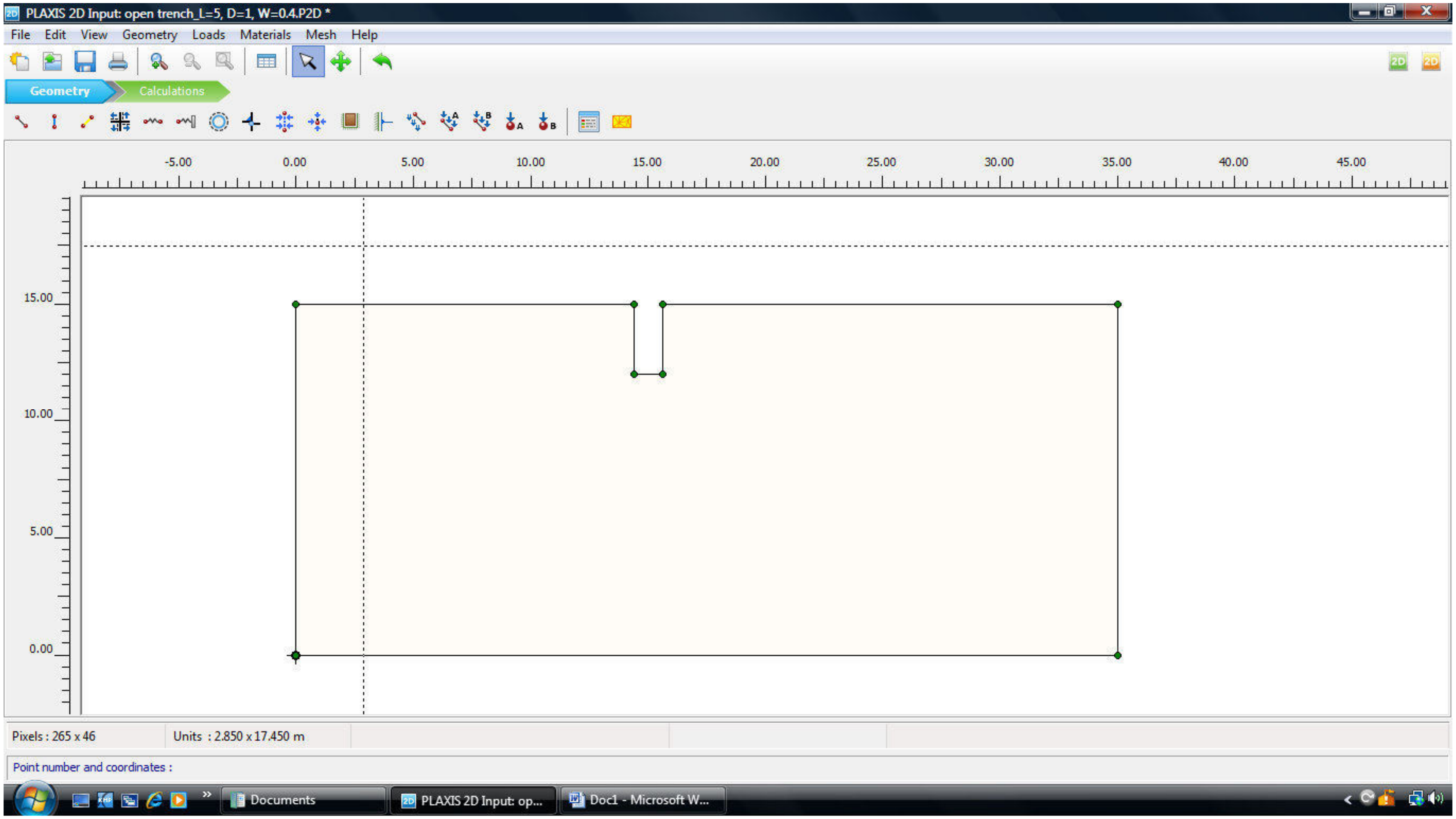

Figure A.3: Creating model geometry of a half-space with an open trench

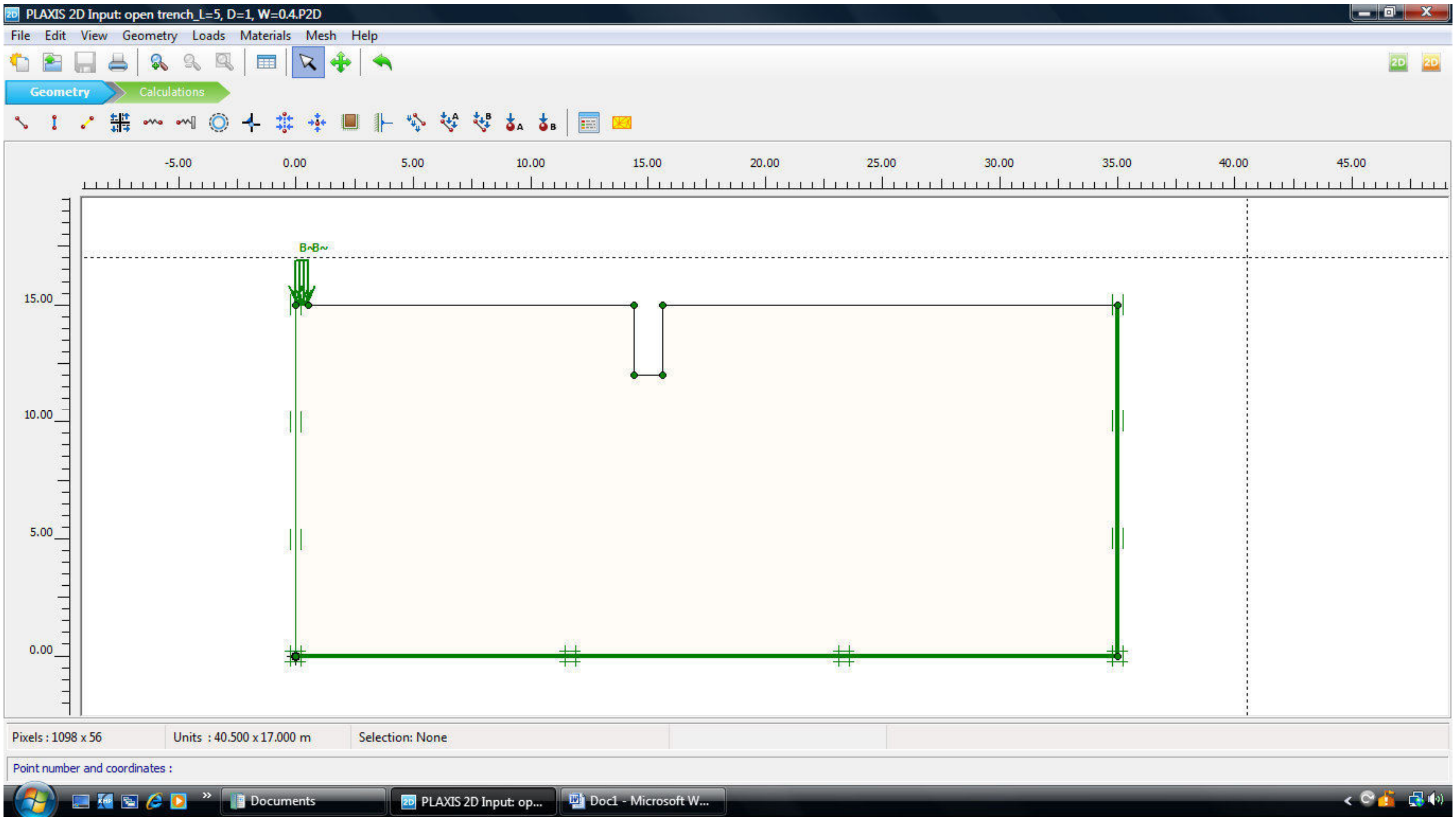

Figure A.4: Assigning loads and model boundaries

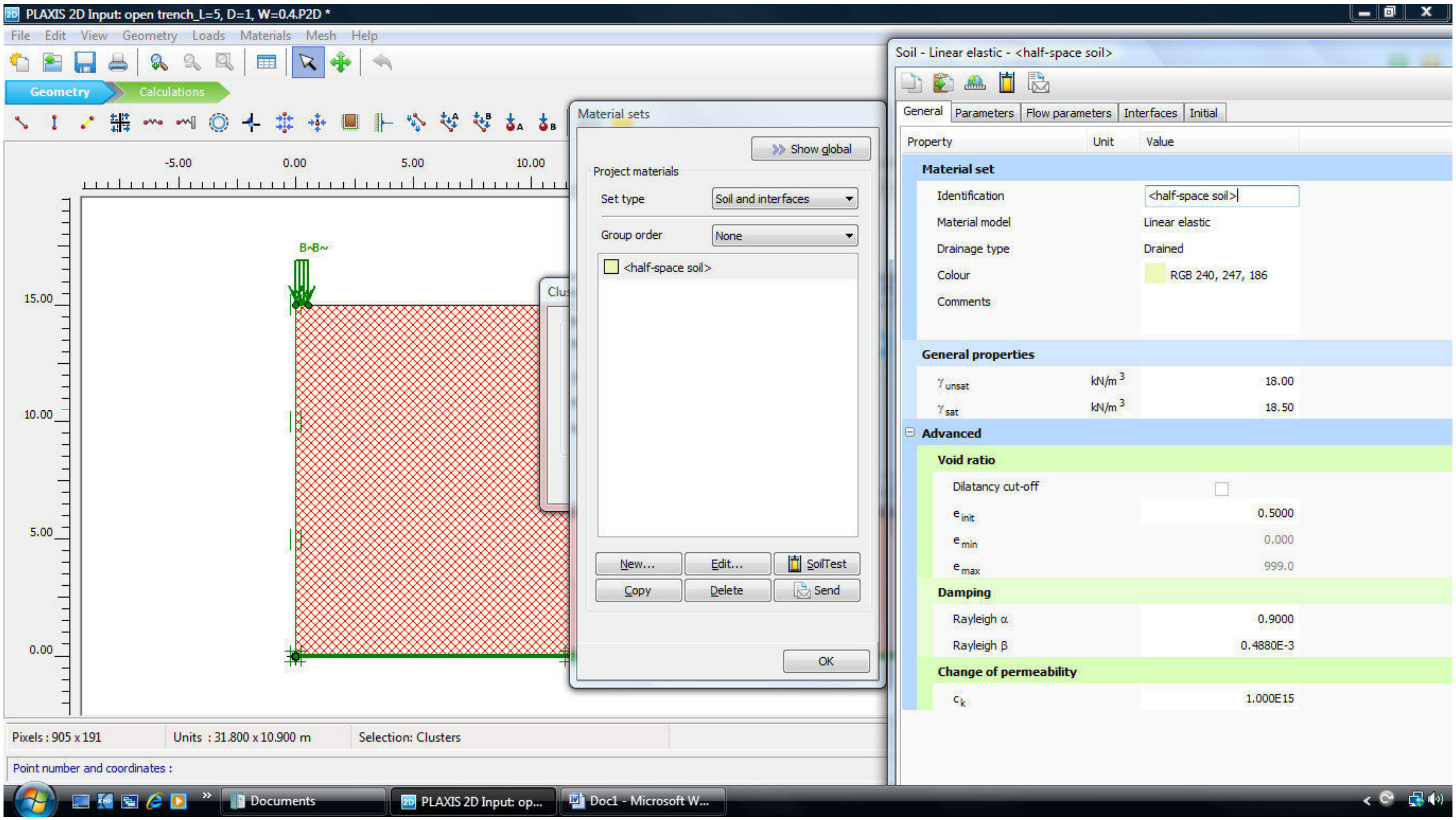

Figure A.5: Creating material data set for half-space soil

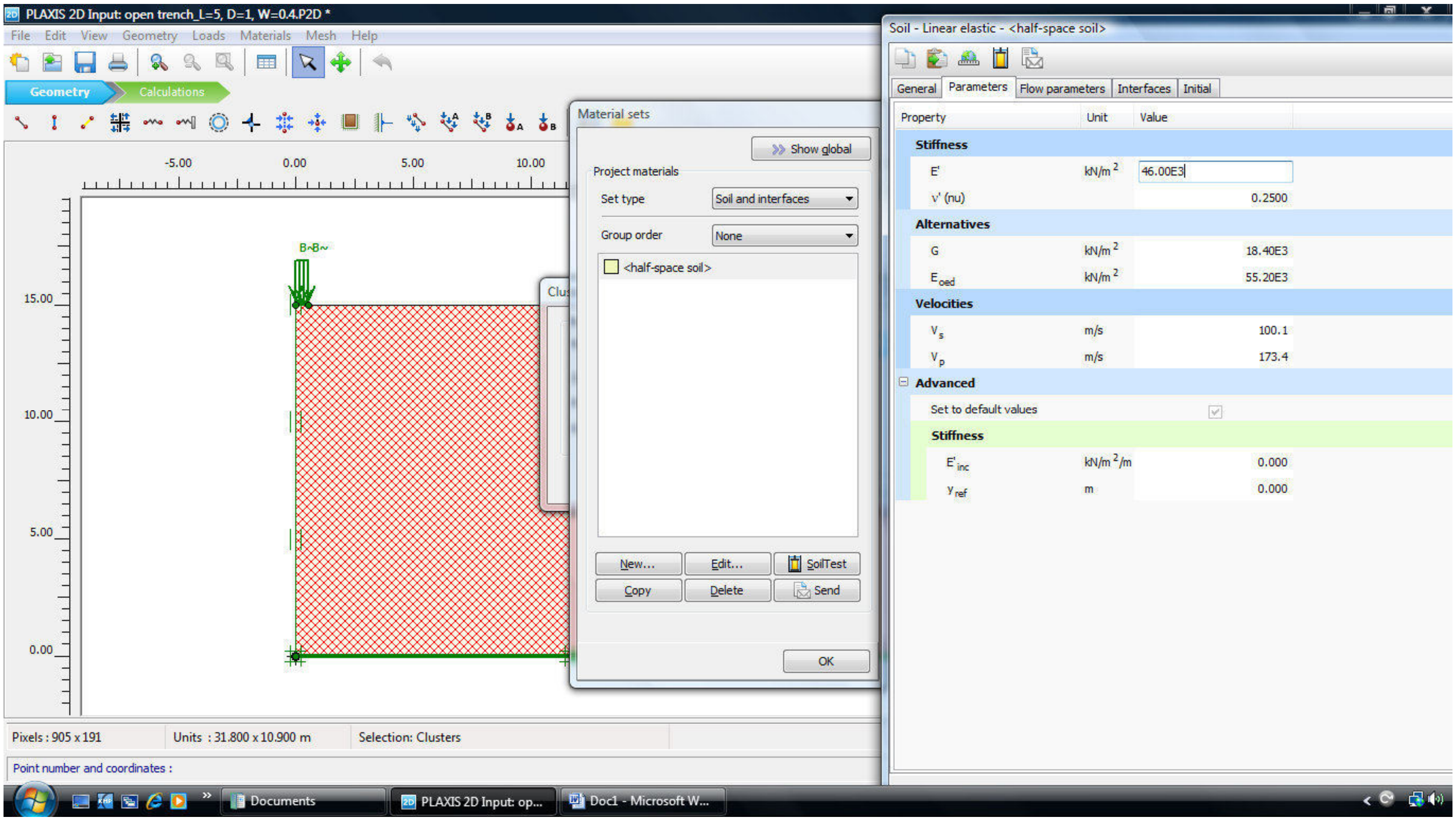

Figure A.6: Assigning elastic parameters to half-space soil

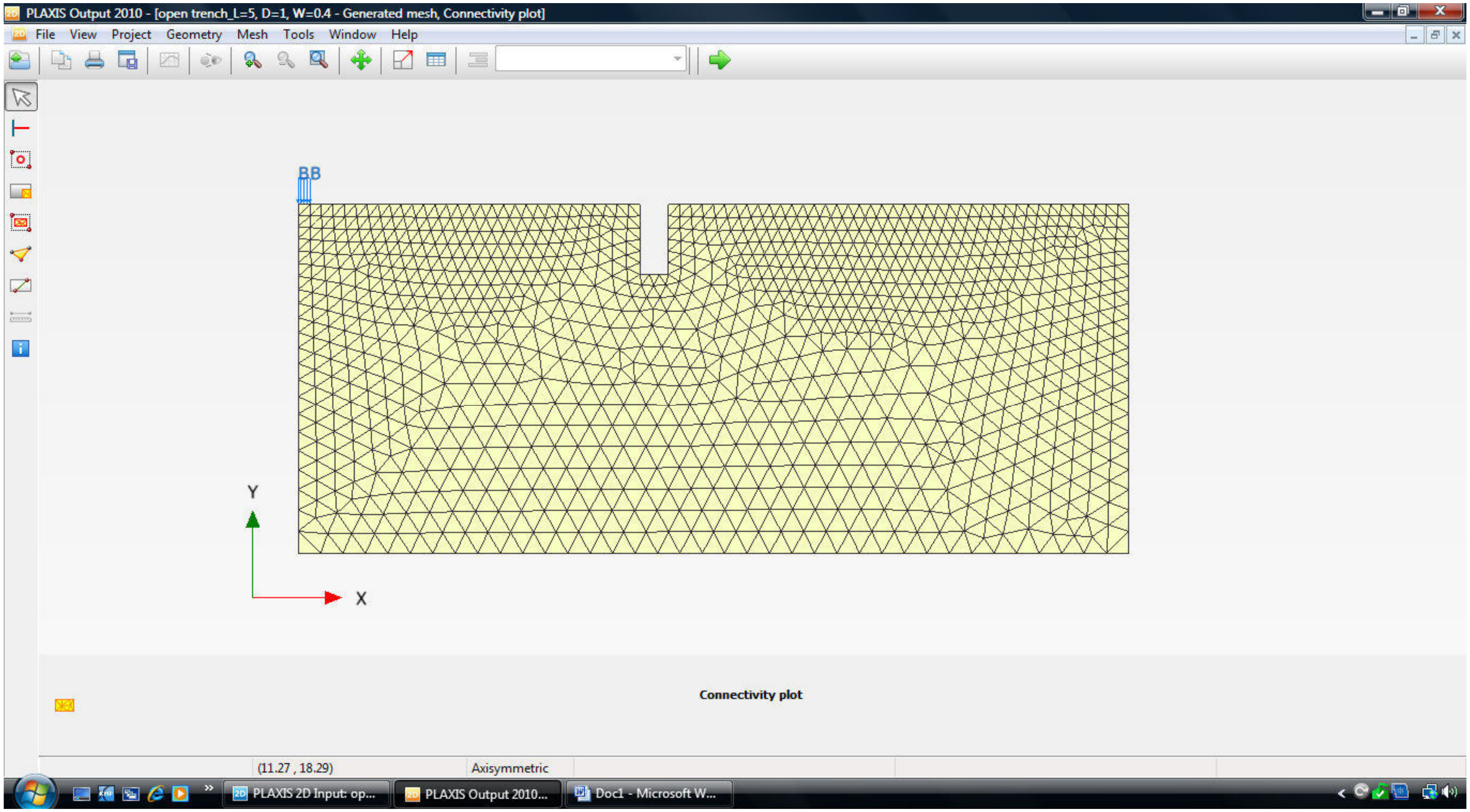

Figure A.7: Mesh generation

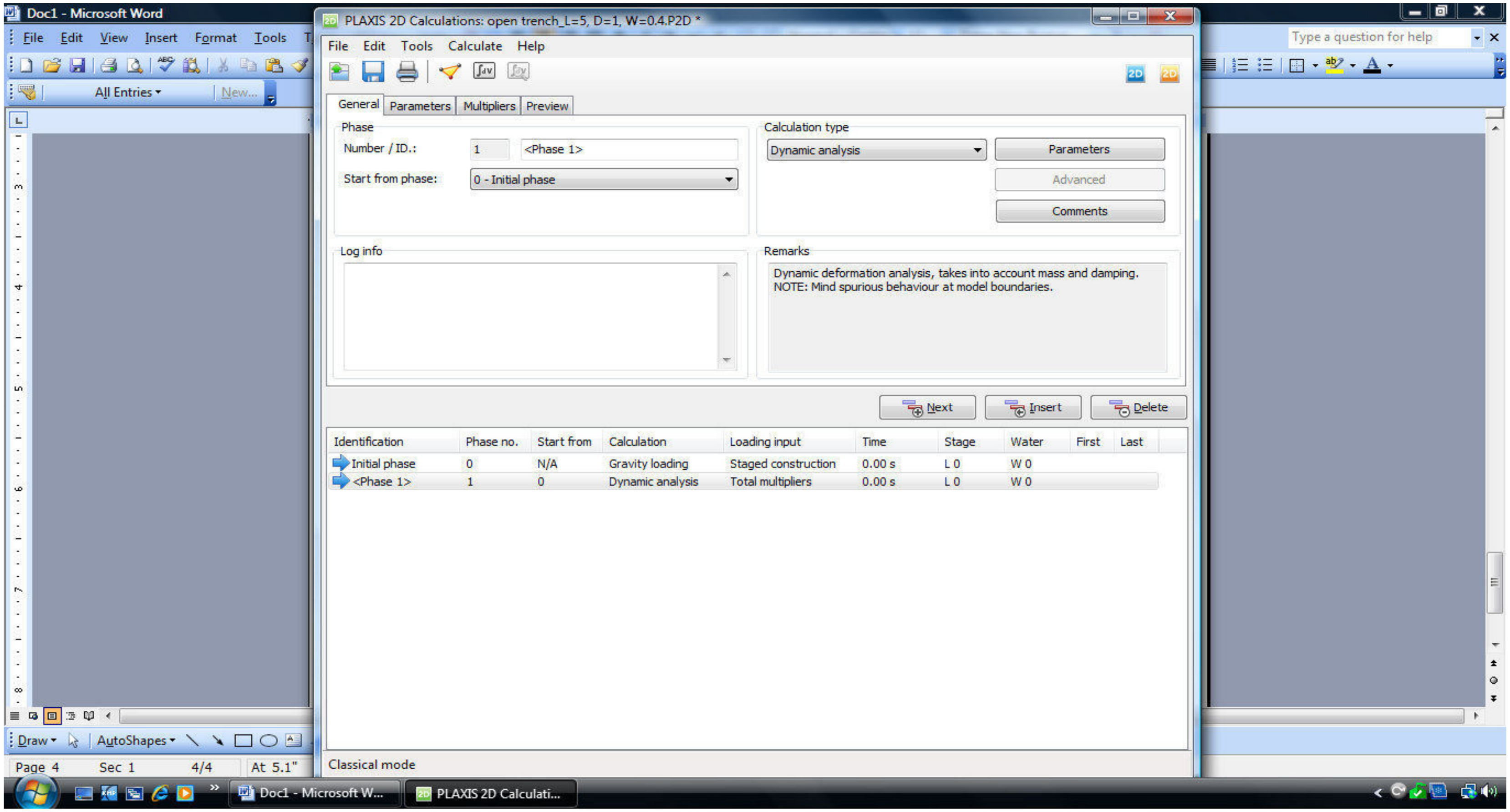

Figure A.8: Calculation program

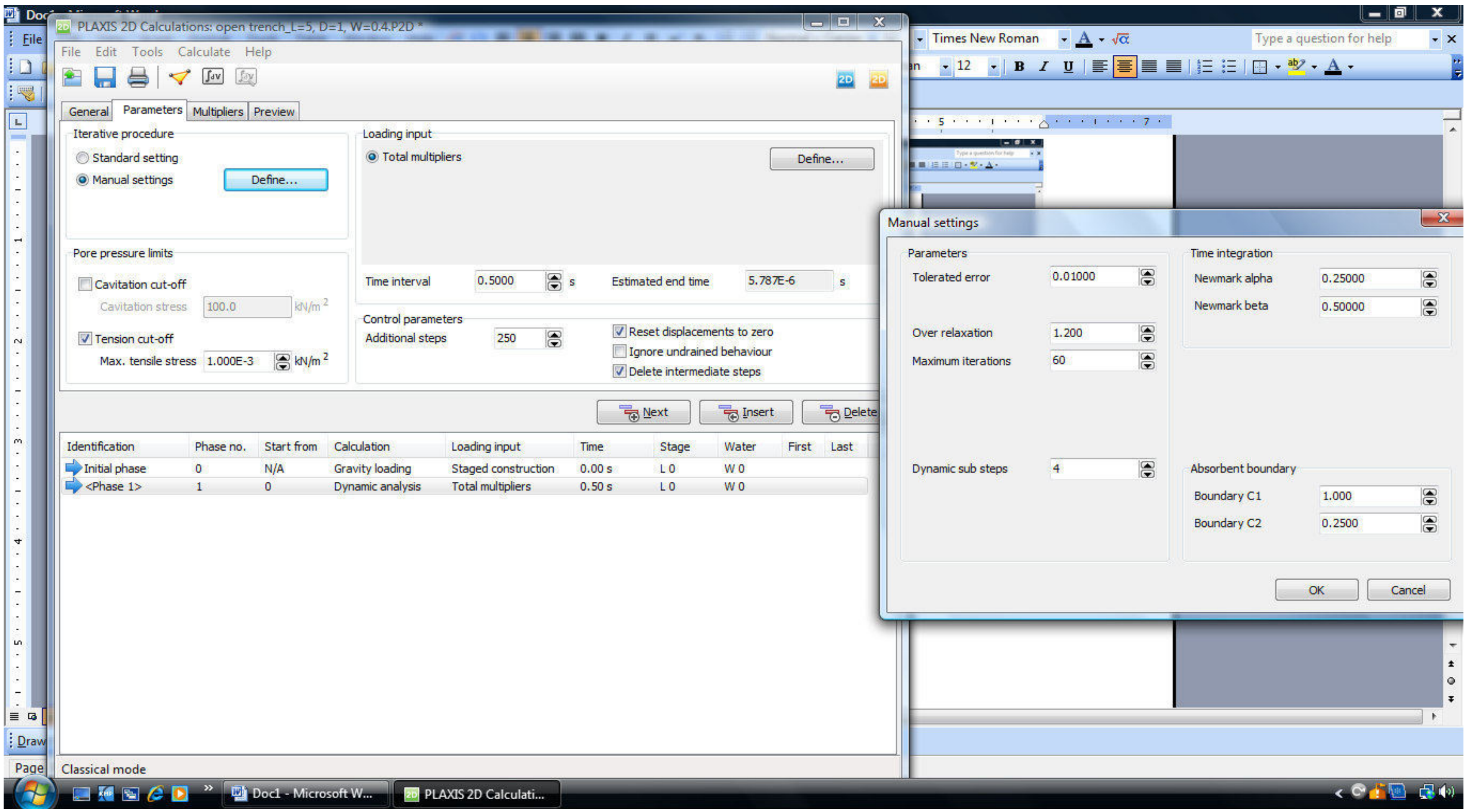

Figure A.9: Defining parameters for dynamic analysis

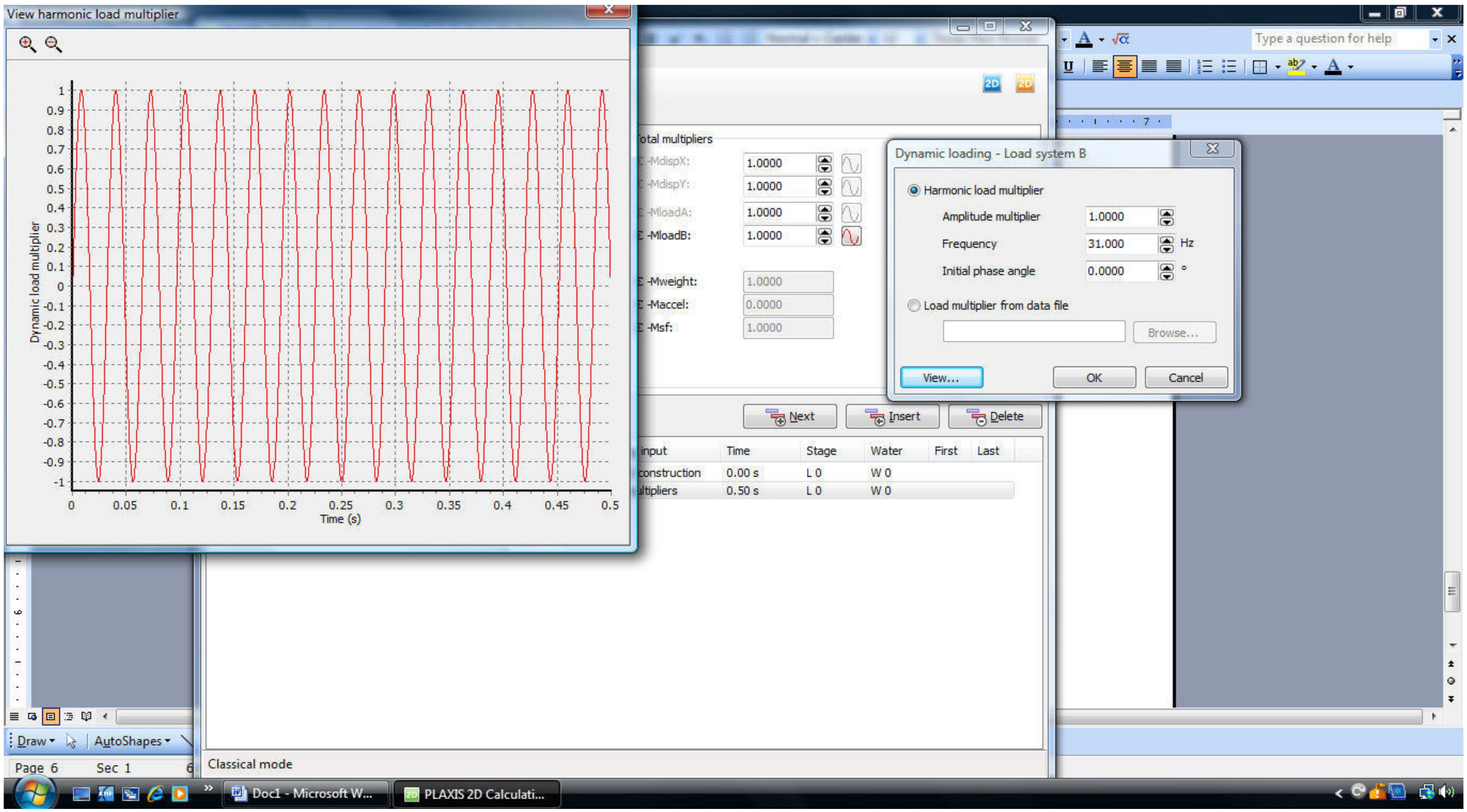

Figure A.10: Defining dynamic load parameters in calculation program

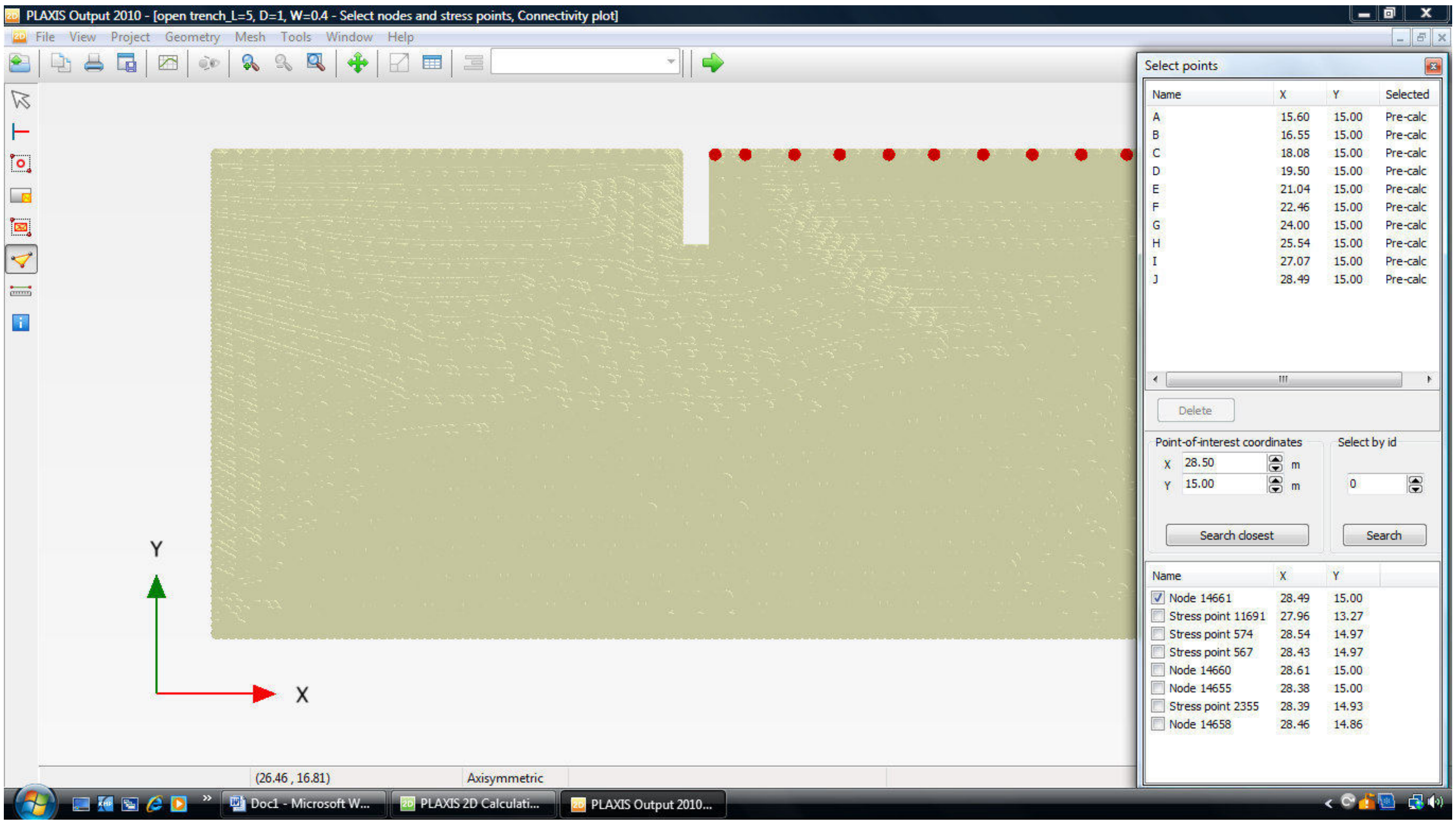

Figure A.11: Node selection for displacement-time histories

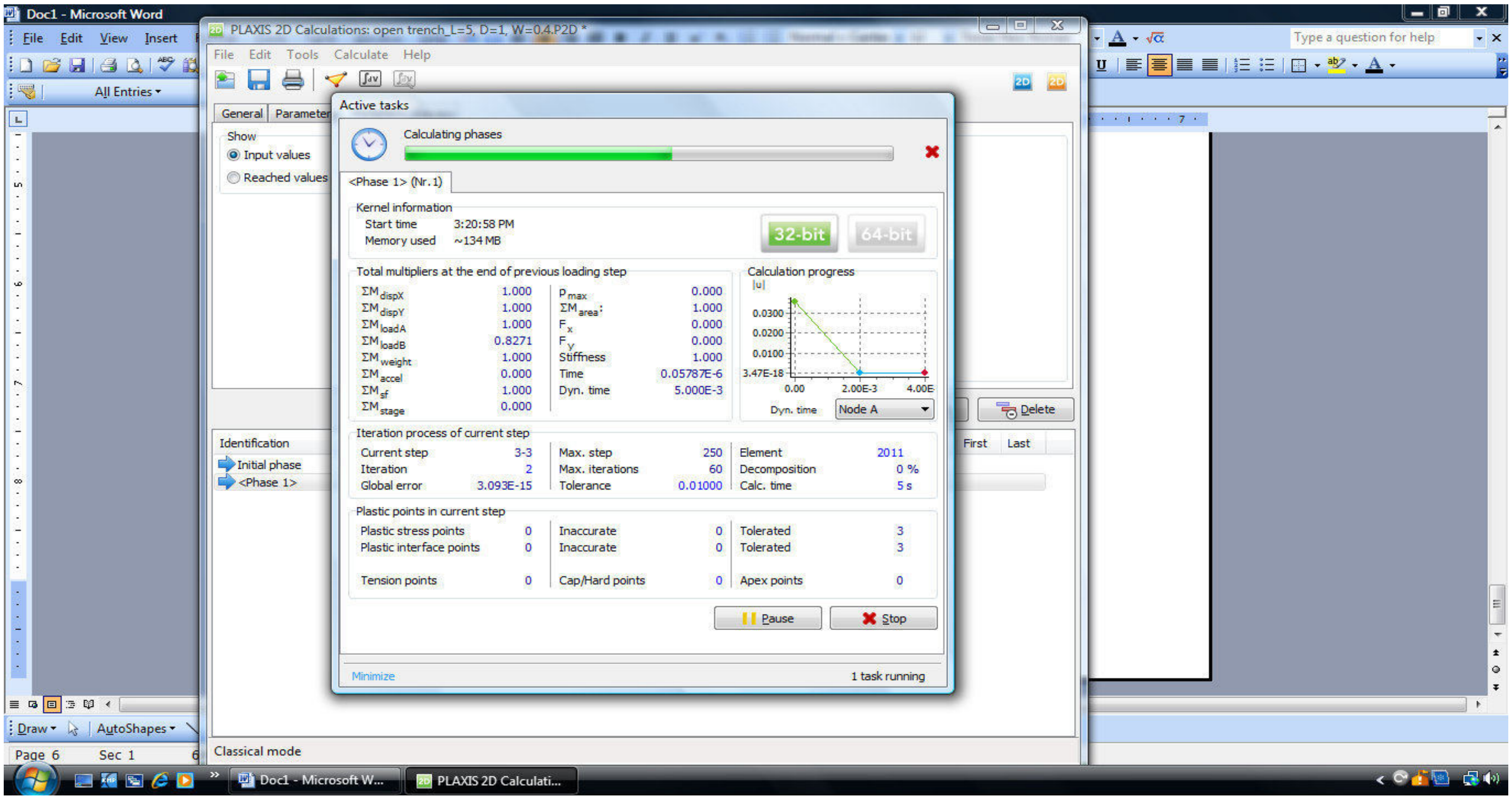

Figure A.12: Starting calculation phase

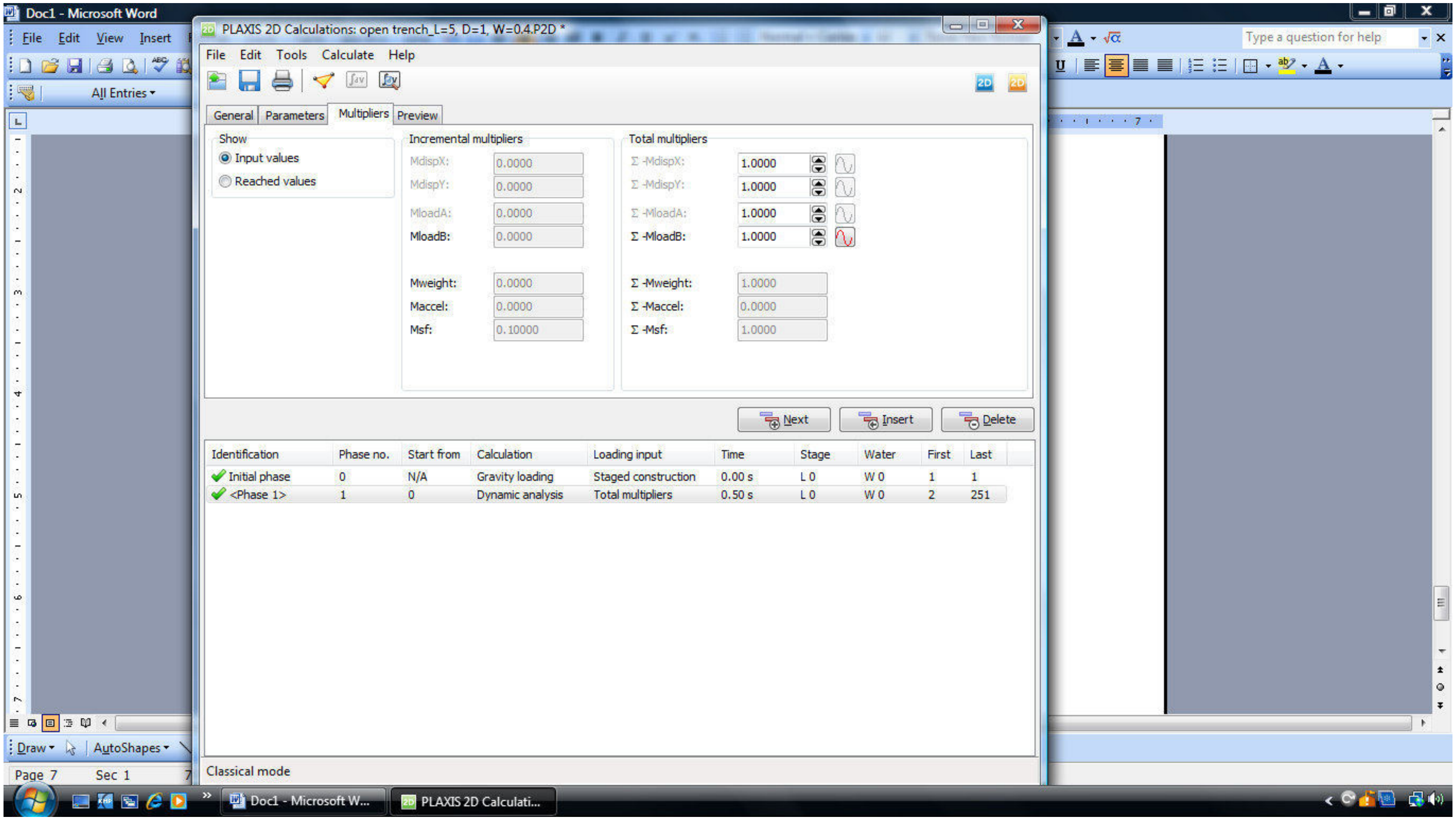

Figure A.13: End of calculation phase

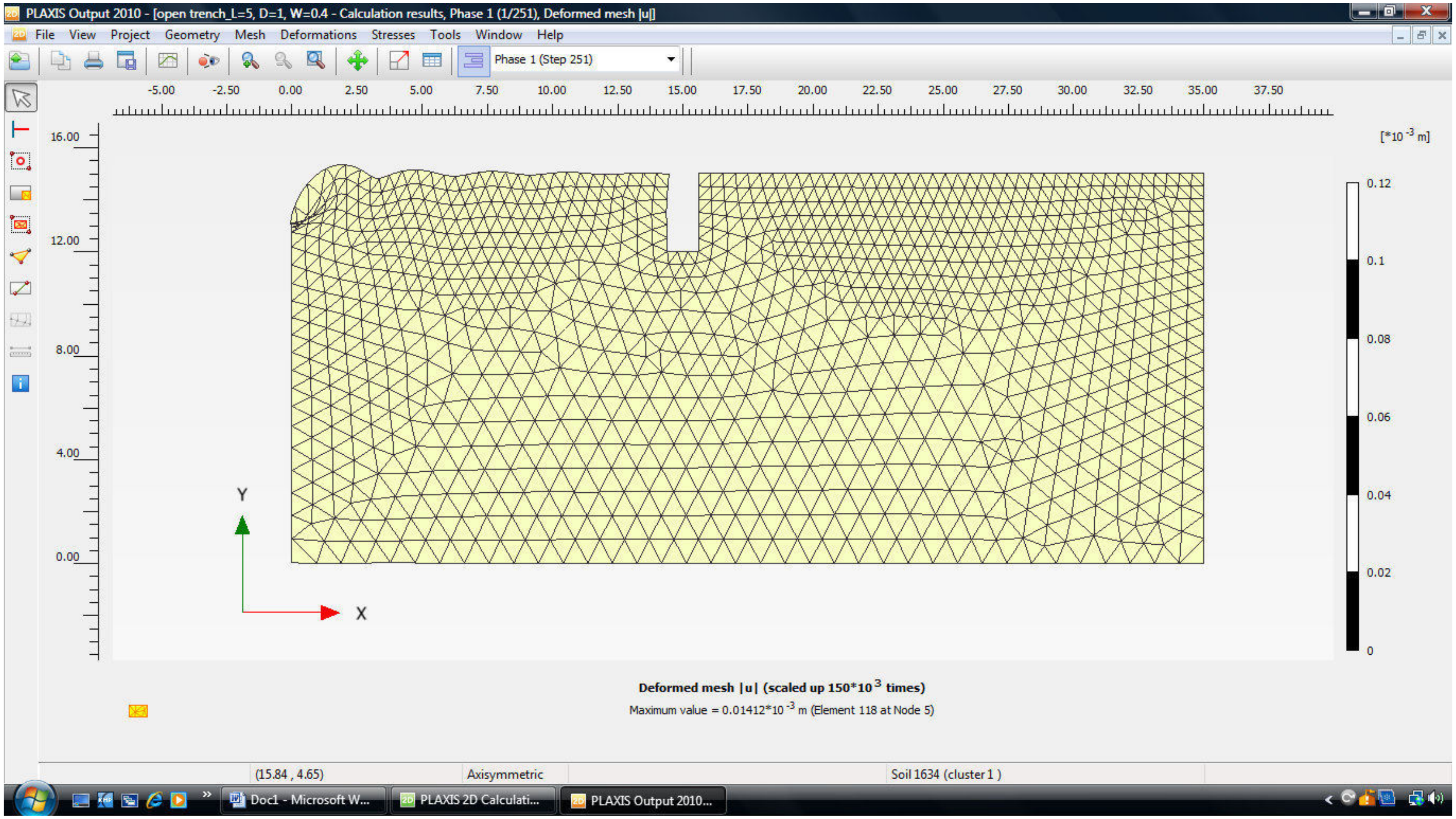

Figure A.14: Deformed mesh

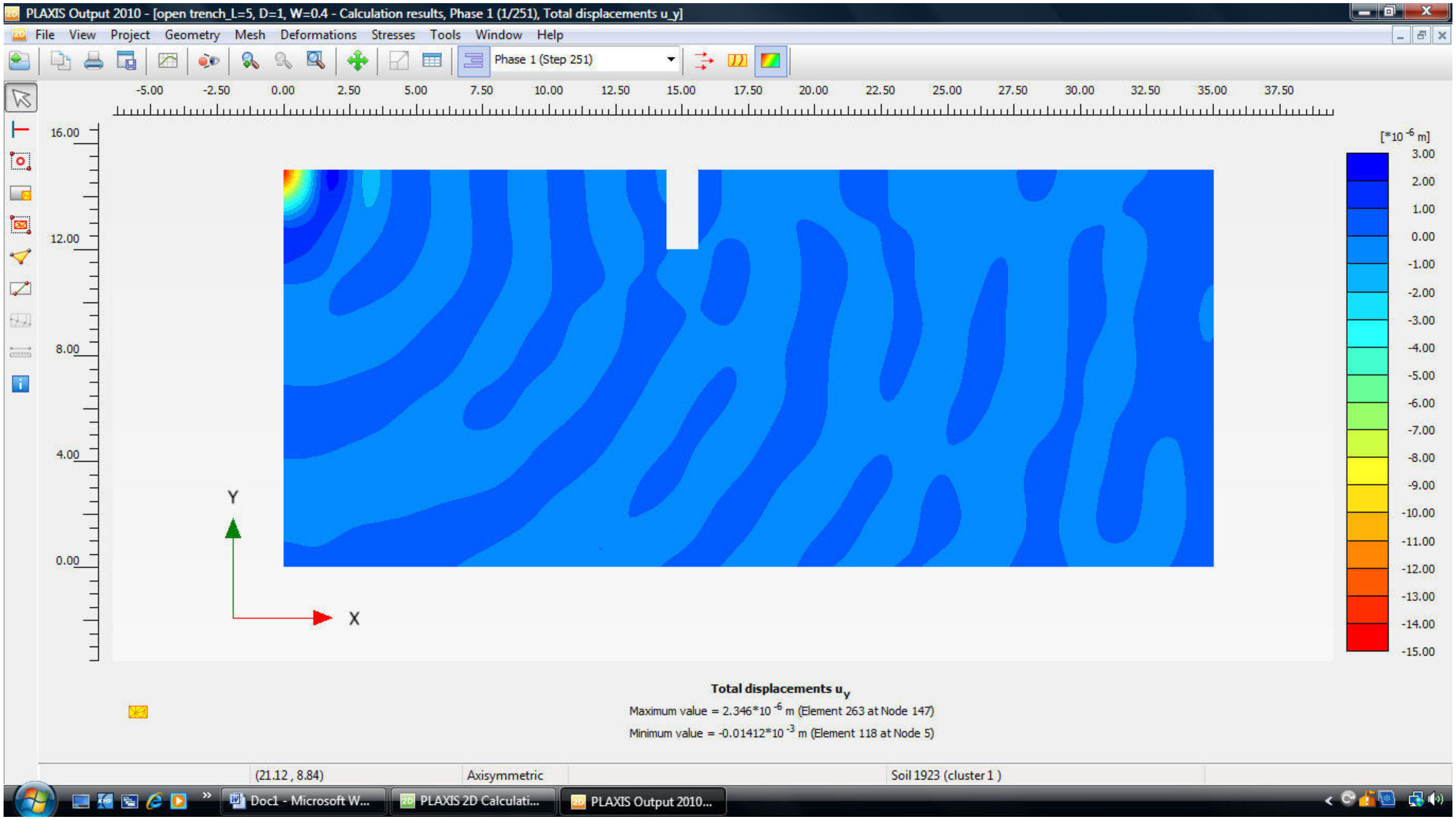

Figure A.15: Contour map showing vertical displacement components

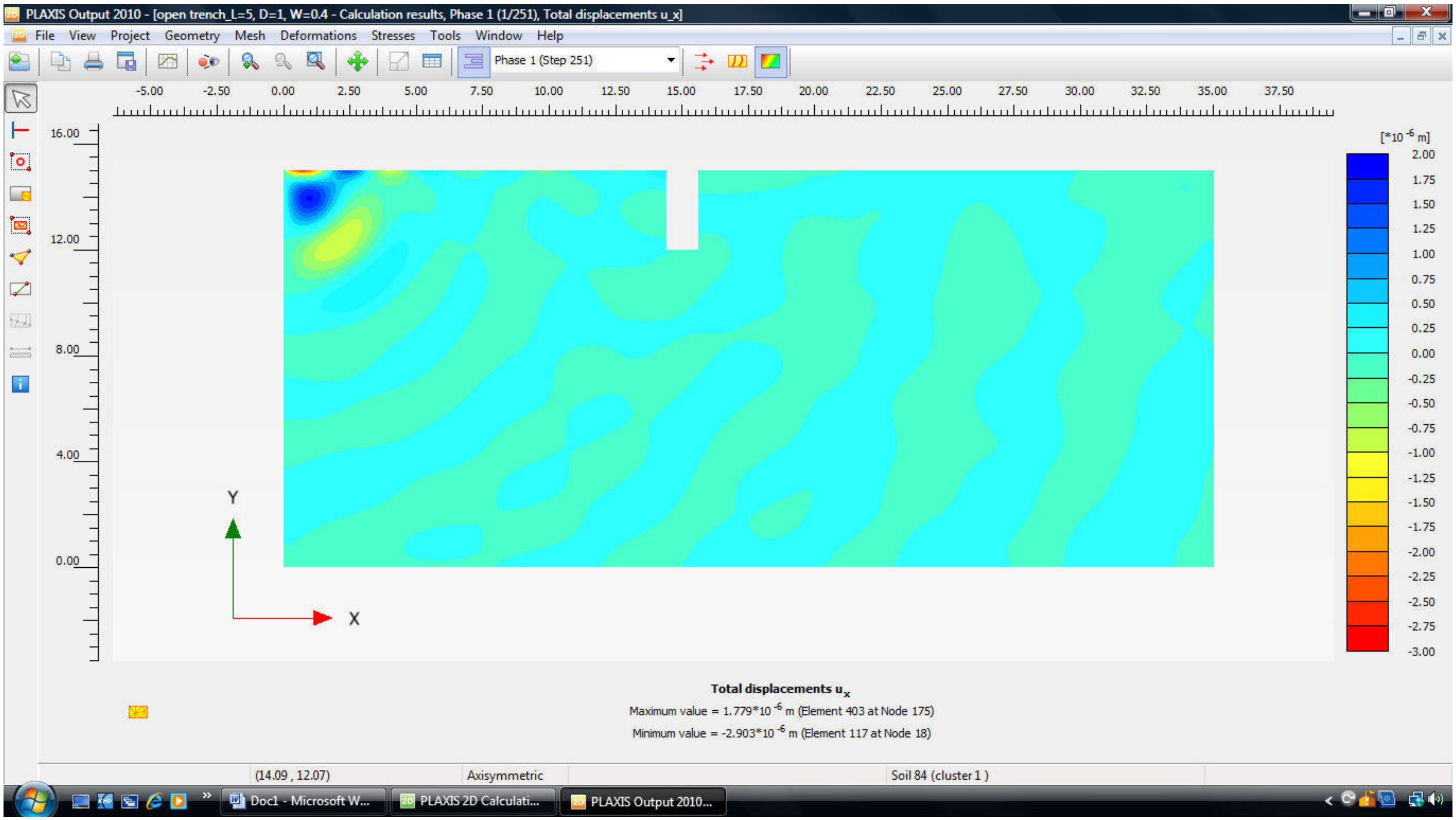

Figure A.16: Contour map showing horizontal displacement components

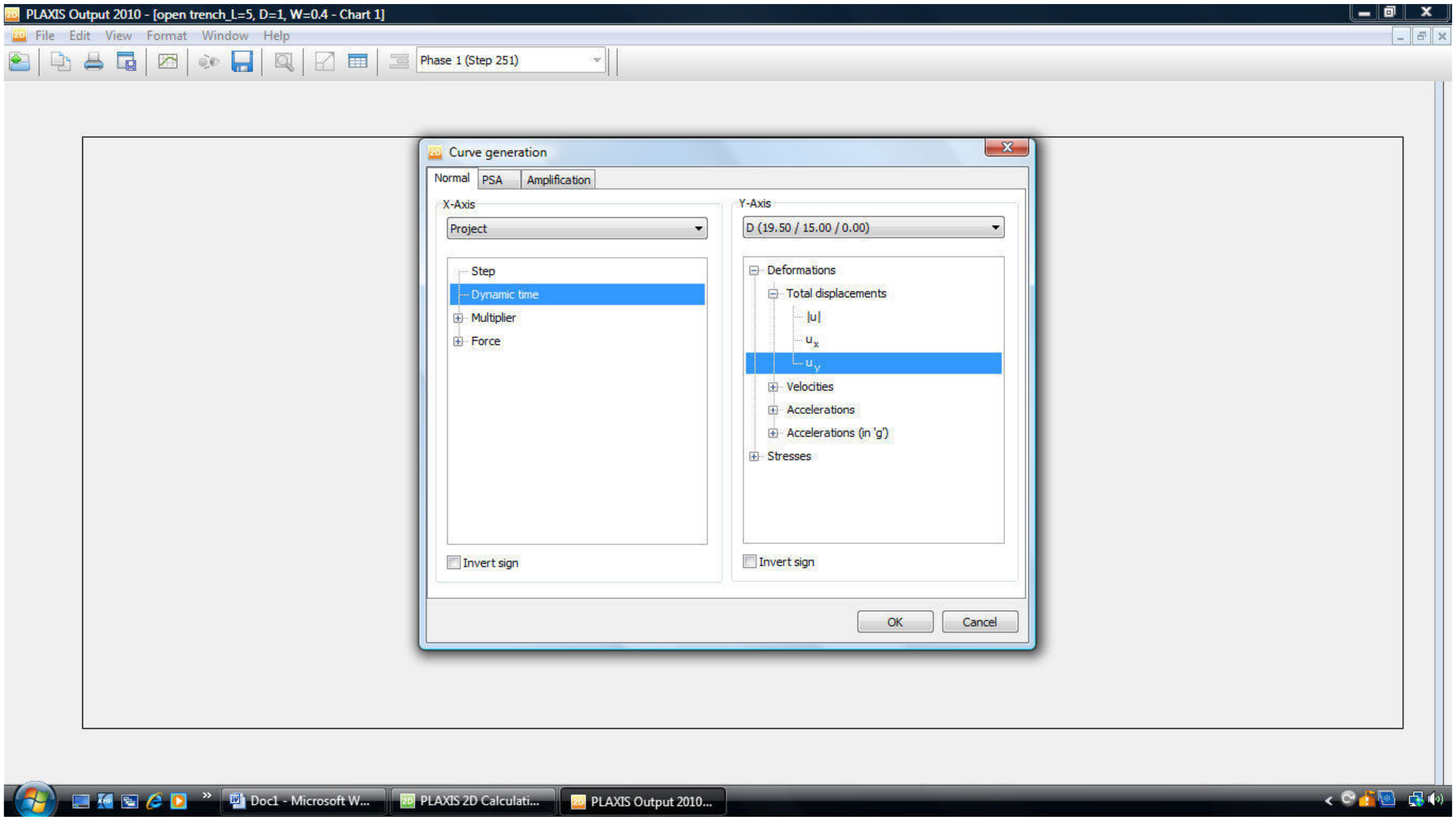

Figure A.17: Curve generation at a preselected node

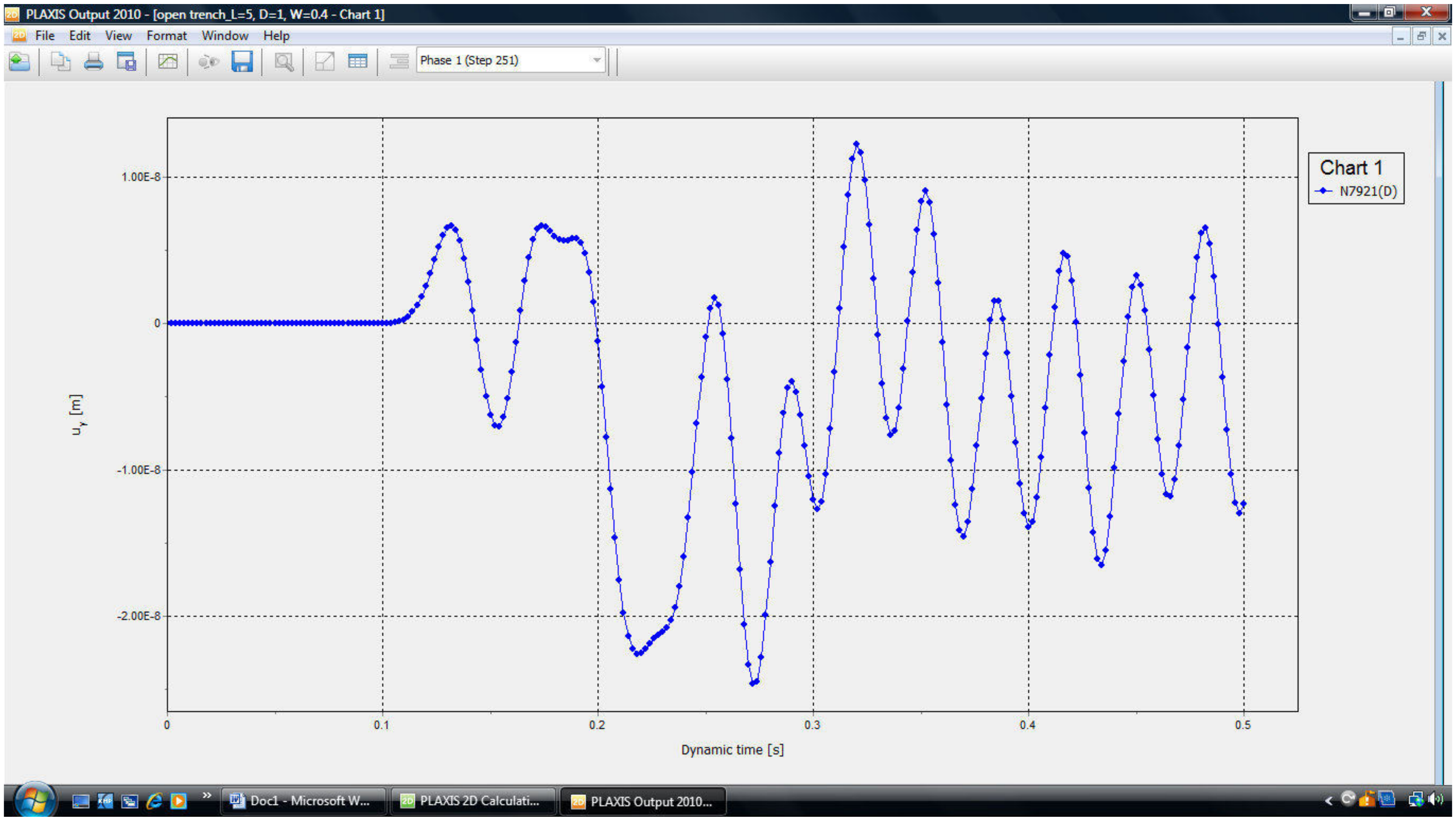

Figure A.18: Displacement-time curve for vertical component of surface displacement at the desired node

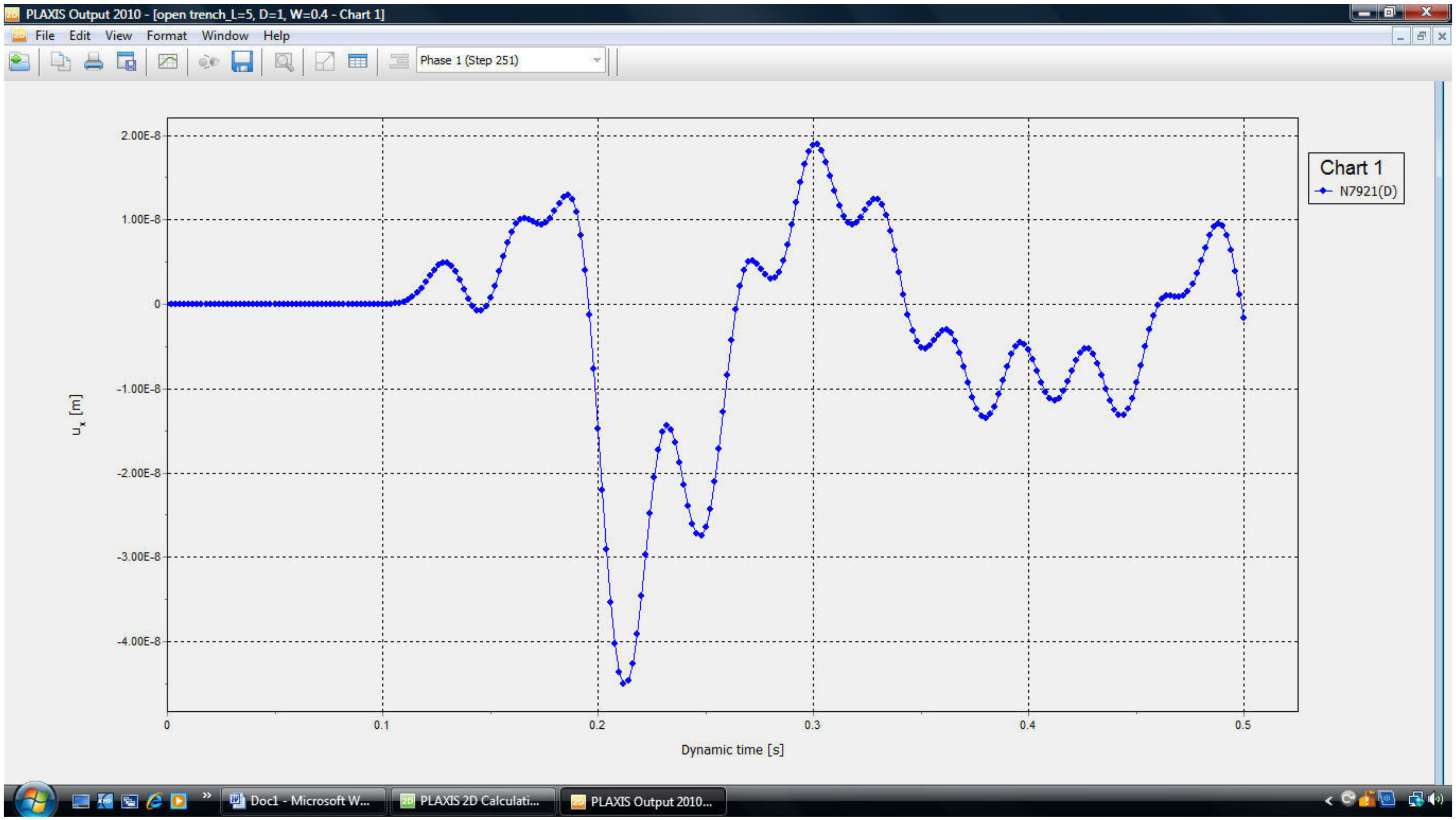

Figure A.19: Displacement-time curve for horizontal component of surface displacement at the desired node

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} or A_{mx} 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*.

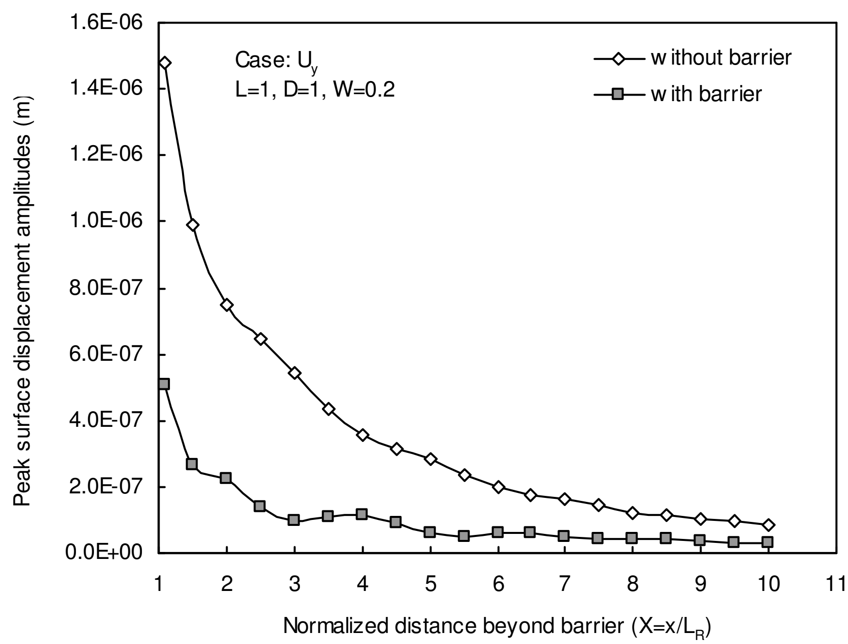

Figure B.1: Peak surface displacement amplitudes with and without barrier measured at different points beyond barrier

$$A_{my} = \frac{1}{s}\int_{o}^{s} A_R(x)dx \tag{B.1}$$

$\int_0^s A_R(x)dx$ = Area bounded by A_R curve and X-axis

s = Length of zone of study

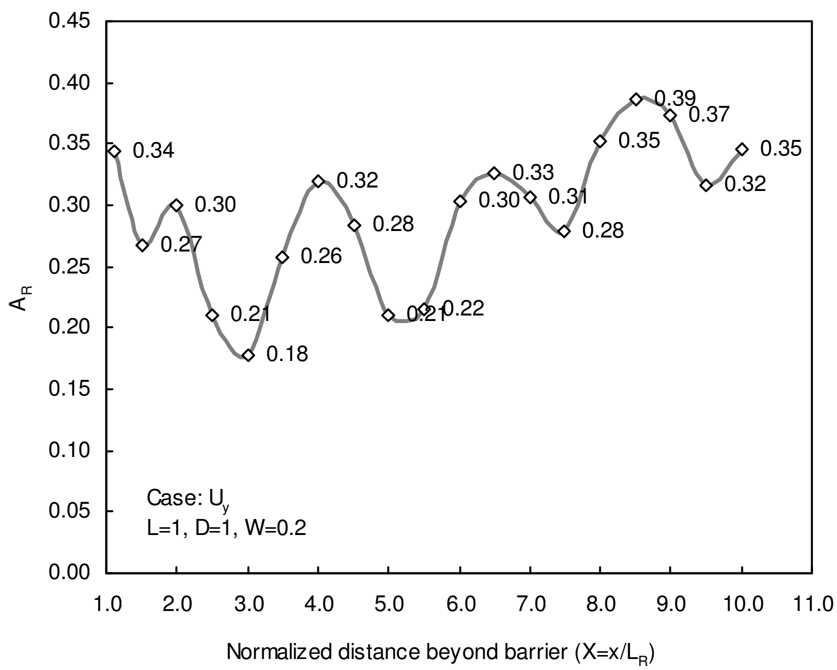

Figure B.2: Amplitude reduction factors versus normalized distances from barrier

The distance between the 1st two observations is $0.4L_R$ ($=1.5L_R-1.1L_R$) and all other observations are taken in intervals of $0.5L_R$. Applying trapezoidal rule,

$$Area = 0.4L_R\left(\frac{0.34+0.27}{2}\right)+\frac{0.5L_R}{2}\left[(0.27+0.35)+2\begin{pmatrix}0.30+0.21+0.18+0.26+\\0.32+0.28+0.21+0.22+\\0.30+0.33+0.31+0.28+\\0.35+0.39+0.37+0.32\end{pmatrix}\right]=2.592L_R$$

$s = 10L_R-1.1L_R = 8.9L_R$

$A_{my} = 2.592L_R/8.9L_R = 0.29$

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

D	A_{my}			Average A_{my}
	W=0.2	W=0.4	W=0.6	
0.3	0.62	0.57	0.54	0.576667
0.4	0.48	0.43	0.4	0.436667
0.6	0.33	0.3	0.27	0.3
0.8	0.25	0.22	0.21	0.226667
1.0	0.19	0.17	0.16	0.173333
1.2	0.17	0.15	0.14	0.153333
1.5	0.14	0.13	0.12	0.13

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:

$$y = Ax^{B} \tag{C.1a}$$

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:

$$b = \frac{n\sum \ln x \ln y - \sum \ln x \sum \ln y}{n\sum (\ln x)^2 - \left(\sum \ln x\right)^2} \qquad \text{(C.1b)}$$

$$a = \frac{\sum \ln y - b\sum \ln x}{n} \qquad \text{(C.1c)}$$

Where, $B = b$ and $A = e^a$

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

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

Table C.2: Fitting regression curve

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

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

$$a = \frac{(-9.73532) - (-0.9463)(-2.26645)}{7} = -1.69716$$

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:

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

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

$$A_{my} = 0.18 D^{(-0.95)} \qquad \text{(C.2)}$$

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.

LIST OF PUBLICATIONS

Considerable part of the work is published in international peer-reviewed journals and conference (national and international) proceedings. Remaining part will be submitted for possible publication in journals/conference proceedings. Publications on the part of this work are listed as follows:

- Saikia, A. Numerical study on screening of surface waves using a pair of softer backfilled trenches, *Soil Dynamics and Earthquake Engineering*, **65** (October), 206--213, 2014.

- Saikia, A. & Das, U.K. Analysis and design of open trench barriers in screening steady-state surface vibrations, *Earthquake Engineering and Engineering Vibration*, **13** (3), 545--554, 2014.

- Saikia, A., Dutta, A.K., & Das, U.K. Finite element study on vibration isolation using dual open trench barriers, in *Proceedings of International Conference on Innovations in Civil Engineering (ICICE), IOSR journal of Mechanical and Civil Engineering*, **1**, 20--29, 2014.

- Saikia, A. & Das, U.K. Numerical study on vibration isolation using open trenches, in *Proceedings of Indian Geotechnical Conference (IGC 2013),* Roorkee, India, pp. CD ROM, 2013.

- Saikia, A. Effects of backfill material properties on vibration isolation effectiveness of in-filled trenches, in *Proceedings of Advances in Civil and Infrastructure Engineering (ACIE)*, Tezpur, India, pp. CD ROM, 2015.