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Xdisp

Oasys XDisp

Help Guide

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Oasys XDisp

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Printed: March 2019

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Part I

1 About XDisp

1.1 General Program Description

XDisp Excavation Induced Ground Displacements

XDisp calculates the ground movements induced by tunnelling, embedded wall excavations or mining works, in terms of three dimensional displacements and horizontal strains. It can perform subsequent building, utility and rail damage assessments using the calculated ground movements. Multiple construction stages may be specified.

Tunnels are specified as cylindrical excavations in soil. Several methods of solution are available to define the profile of the settlement curves. The equations used are based on the normal probability (Gaussian) distribution theory. The user is required to define the estimated Volume Loss (V_L) above the tunnel due to deformation. XDisp will then use this to define the settlement profile at the surface or at a specified depth.

Embedded wall excavations are described in plan as polygons with a level at each corner or as circles with a single base level. Each wall of a polygonal excavation, and each circular excavation is assigned horizontal and vertical ground movement curves that are used to calculate soil displacements. Settlements and horizontal ground displacements may be calculated for the construction of retaining walls and for excavation in front of the retaining walls to form restrained cuts or basements.

Total displacements at specified locations are calculated by summing those that result from each tunnel and embedded wall excavation.

Building Damage Assessment may be performed using the Burland (1995) assessment method. Sub-buildings are specified by their locations and bending properties and associated with lines of displacement points and a set of damage category tensile strains that define the thresholds of each damage category.

Utility Damage Assessment may be performed by assessment of the extent of rotation and pullout of joints, and of axial and flexural strain.

Rail Damage Assessment may be performed by assessment of the cant and twist of rail tracks.

Staged Construction allows excavations or tunnels to be included or excluded in different stages of an analysis, and excavation depths and tunnel diameters to be varied from one stage to another.

Mines are specified as excavations of rectangular cross-section in rock. The method of ground movement calculation is based on an influence function/zone area approach to subsidence and horizontal displacement calculation as described by Ren et al (1987). Stochastic influence functions are used.

A COM Application Programming Interface (API) is provided to facilitate automation, allowing the program to be run directly from external scripts (e.g. using VB or Python) without the need to interact with the user-interface.

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1.2 Program Features

Some program features are applicable to tunnels and excavations, some to mines, and some to both. The problem type is specified in the Problem Type dialog.

Feature	Problem Type Applicability	
	Tunnelling and/or Embedded Wall Excavations	Mining
Tunnels	✓	-
Embedded Wall Excavations	✓	-
Mines	-	✓
Building Damage Assessment	✓	✓
Utility Damage Assessment	✓	✓
Rail Damage Assessment	✓	✓
Staged Construction	✓	-

1.2.1 Tunnels

A tunnel is specified as an excavation of circular cross-section in soil. Several methods of solution are available to create the profile of settlement above the tunnels. These include methods for the following.

- Analysis methods to model settlements in both fine (cohesive) and coarse (granular) grained soils
- Two-layer systems with level or inclined soil interfaces
- Settlement profiles due to multiple tunnels
- Deformation and strain data plots for lines of any orientation and level above tunnel axis level
- Sub-surface displacement methods

1.2.2 Embedded Wall Excavations

An embedded wall excavation is specified by a polygon or circle describing its plan area, top and bottom levels, and its associated vertical and horizontal ground movement curves. It is used to model soil displacements caused by installation of, or excavation in front of, embedded walls. The following features are available.

- Ground movement curves chosen from a library of pre-programmed curves, or specified by the user explicitly
- Soil displacements arising from either installation of, and excavation beside, retaining walls by selecting appropriate ground movement curves
- Multiple embedded wall excavations
- Deformation data plots for lines of any orientation and level

1.2.3 Mines

A mine is specified as an excavation of rectangular cross-section in rock. The following features are available.

- Overlying strata may form a two-layer system, but with a horizontal interface
- One method of solution is available (the influence function/zone area approach as described by Ren et al (1987)) with results only available at ground surface level
- Deformation data may only be plotted for horizontal lines at ground level

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1.2.4 Building Damage Assessment

Building Damage Assessment is performed using the Burland (1995) assessment method.

- Each 'sub-building wall or facade is given a location by association with a displacement line.
- Horizontal displacements are calculated for the position of that displacement line.
- Vertical displacements are calculated for three vertical offsets of the displacement line. Building damage calculations are performed for each of those vertical offsets, using the horizontal displacements calculated at the level of the displacement line.
- Each 'sub-building' is given a set of damage category strains to define the threshold of 5 damage categories based upon the geometry defined for the building.
- Either user-defined damage category strains, or pre-defined values from Burland (1995), may be chosen.
- Damage categories are calculated for each hogging and sagging segment along the length of each sub-building.
- Adjacent hogging and sagging segments may be combined for damage category assessment as one segment.
- Charts of vertical and horizontal displacement may be viewed for each sub-building.
- Damage category interaction charts may be viewed for each segment of each sub-building.

1.2.5 Utility Damage Assessment

XDisp performs detailed damage assessment of a utility by calculating the pullout, rotation, axial strain and flexural strain values at different points along the utility's length. It then checks whether these values are falling within acceptance criteria.

- Each 'sub-utility' is given a location by association with a displacement line.
- Each 'sub-utility' is given a set of cross-sectional dimensions (internal diameter and wall thickness).
- Each 'sub-utility' is given a set of parameters and acceptance criteria to determine the damage limits.
- Displacements are calculated for the position of the displacement line.
- 'Sub-Utility' damage is calculated using those displacements to determine joint rotations, pullout and axial and flexural strains along the length of the utility.
- Charts of rotation, pullout and strains along the 'sub-utility' length may be viewed for each 'sub-utility'.

1.2.6 Rail Damage Assessment

XDisp performs the following aspects of rail damage assessment using ground movements calculated by the program.

- Cant
- Twist (both short and long base)

Acceptance criteria may be specified against which the results calculated by the program are compared.

Charts are available for the results versus distance along the rail track.

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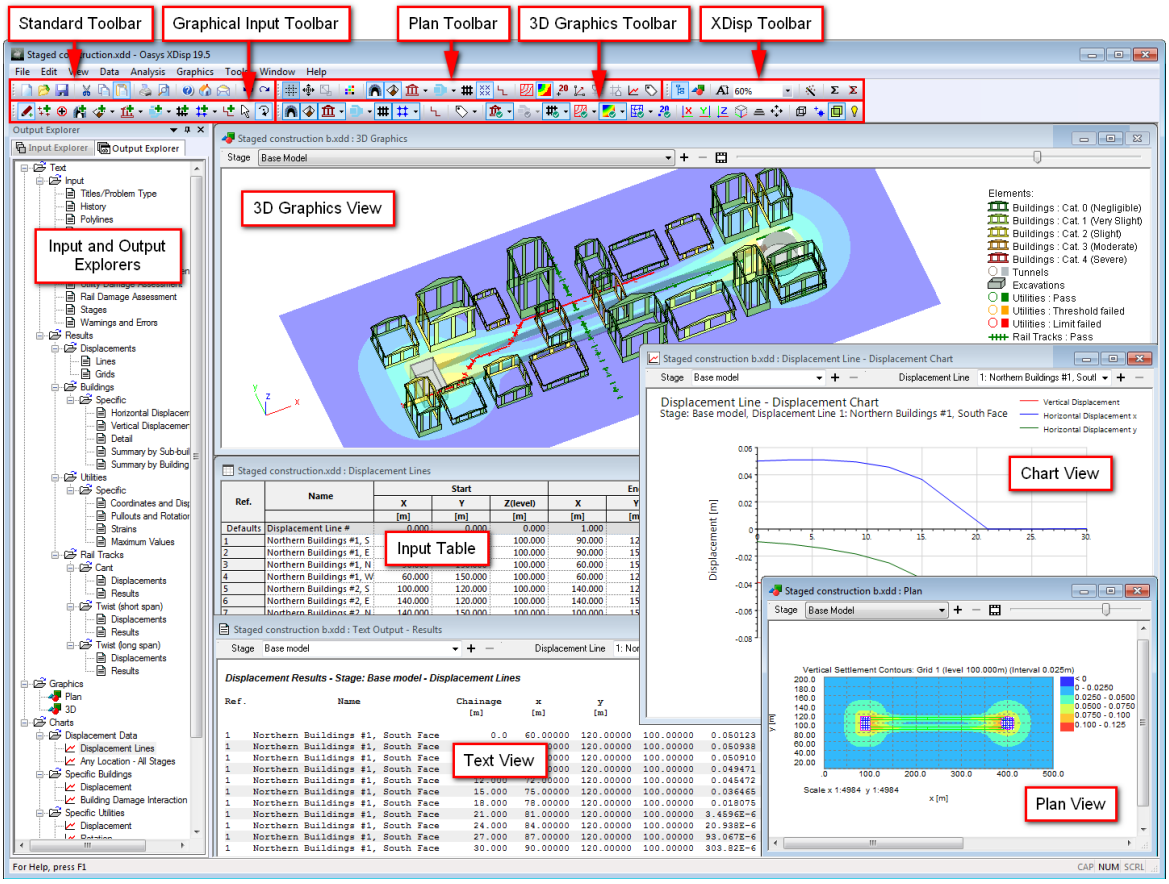
1.2.7 Staged Construction

XDisp allows stages of construction to be modelled in terms of:

- inclusion or exclusion of tunnels in particular stages
- varying embedded retaining wall/excavation depths in different stages
- varying tunnel diameters in different stages in order to represent, for instance, pilot tunnels advancing ahead of main tunnels.

1.3 Components of the User Interface

The components of XDisp's user interface are the Input Explorer, the Output Explorer, input tables, the 3D Graphics View, the Plan View, the Text View, Chart Views, toolbars, menus and input dialogs. The key components are illustrated below.



1.4 Sample Files

Sample files are provided during the installation process. These demonstrate XDisp's features. By default they are installed in the folder 'C:\Program Files\Oasys\XDisp *n*\Samples', where *n* indicates the version of the program. These files may be opened and inspected in XDisp in order to become familiar with the typical input data that is required to create an XDisp model.

The sample files are named to indicate the features of the program that they exercise. The data they contain should not be considered as recommended data. It may have been chosen to demonstrate a feature and/or generate significant results.

DXF files are also provided to demonstrate DXF import.

A sample set of utility dimensions and criteria is provided in the file 'SampleDimensionsAndCriteria.xdd'. Once opened its data can be copied from the input tables to a user's own data file in order to refer to it there. Alternatively the sample file may be saved with a new name and opened to form the basis of a new data file.

1.5 File Types

Two types of data file format may be used to store XDisp data: binary (identified by the file extension "*.xdd"); or JSON text (identified by the file extension "*.json"). To save the required type choose "File -> Save As" from the program menu, then "Save as type" in the subsequent Windows "Save As" dialog. Similarly, to open the required type choose "File -> Open" from the program menu, then the equivalent type selector field of the Windows "Open" dialog.

The JSON (JavaScript Object Notation) text option allows user-readable data to be edited outside the program, e.g. for automation purposes, but may lead to corruption of data if the text is not formatted correctly. Being a text file its size on disk can be far larger than the equivalent binary file, particularly if results are included. The JSON file follows a standard JSON style (see JSON.org) so lists a series of objects containing name/value pairs. The names are textual descriptions of input data items in XDisp. The values are their data values.

A sample file "JSON Sample.json" is issued with the program in the Sample Files folder. That file contains examples of all input data and results. Its format may be inspected in a text editor. e.g. Microsoft Notepad, and, together with the Data Input descriptions in this manual, avoids the need for detailed description here. Alternatively, data may be input into the program's interface and a JSON file saved from the program. That file can then be inspected in a text editor to determine the format that the program has created and can therefore read.

JSON data files may be created outside XDisp to be read, edited, analysed and/or saved by XDisp using its COM API. This avoids the need to operate the user-interface. Some JSON objects have no effect on the analysis or its results and so may be omitted from the JSON file if it is to be used in this automated way. Examples are: "Units", "Graphic Settings" and "File History". "Units" are used to specify the display of values in the user-interface. All values in the JSON data file should be specified in SI units.

1.6 Online Resources

The following online resources are available at the Oasys internet page (www.oasys-software.com).

- Video tutorials for introductions to features
- Frequently asked questions
- Change logs listing a release-by-release summary of new features, minor improvements and bug fixes

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1.7 Program Variants

XDisp is available in 2 variants:

XDisp Pro	- all features enabled
XDisp	- Stages, Stage Properties, Bulk Chart Export and Application Programming Interface (API) disabled

When opened, an XDisp data file is checked against the features permitted by the user's licence. If the file contains data that is not permitted by the licence then a warning is presented enabling the user to cancel the file-opening operation or to proceed and allow the prohibited data to be deleted from the model. The user may wish then to save the file with a new name to avoid over-writing the original data file containing the more extensive model data.

Users are invited to contact Oasys if they wish to upgrade their licence from XDisp to XDisp Pro and so be able to model Staged Construction and perform Bulk Chart Export.

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Part II

2 Analysis Methods

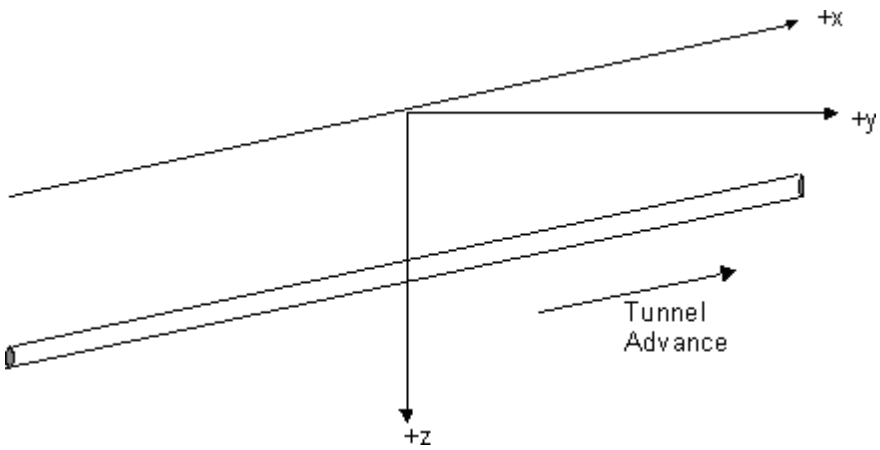
2.1 Tunnel Method

XDisp's tunnel analysis method calculates the settlement profile above an excavated tunnel, once the user has entered the estimated ground loss.

For the purposes of displacement calculations within the program, and where describing analysis methods and their profile widths and depths elsewhere in this manual, a local coordinate system is used. This is shown in the diagram below.

The 'global' x, y and z coordinates, that are used in the program's interface to specify tunnel and displacement grid locations, are converted into this local coordinate system in order to apply the analysis methods. Displacement Lines', Grids' and Points' results are output in the global coordinate system. Horizontal displacements that are shown graphically for sub-building displacement charts are reported as those in the direction of the sub-building's alignment.

Local Coordinate System of Tunnel



2.1.1 General Assumptions

Greenfield calculations are typically based on the assumption that the “settlement trough” at the ground surface (or at any level in the ground above the tunnel) normal or “transverse” to the line of the tunnel can be approximated by an inverted normal probability (or “Gaussian”) curve as shown in the first figure below. Vertical displacements in the longitudinal direction can similarly be approximated by a cumulative probability curve (second figure below). These are empirically based assumptions that have been developed in the past from consideration of monitoring case history data. The two figures below are presented in a normalised form for a single tunnel.

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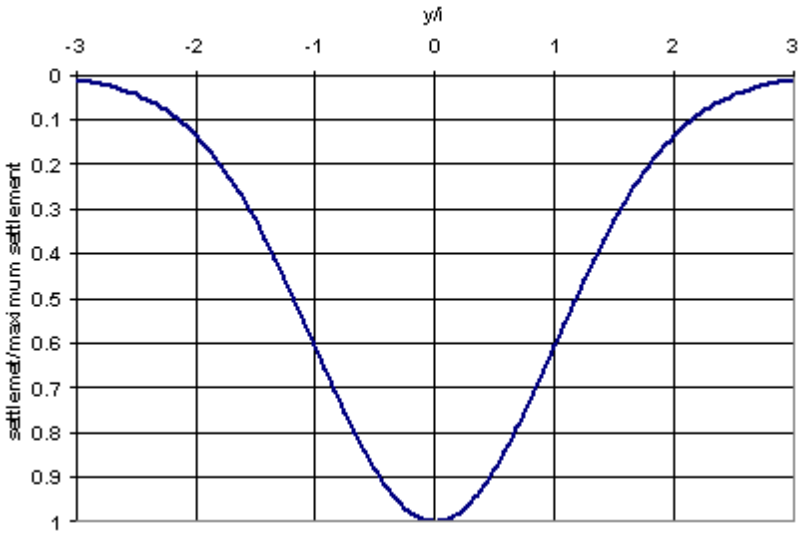
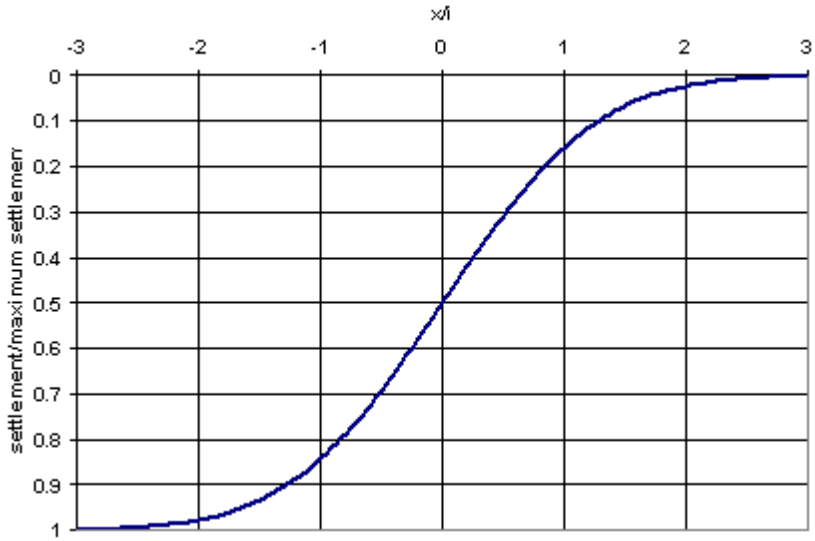
General Form of the Transverse Settlement Trough



General Form of the Longitudinal Settlement Trough



The geometry of the settlement trough is uniquely defined by selecting values for the volume loss and the width of the trough relative to the depth of the tunnel – termed the “trough width parameter”. In the figures above the tunnel face is located at y/ i = x/ i = 0, with i representing the point of inflexion on the transverse profile, equivalent to one standard deviation in a normal probability distribution.

The complete 3D form of a tunnelling induced settlement trough appears as illustrated in the figure below after Yeates (1985). The equations that define the form and extent of the settlement trough will be discussed in the sections Volume Loss and Tunnel Settlement Trough Width.

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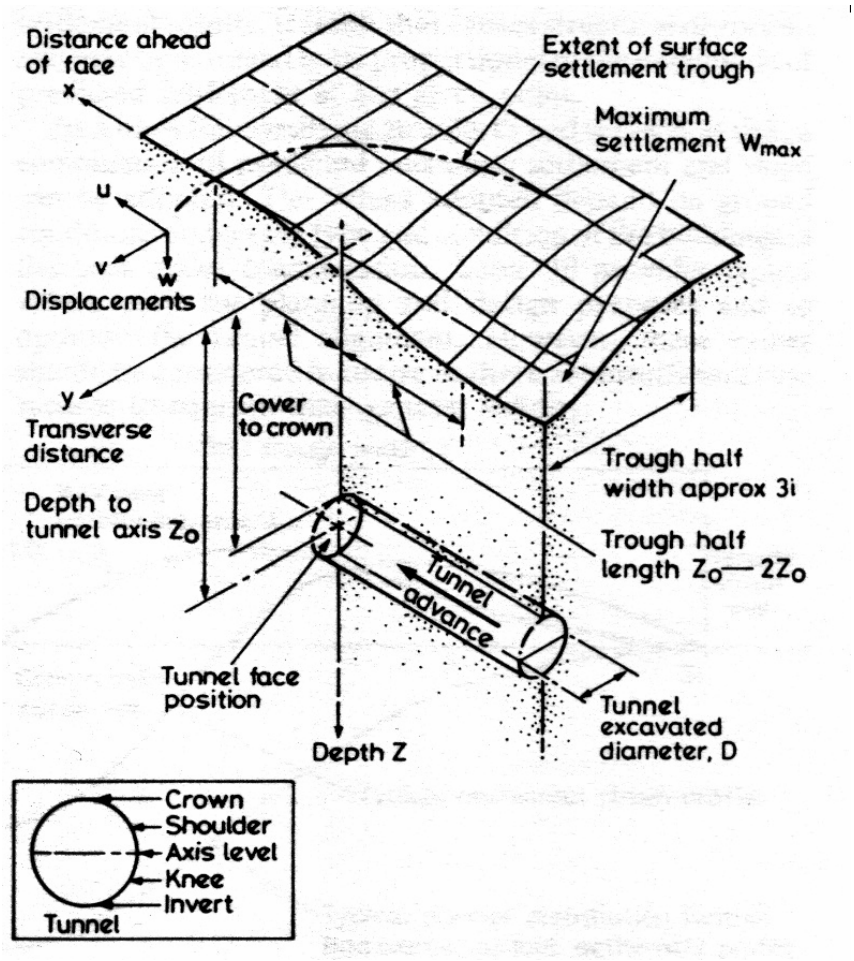
3D Schematic of the Settlement Trough (from Yeates (1985))



As identified in this figure the settlement profile in the direction of the tunnel advance is often described by analogy to a “bow wave” of an advancing ship. In the direction of the tunnel axis this is termed the longitudinal settlement trough, which can be obtained from a cumulative normal probability distribution.

In many practical situations it may be necessary to estimate ground movements on a plane that is not normal to or parallel to the tunnel axis. Depending on the analysis method chosen, the equations proposed by Attewell and Woodman (1982) (surface and sub-surface), or Harris and Alvarado (sub-surface only) are used in **XDisp** for this situation in terms of a *G-function* obtained from the numerical integration of the normal probability function. See Three Dimensional Form of Movement Equations for details of these equations. The Attewell and Woodman equations are used in combination with a range of published k derivation methods. Harris and Alvarado defines its own k derivation method.

2.1.2 Volume Loss

The fundamental parameter that underlies all empirical methods of estimating tunnelling settlement is the volume loss. Volume loss can be defined as the ratio of the *additional volume of excavated ground removed (V_s) over the theoretical volume of the tunnel (V_o)* when short-term equilibrium has been attained. It is usually defined in a two dimensional sense as a percentage of the excavated

face area. That is, the volume loss is equivalent to a proportion of the cross sectional area:

$V_L\%$	=	$(V_s/V_o)*100\%$
V_s	=	additional excavated volume (per m run)
	=	$A_{exc} - A_o$ (m^2 or m^3/m run)
V_0	=	theoretical volume of tunnel
A_{exc}	=	actual excavated area
A_o	=	theoretical cross-sectional area of tunnel excavation

Short-term volume loss may be separated into the following components:

a) ground lost at the face due to movements in an axial direction (face intrusion or face "take");

b) radial movements due to over-excavation as a result of the use of a bead on a shield or over cutting on a tunnel boring machine (TBM), or due to "diving", "pitching", "yawing" of the shield or TBM or driving on a curve;

c) radial movements due to temporary loss of support at the rear of the shield or TBM during lining construction;

d) closure of the ungrouted annulus around the newly completed ring (non-expanded type of linings);

e) initial distortion of the completed tunnel ring due to gravitational loading.

N.B. XDisp takes the volume loss to be volume loss per unit horizontal length. However, the user generally inputs volume loss per unit length of tunnel which means that for inclined tunnels total volume loss, and hence settlements, are underestimated. Without modifying the XDisp code it is possible to divide the volume loss per unit length of tunnel by the cosine of angle of inclination of the tunnel to get the volume loss per unit horizontal length and input this into the program. The XDisp calculation will then be correct.

2.1.3 Three Dimensional Form of Movement Equations

Either of two sets of three-dimensional forms of movement equations may be used: Attewell and Woodman (1982) (surface and sub-surface) or Harris and Alvarado (sub-surface only). The Attewell and Woodman equations are used in combination with a range of published k derivation methods. Harris and Alvarado defines its own k derivation method.

Note that the O'Reilly and New (1982) and Mair et al (1993)/Taylor (1995) Analysis Methods have their own definitions for the horizontal displacements transverse to the tunnel. See Analysis Methods.

Attewell and Woodman

The following equations giving displacements and strains at any point are derived from Attewell and Woodman (1982). These are used for all ground movement calculations, in combination with a specified k derivation method, unless the Harris and Alvarado method for sub-surface movements (see below) is chosen. These equations are applicable to surface and sub-surface movements.

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$$w = \frac{V_s}{\sqrt{2\pi}i}\exp\left(-\frac{y^2}{2i^2}\right)\left\{G\left(\frac{x - x_i}{i}\right) - G\left(\frac{x - x_f}{i}\right)\right\}$$

$$v = -\frac{n}{(z_0 - z)}yw$$

$$u = \frac{nV_s}{2\pi(z_0 - z)}\exp\left(-\frac{y^2}{2i^2}\right)\left\{\exp\left(-\frac{(x - x_i)^2}{2i^2}\right) - \exp\left(-\frac{(x - x_f)^2}{2i^2}\right)\right\}$$

$$\varepsilon_z = -\frac{nV_s}{\sqrt{2\pi}i(z_0 - z)}\exp\left(-\frac{y^2}{2i^2}\right)\left(-\frac{1}{\sqrt{2\pi}}\right)$$

$$\left\{\left(\frac{x - x_i}{i}\right)\exp\left(-\frac{(x - x_i)^2}{2i^2}\right) - \left(\frac{x - x_f}{i}\right)\exp\left(-\frac{(x - x_f)^2}{2i^2}\right) + \left(\frac{y^2}{i^2} - 1\right)\left[G\left(\frac{x - x_i}{i}\right) - G\left(\frac{x - x_f}{i}\right)\right]\right\}$$

$$\varepsilon_y = -\frac{n}{(z_0 - z)}w\left(\frac{y^2}{i^2} - 1\right)$$

$$\varepsilon_x = -\frac{nV_s}{2\pi i(z_0 - z)}\exp\left(-\frac{y^2}{2i^2}\right)\left\{\left(\frac{x - x_i}{i}\right)\exp\left(-\frac{(x - x_i)^2}{2i^2}\right) - \left(\frac{x - x_f}{i}\right)\exp\left(-\frac{(x - x_f)^2}{2i^2}\right)\right\}$$

$$\gamma_{xy} = \frac{V_s}{2\pi(z_0 - z)}\exp\left(-\frac{y^2}{2i^2}\right)\left(-\frac{y}{i^2}\right)\left\{\exp\left(-\frac{(x - x_i)^2}{2i^2}\right) - \exp\left(-\frac{(x - x_f)^2}{2i^2}\right)\right\}$$

$$-\frac{1}{(z_0 - z)}\frac{V_s}{\sqrt{2\pi}i}\exp\left(-\frac{y^2}{2i^2}\right)\left\{\frac{1}{\sqrt{2\pi}}\exp\left(-\frac{(x - x_i)^2}{2i^2}\right) - \frac{1}{\sqrt{2\pi}}\exp\left(-\frac{(x - x_f)^2}{2i^2}\right)\right\}$$

where:

x,y,z	=	cartesian coordinates of any point in the ground deformation field (z positive downward).
u,v,w	=	ground displacements in the x,y,z directions respectively. u and v are always towards the origin of the cartesian coordinate system. w (settlement) is always positive downwards.
$\varepsilon_x, \varepsilon_y, \varepsilon_z$	=	ground strains in the x,y,z directions respectively. These strains can change from tensile (positive) to compressive (negative) depending upon position in the deformation field. Tensile ground strains are more likely to have a serious effect upon the brittle foundation of a building or upon a brittle pipe than are compressive ground strains.

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γ_{xy} = ground shear strain in a horizontal plane.

z_0 = depth of the effective source of ground loss (taken as approximating to the tunnel axis).

n = power of (z_0 - z) to which i_x, i_y and i are proportional.

V_s = volume of the settlement trough per unit distance of tunnel advance, the settlement being attributable to ground losses and not incorporating any longer term consolidation.

i = parameter defining the form and span of the settlement trough on the assumption that the semi-transverse (y-axis) settlement profile can be described by a normal probability equation (Schmidt (1969), Peck (1969), Attewell (1978)).

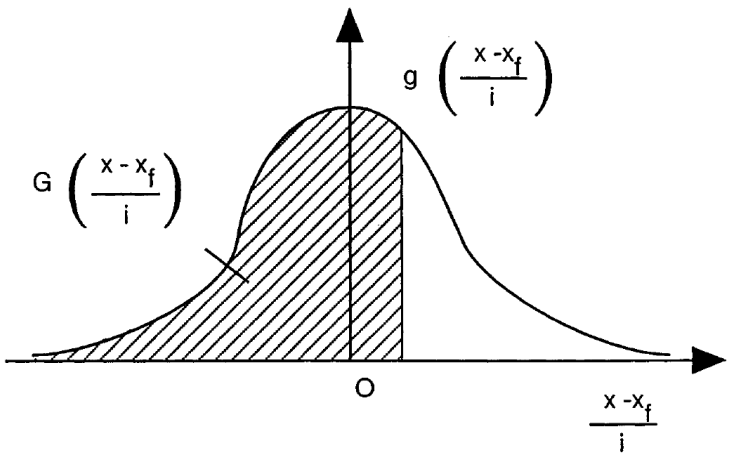
It is the horizontal surface distance from a vertical line through the centre of the tunnel to the point of inflexion of the settlement trough.

x_i = initial or tunnel start point (y=0).

x_f = face or final tunnel position (y=0).

$G\left(\frac{x - x_f}{i}\right)$ = a function of the normal probability curve which is described by the following equation:

$$G(a) = -\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{a} \exp\left(-\frac{B^2}{2}\right) dB$$



The two-dimensional form of movements transverse to a tunnel reduces to.

$$S = S_{max} e^{-y^2/2i^2}$$

$$V_s = (2\pi)^{0.5} i S_{max}$$

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where:

S = settlement at horizontal distance y from tunnel axis

S_{max} = maximum settlement (above tunnel axis alignment)

Harris and Alvarado

The Harris and Alvarado movement equations are applicable to sub-surface movements only.

$$S = \frac{V_s}{2i\sqrt{2\pi}} \exp\left(\frac{-\hat{y}^2}{2}\right)\left[\operatorname{erf}\left(\frac{\hat{x}_i}{\sqrt{2}}\right) - \operatorname{erf}\left(\frac{\hat{x}_f}{\sqrt{2}}\right)\right]$$

$$h_y = -\frac{mV_s y}{2i(z_{inv} - z)\sqrt{2\pi}} \exp\left(\frac{-\hat{y}^2}{2}\right)\left[\operatorname{erf}\left(\frac{\hat{x}_i}{\sqrt{2}}\right) - \operatorname{erf}\left(\frac{\hat{x}_f}{\sqrt{2}}\right)\right]$$

$$h_x = \left[\frac{mV_s}{2\pi(z_{inv} - z)}\right]\left[\exp\left(-\frac{\left(\hat{x}_i^{\,2} + \hat{y}^2\right)}{2}\right) - \exp\left(-\frac{\left(\hat{x}_f^{\,2} + \hat{y}^2\right)}{2}\right)\right]$$

$$\operatorname{erf}\left(\frac{\hat{x}_i}{\sqrt{2}}\right) = \frac{2}{\sqrt{\pi}} \int_0^{\frac{\hat{x}_i}{\sqrt{2}}} e^{-t^2}\, dt$$

$$i = i_0\left(\frac{z_{inv} - z}{z_{inv}}\right)^m$$

$$i_0 = i_{ref}\left(1 - \left(\frac{z_{ref} - z}{z_{ref}}\right)\right)^n$$

$$\hat{x}_i = \frac{x - x_i}{i}$$

$$\hat{x}_f = \frac{x - x_f}{i}$$

$$\hat{y}_i = \frac{y}{i}$$

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where:

S = settlement at depth z, at transverse horizontal distance y from tunnel axis, and at longitudinal horizontal distance x (start of tunnel being at x_i; end of tunnel being at x_f)

h_y = horizontal ground movement in direction transverse to tunnel axis, at transverse horizontal distance y from tunnel axis, and at longitudinal horizontal distance x (start of tunnel being at x_i; end of tunnel being at x_f)

h_x = horizontal ground movement in direction parallel to tunnel axis, at transverse horizontal distance y from tunnel axis, and at longitudinal horizontal distance x (start of tunnel being at x_i; end of tunnel being at x_f)

V_s = volume of soil displaced in settlement trough

i = distance from tunnel axis to point of inflexion at depth z

i_0 = distance from tunnel axis to point of inflexion at surface

i_{ref} = 12.5 metres

z = depth below ground surface

z_{inv} = depth of tunnel invert below ground surface

z_{ref} = 30 metres

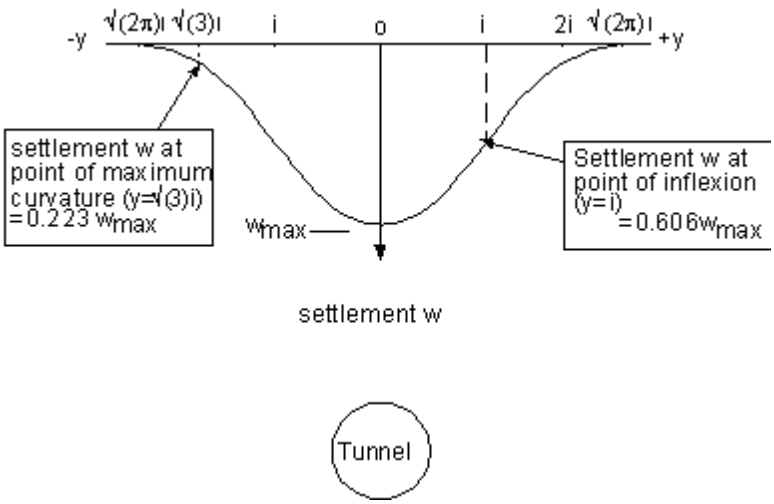
n = 0.8

m = user-specified exponent (for a typical London clay Harris and Alvarado recommend m of 0.5)

2.1.4 Tunnel Settlement Trough Width

The width of the settlement trough perpendicular to the tunnel is defined in terms of distance 'i' in metres from the tunnel centre-line to the point of inflexion on the curve.

Tunnel Settlement Trough Width



XDisp provides a number of options to calculate 'i' via selection of a 'k Derivation Method'. A 'k' value provides a relationship between the distance 'i' and the depth to tunnel axis level. Lower values lead to steeper and narrower troughs. Higher values lead to wider shallower troughs. The methods listed

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in the table below describe the relationship between 'k' and 'i' and the calculation of settlement and horizontal movement using those 'k' or 'i' values.

These methods have varying applicability. Some apply to the calculation of surface displacements for single-layered soil. Some apply to the calculation of sub-surface displacements for single-layered soil. One applies to surface displacements for two-layered soil. The table below summarises the applicability of each method/k Derivation Method combination.

Three-Dimensional Form of Movement Equations	Analysis Method	k Derivation Method	Applicability			
			Surface Displacements	Sub-surface Displacements	Single-layered Soil	Dual-layered Soil
Attewell and Woodman	-	User-specified k	✓	-	✓	-
		O'Reilly and New	✓	-	✓	-
		Boscardin	✓	-	✓	-
		Selby	✓	-	-	✓
	Mair et al	-	-	✓	✓	-
	New and Bowers	User-specified k	-	✓	✓	-
Harris and Alvarado	Harris and Alvarado	-	-	✓	✓	-

When specifying sub-surface displacement calculation points, the user is presented with the choice of either the Mair et al (1993) method, the New and Bowers (1994) method, or the Harris and Alvarado method. These are described in Analysis Methods. The O'Reilly and New (1982), Boscardin and Selby (1988) k derivation methods are described in k derivation methods.

Mair et al is applicable for surface displacements if a k value of 0.5 can be relied upon - which would potentially be the case for clay. Similarly, it could be argued that the New and Bowers/User-specified method could be used for surface displacements as it has been validated for those the Heathrow Express Trial tunnel, see New and Bowers (1994).

Users should check movements below a 45º line from the invert of the tunnel are bench-marked against case study data.

2.1.4.1 Analysis Methods

(All length dimensions in these equations are in metres. Volume is in cubic metres.)

a) O'Reilly and New (1982)

$$k = \frac{i}{z}$$

$$h = \frac{yS}{z_0}$$

where:

y	= horizontal distance from tunnel axis
z	= the axis level of the tunnel to the ground surface
z_0	= distance from surface level to tunnel axis
S	= settlement at horizontal distance y from tunnel axis
S_{max}	= maximum settlement (above tunnel axis alignment)
i	= horizontal distance from tunnel axis to point of inflexion of settlement trough
V_S	= volume of soil displaced in settlement trough
V_L	= volume loss (can be expressed as a percentage by multiplying by 100%)
h	= horizontal displacement at distance y from tunnel axis
D	= tunnel diameter

b) Mair et al (1993)

$$i = z_0\left(0.175 + 0.325\left(1 - \frac{z}{z_0}\right)\right)$$

$$h = \frac{-0.325yS}{i}$$

where:

y	= horizontal distance from tunnel axis
z_0	= distance from surface to tunnel axis level
z	= depth below ground surface
i	= distance from axis to point of inflexion at depth z
S	= settlement at depth z and at transverse horizontal distance of y from tunnel axis (as calculated in (a) above)
R	= radius of tunnel
h	= horizontal displacement at depth z and at distance y from tunnel axis

The calculation of h is based on the Taylor (1995) extension to Mair et al's method.

A warning is issued if z/z_0 is greater than 0.8 or z is greater than the depth to the tunnel crown. In such circumstances calculations are moving outside the scenarios covered by the case study data on which the Mair et al method is based.

c) New and Bowers (1994)

This method assumes displacements are directed towards a 'ribbon' of volume loss taking place at the tunnel invert level. For details of this method see references. This method may also be referred to as the 'Ribbon Sink' method.

d) Harris and Alvarado (in preparation)

See also Three Dimensional Form of Movement Equations.

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2.1.4.2 k Derivation Methods

a) User-specified k

Typical user-specified k values for soils would be:

Soil	Range of k
Stiff, fissured clay	0.4 to 0.5
Glacial deposits	0.5 to 0.6
Recent soft, silty clay	0.6 to 0.7
Granular soils above water table	0.2 to 0.3

(See O'Reilly and New (1982).)

b) O'Reilly and New (1982)

Cohesive soils: $i = 0.43z_0 + 1.1$ metres
Granular soils*: $i = 0.28z_0 - 0.12$ metres

* From Fig.4 of O'Reilly and New (1982).

(i and z_0 in metres.)

Before version 18.3 of Tunset (XDisp's predecessor), the program referred to this method as the Attewell method.

c) Boscardin

Cohesive soils: $i = 0.5z_0$ metres
Granular soils: $i = 0.25z_0$ metres

(i and z_0 in metres.)

d) Selby (1988)

Clay overlain by sand: $i = 0.43z_2 + 0.28z_1 + 1.1$ metres
Sand overlain by clay: $i = 0.28z_2 + 0.43z_1 - 0.1$ metres
where: z_1 = thickness of upper layer
z_2 = thickness of tunnel stratum

(i, z_1 and z_2 in metres.)

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2.2 Embedded Wall Excavation Method

This methodology follows that which is proposed in CIRIA Report C580 and CIRIA Report C760 for ground movements beside embedded retaining walls. It calculates movements due to the installation of an embedded wall and due to the excavation in front of the embedded wall.

An embedded wall excavation is defined by a polygon or circle in plan with top and bottom levels. See Re-entrant Corners for caution when specifying corners with internal angles of greater than 180º. Bottom levels may vary from one corner to another for a polygonal excavation. Circular excavations have single vertical and horizontal ground movement curves. Polygonal excavations have multiple ground movement curves - one for each side of the excavation.

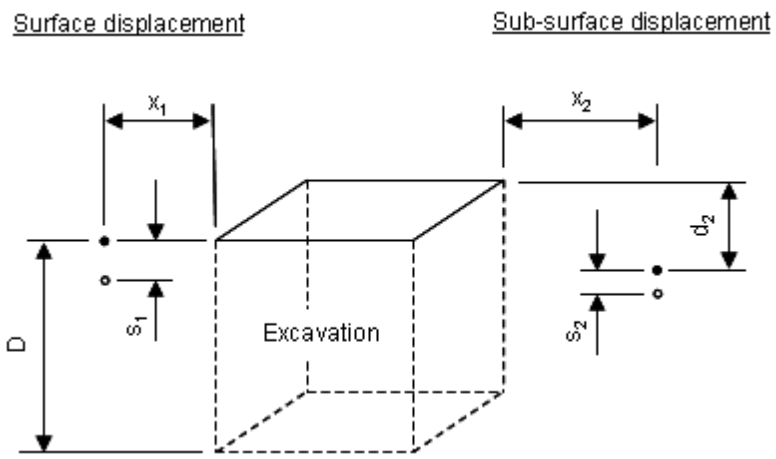
Ground movement curves may be specified for movements at the soil surface and sub-surface or for movements at the surface only. The former are specified by a series of local x, y and z coordinates, while the latter are specified by a series of local x and z coordinates only. The x coordinates represent the ratio of a point's distance from the wall or excavation to the depth of the wall or excavation. The y coordinates represent the ratio of a point's depth below the top of the wall or excavation to the depth of the wall or excavation. The z coordinates represent the ratio of the movement of the point to the depth of the wall or excavation. Vertical and horizontal movements are specified independently.

A curve is fitted to these sets of coordinates, either as a 2 dimensional line graph (for surface movement data sets) or a 3 dimensional surface graph (for surface and sub-surface movement data sets).

Positions at which soil movements are to be calculated are specified, as for tunnels and mines, via displacement grids, lines and points. The movement of each position is calculated as shown below. This method is used to calculate both vertical and horizontal displacements. If displacement points are sited above the surface level of the excavation, then their displacements are calculated as though they were at the surface level.

Irregularly shaped excavations may be modelled following the procedure outlined in Irregularly Shaped Excavations.

Schematic Diagram of Excavation



x = distance to wall or excavation

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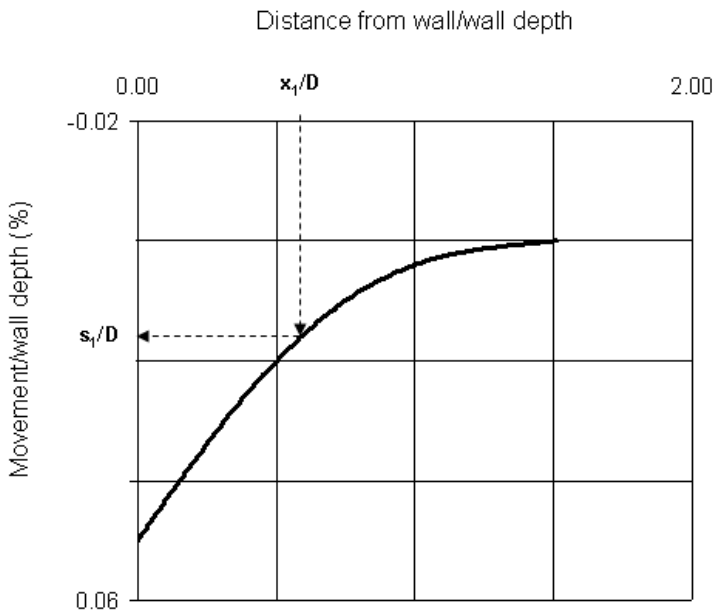
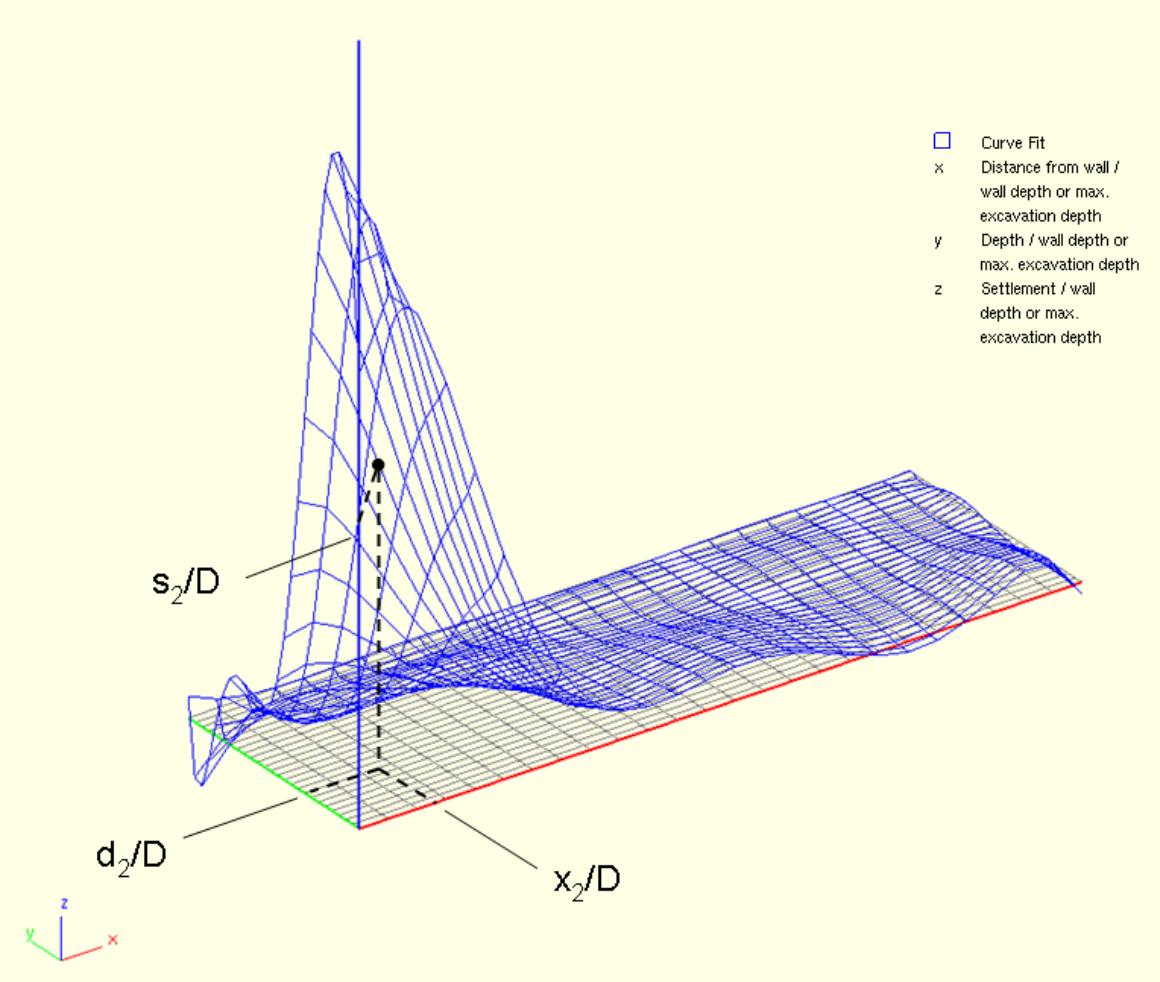
s = movement due to wall installation or excavation (either vertical or horizontal)
D = wall or excavation depth
d = depth of sub-surface point below top of excavation
• = soil position before wall installation or excavation
o = soil position after wall installation or excavation

If an excavation has a variable depth then the depth D is taken to be the depth of the wall or excavation at the position on the side from which a line drawn normal to that side will intersect the displacement point.

Ground Movement Curve - Surface Movements Only



Ground Movement Curve - Surface and Sub-surface Movements



XDisp performs the following steps for each excavation to calculate the displacement of each displacement point.

(a) If the excavation has been associated with a curve of surface movement only and the displacement point is level with the top of that excavation

1. calculate the distance of the point from the wall/excavation (x)
2. calculate the depth (D) of the excavation at the side closest to the point
3. calculate x/D
4. calculate s/D from x/D and the appropriate ground movement curve
5. calculate s

(b) If the excavation has been associated with a curve of surface movement only and

(i) the displacement point is below the top of that excavation, then s is set to zero.

or

(ii) the displacement point is above the top of that excavation, then s is calculated as though the displacement point were at the level of the surface of the excavation

(c) If the excavation has been associated with a curve of surface and sub-surface movement, and the displacement point is level with or below the top of that excavation

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1. calculate the distance of the point from the wall/excavation (x)
2. calculate the depth (D) of the excavation at the side closest to the point
3. calculate x/D
4. calculate the depth of the point from the top of the wall/excavation (y)
5. calculate y/D
6. calculate s/D from x/D and y/D and the appropriate ground movement curve
7. calculate s

(d) If the excavation has been associated with a curve of surface and sub-surface movement and

(i) the displacement point is below the top of that excavation, then s is set to zero.

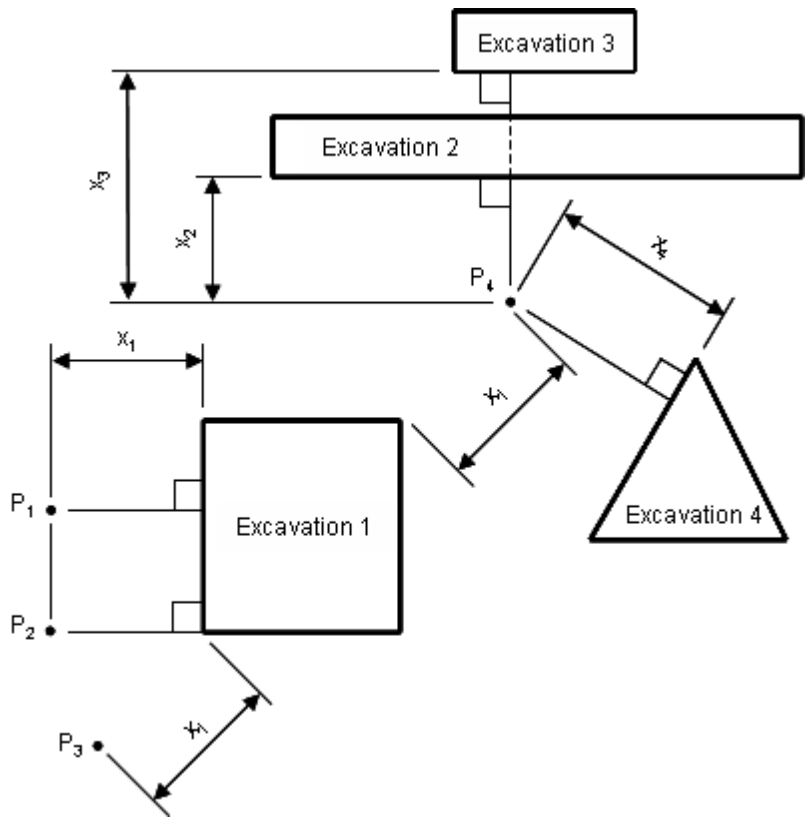
or

(ii) the displacement point is above the top of that excavation, then s is calculated as though the displacement point were at the level of the surface of the excavation

The total horizontal and vertical displacement of the displacement point is calculated by a vector sum of the horizontal and vertical displacements arising from each excavation.

N.B. Warnings

Plan of Multiple Excavations
(to demonstrate cautionary notes)



1) If corner stiffening is not invoked then the displacements that are calculated for positions that are within the arc of an excavation's corner (i.e. positions that cannot be reached by drawing a perpendicular line from any side of the excavation) are based on the distance measured to the corner. Hence the magnitude of the horizontal and vertical movements of positions P_1 and P_3, in the plan above, will be calculated to be equal.

2) No adjustment is made to the calculation to allow for the distance of the point along the length of a side of the excavation. Hence the magnitude of the horizontal and vertical movements of positions P_1 and P_2, in the plan above, will be calculated to be equal.

3) Multiple excavations may be specified. The displacements resulting from these excavations are calculated by summing the displacements resulting from each individual excavation. No account has been taken of the interactions between excavations (e.g. overlapping zones of influence or 'shielding' of one excavation by another). Hence the horizontal and vertical displacement of position P_4 in the plan above will be calculated as the sum of the results calculated for each of the four excavations.

2.2.1 Horizontal Components of Ground Movements around Corners

Embedded Wall Excavations Method describes the calculation of ground movements for displacement points under the direct influence of sides of excavations (i.e. displacement points to which a line can be subtended from sides of one or more excavations). The horizontal movement is always considered to be towards the excavation, i.e. along that subtended line.

CIRIA C580/C760, on which XDisp's method for modelling ground movements behind walls of excavations is based, considers only movements for points lying at right angles behind single walls in a plane strain condition. It does not consider how movements should be calculated within the zone of influence of corners, i.e. where movements would be influenced by two walls adjacent to the re-entrant corner so that strains are no longer planar.

If corner stiffening is not applied in the polygonal excavation input data then XDisp calculates movements in the arcs around corners as described below.

The calculation of the horizontal ground movements for a displacement point that is located in the arc of a corner, and a distance d from the corner, depends on the magnitudes and directions of the horizontal movements at the adjacent sides for points an equivalent distance d from those sides.

Plan of Excavation

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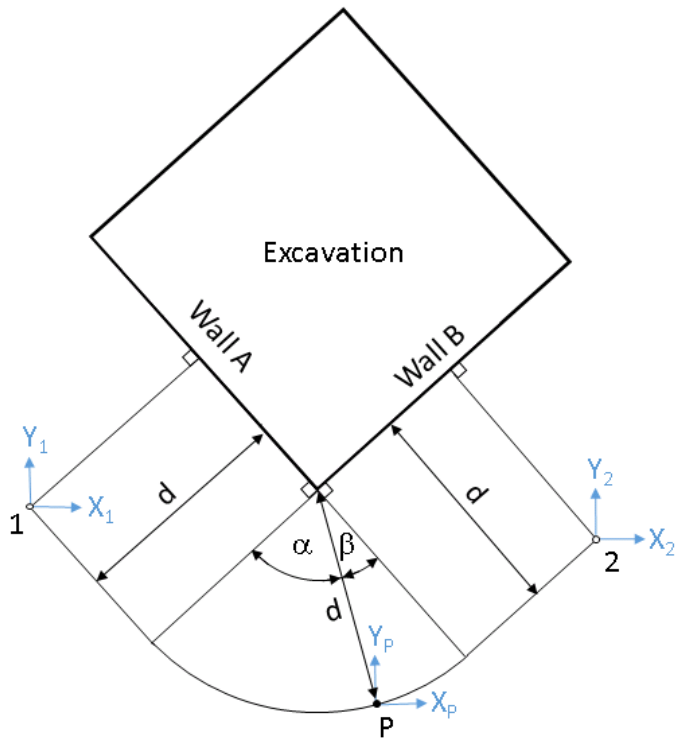


If P is a displacement point in the arc of the corner of an excavation, then its horizontal ground movement components (X_p and Y_p) are given by:

$$X_p = p_a X_1 + p_b X_2$$

$$Y_p = p_a Y_1 + p_b Y_2$$

where, for unstiffened corners,

$$p_a = \frac{\beta}{\alpha + \beta}$$

$$p_b = \frac{\alpha}{\alpha + \beta}$$

and for stiffened corners p_a and p_b are as defined in Corner Stiffening.

Vertical movements are calculated similarly, using factored contributions from each wall.

2.2.2 Corner Stiffening

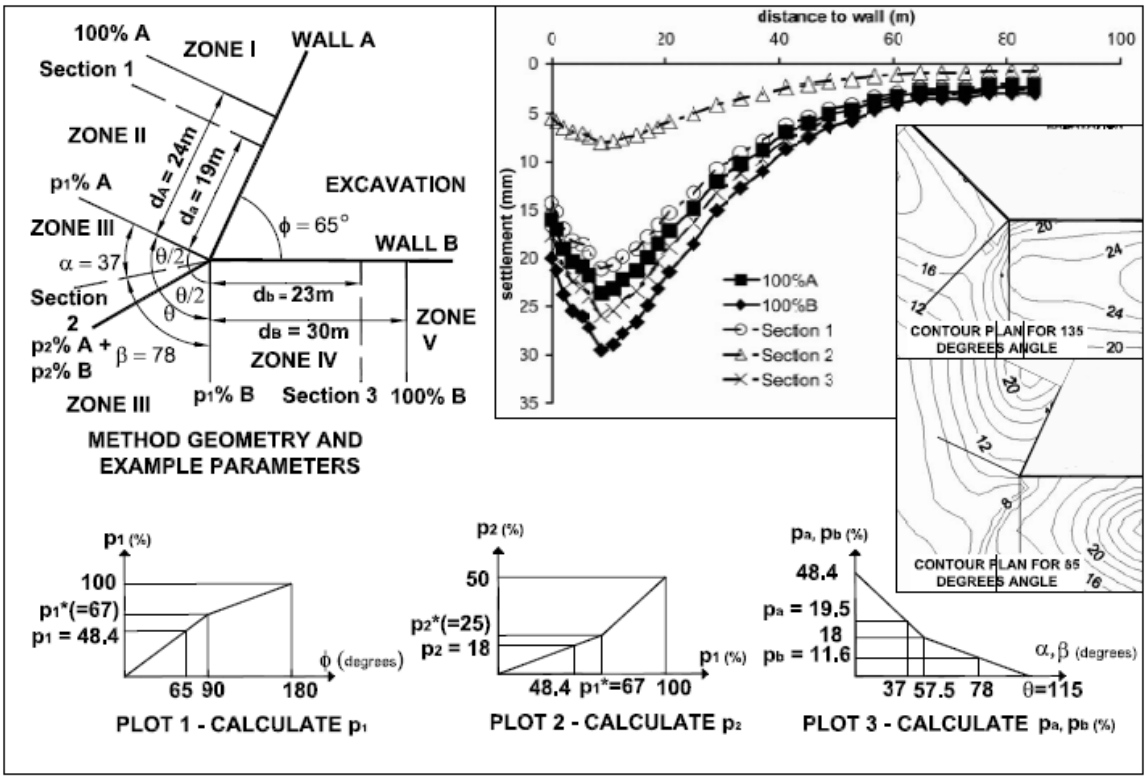
The ground movement curves are considered to represent 100% ground movement profile. However, this is not really true for retained cut excavations(for instance basement excavations), as there is increased stiffness at corners. From case studies, it has been observed that such effects result in smaller ground movements. XDisp considers such corner effects and adjusts the ground movement based on the method suggested by Fuentes and Devriendt. This method works for all corners except for re-entrant corners.

Implementation of the Method:

The "Zone Identification" figure and discussion below from Fuentes and Devriendt explains the implementation of this method through an example.

The input parameters which are required for this method apart from the geometry are:

- p_1* : the percentage of the "100% ground movement profile" that occurs along the line which is normal to a wall adjacent to the corner of the excavation (See figure below).
- p_2* : the percentage of the "100% ground movement profile" that occurs along the line which is at an angle θ/2 to the line along which p_1* is calculated. Where, θ is the angle at the corner of the excavation between the lines normal to the two retaining walls (See figure below).
- Settlement at 100% A
- Settlement at 100% B



Zone Identification, method's parameters, geometry, and plots (Plot 1-calculation of p1, Plot 2-calculation of p2, Plot 3-calculation of pa and pb) and example of method application

The percentage factors that are to be applied to 100% movements in sides A and B, to calculate the settlement at the point under consideration, are calculated from this input.

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The plots to be used to calculate these factors, and the equation used to calculate the settlement, depend on the zone in which the point lies. The zones are illustrated in the figure above. The table below from Fuentes and Devriendt lists the plots and equations used for different zones.

Plots and equations used for different zones

Plot	Input	Zones I and V	Zones II and IV	Zone III
1	p_1^* and ∅	X	✓	✓
2	p_1^* and p_2^*	X	✓	✓
3	p_1^*, p_2^*, α, and β	X	X	✓
Equations		$p = \%A$ or $p = \%B$	$p = p_1 + (100 - p_1)\frac{d_a}{d_A}\%A$ or $p = p_1 + (100 - p_1)\frac{d_b}{d_B}\%B$	$p = p_a \times \%A + p_b \times \%B$

Note: d_a and d_b are the distances, from the point where the ground movements are to be calculated, to the position of d_A and d_B (see figure below). %A and %B represent the 100%A and 100%B sections.

The figure and table above are reproduced with kind permission of the American Society of Civil Engineers (ASCE).

2.2.3 Excavations with Stepped Bases

There are a number of ways in which excavations with stepped bases may be modelled.

These methods are predominantly geometrical approximations. They are not based on published geotechnical engineering theory but may be considered to provide an adequate approximation to soil movement caused by excavations with stepped bases. Engineering judgment should be used in choosing the most appropriate method given the conditions, and the results reviewed carefully e.g. by validation of the ground movements calculated by XDisp against similar case studies or alternative methods of analysis to ensure they meet expectations.

Five methods are described below. In order to compare them, sample graphical output of contours of vertical ground movement are provided. In the samples, the same vertical movement curve is used for walls - "Excavation in front of low stiffness wall in stiff clay (CIRIA C580 Fig. 2.11(b)).

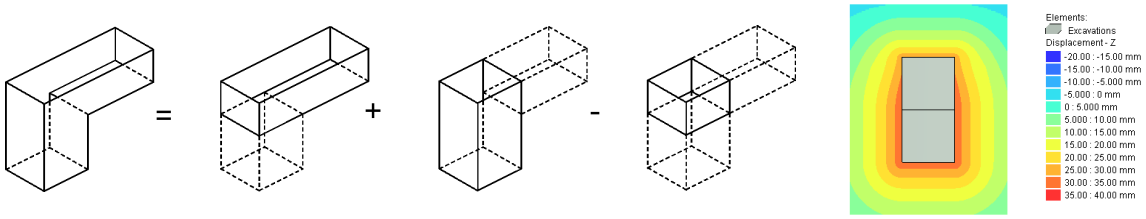
Method 1 - Composite Excavation

Excavations with stepped bases may be modelled by breaking them into sufficient cuboid constituents. Each constituent is specified to have either a positive or negative contribution to soil displacement. XDisp will calculate the soil displacements arising from each excavation. These results are then summed.

Care should be taken when deriving the cuboid constituents in order to ensure that the correct relationship has been specified.

Method 1
Illustration of Excavations Required

Method 1
Vertical Ground Movement at Surface
Sample Contours

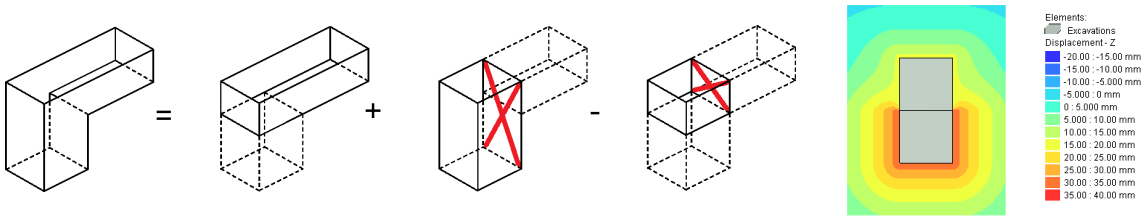


Method 2 - Composite Excavation (with zero ground movement applied to internal walls)

This method is the same as Method 1, but with ground movement curves of zero ground movement being applied to the internal walls, since they would not be present within the excavation in reality. This avoids such "phoney" walls contributing to ground movements. However, the influence of their portions which extend beneath the excavation as "true" walls would also be ignored, and drastic changes in ground movement are now seen alongside the internal walls. If buildings or utilities lie in this area, then their damage results may be unrealistically adversely affected.

Method 2
Illustration of Excavations Required

Method 2
Vertical Ground Movement at Surface Sample Contours



Method 3 - Composite Excavation (with zero ground movement applied to internal walls and internal corner arcs disabled)

This method is the same as Method 2, but with ground movements around the arcs of internal corners disabled. However, as shown in the sample contour results below, this can lead to XDisp calculating more drastic discontinuities in ground movements alongside the junction which may be unrealistic. If buildings or utilities lie in this area, then their damage results may be unrealistically adversely affected.

Method 3
Illustration of Excavations Required

Method 3
Vertical Ground Movement at Surface Sample Contours

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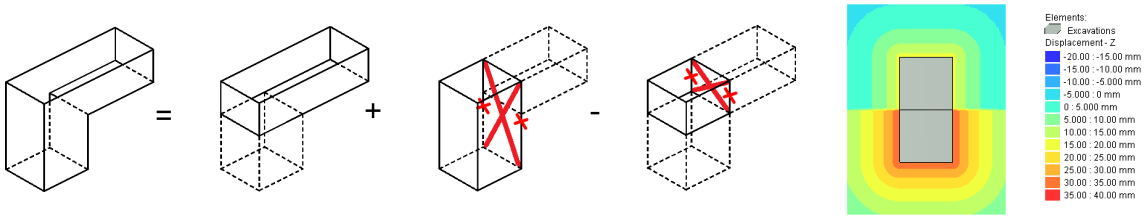
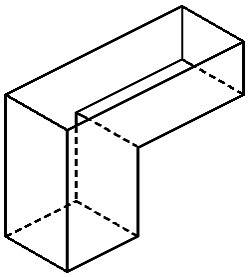


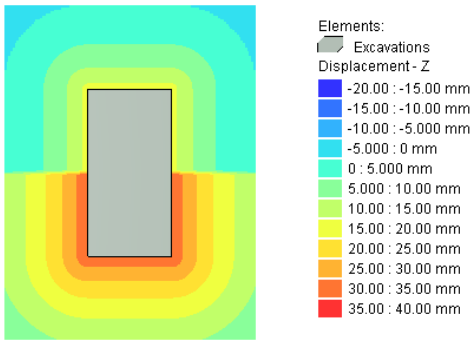
Method 4 - Single Excavation (with stepped base)

Polygonal excavations may be assigned duplicate plan coordinates with different base levels, in this way one wall with one base level may join another wall with a different base level, causing an immediate step in the base. Hence the excavation with the stepped base can be input as a single excavation. Results are identical to Method 3. The same warning applies regarding the discontinuities in ground movements alongside the junction which may be unrealistic and adversely affect building or utility damage results in that area.

Method 4
Illustration of Excavation Required



Method 4
Vertical Ground Movement at Surface
Sample Contours

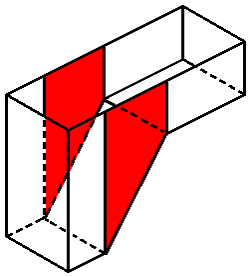


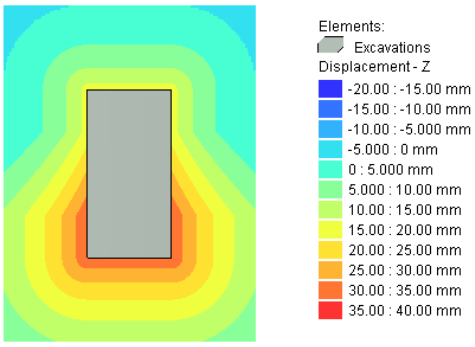
Method 5 - Single Excavation (with sloping base along short walls)

Drastic discontinuities in ground movements arising from the use of Methods 3 or 4 may be avoided by the introduction of short sides of excavation designed to change the base level of the excavation more gradually than at a single point in plan. Although these walls may not exist in reality, they have the effect of "smoothing" the contours and may prove useful in achieving more realistic ground movement results, contour plots, and building and utility damage assessment results.

Method 5
Illustration of Excavation Required

Method 5
Vertical Ground Movement at Surface
Sample Contours





2.2.4 Conjoined Excavations/Corner Arcs

When modelling complex composite excavations it should be borne in mind that Xdisp sums the displacements arising from all the individual excavations in a model and that both excavation sides and excavation corners can have an effect. See the plan and cautionary notes at the end of Embedded Wall Excavation Method.

How would the results for one large rectangular excavation be affected if the same excavation were modelled as two constituent excavations, each representing half the area? The following discussion demonstrates the use of zero movement ground movement curves for internal walls and the disabling of corner arcs. These options are set in Polygonal Excavations Data. This illustration may be a useful reference when complex excavations are to be modelled by combining more than one component excavation.

The contour plots below, show sample vertical displacements, providing a comparison of results for a single rectangular excavation and for two excavations conjoined.

(1) Single rectangular excavation of plan dimensions L x W, and depth D. Identical ground movement curves for all walls with no corner stiffening:

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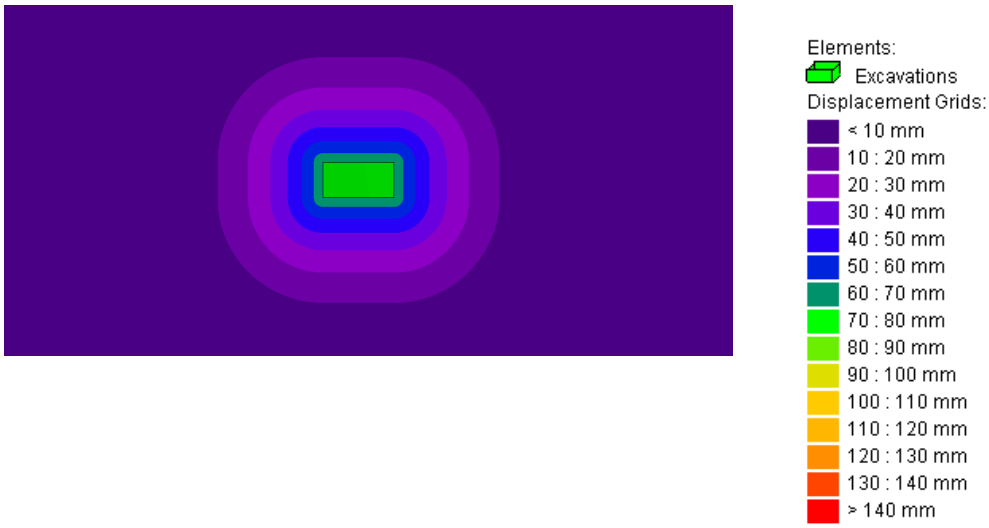
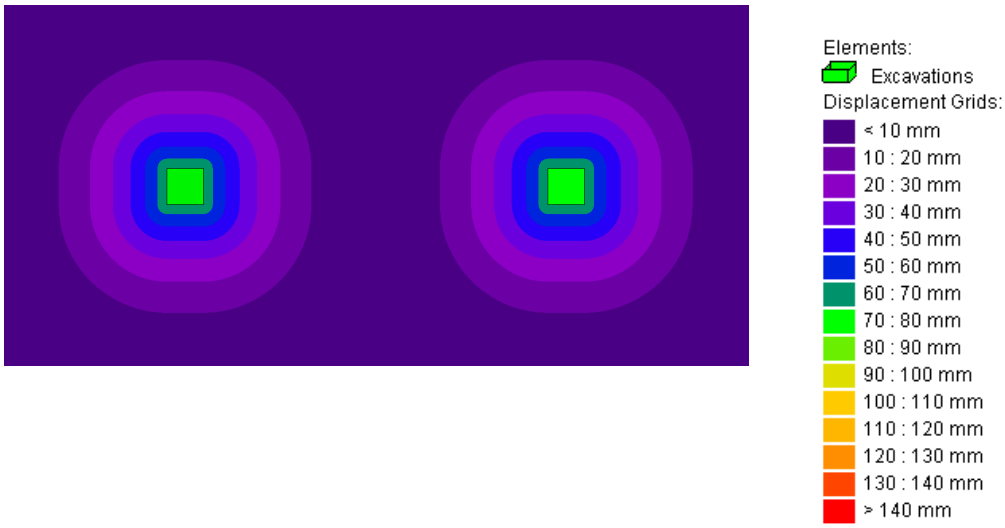


(2) Twin excavations each of plan dimension L/2 x W and depth D, with identical ground movement curves assigned to all sides and no corner stiffening...

(2.1) ...widely detached:



(2.2) ... attached:

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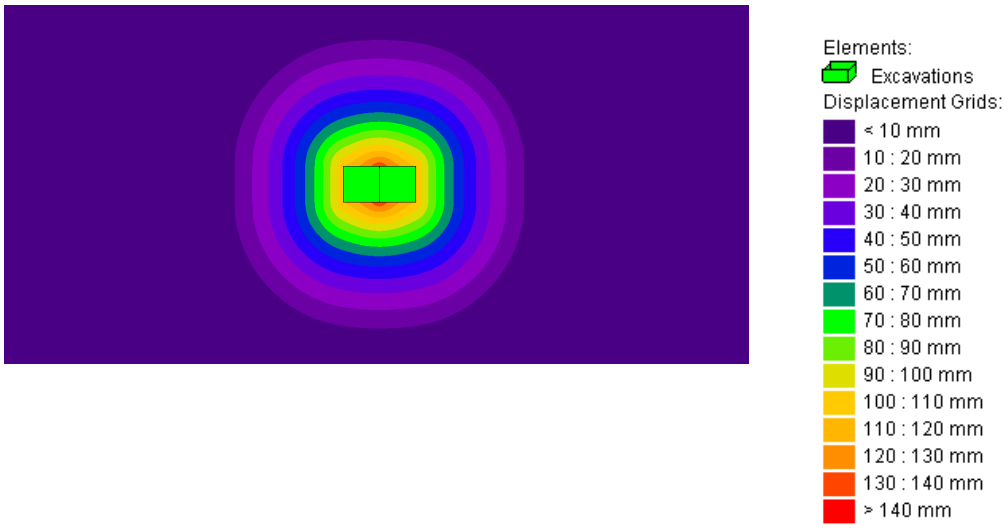
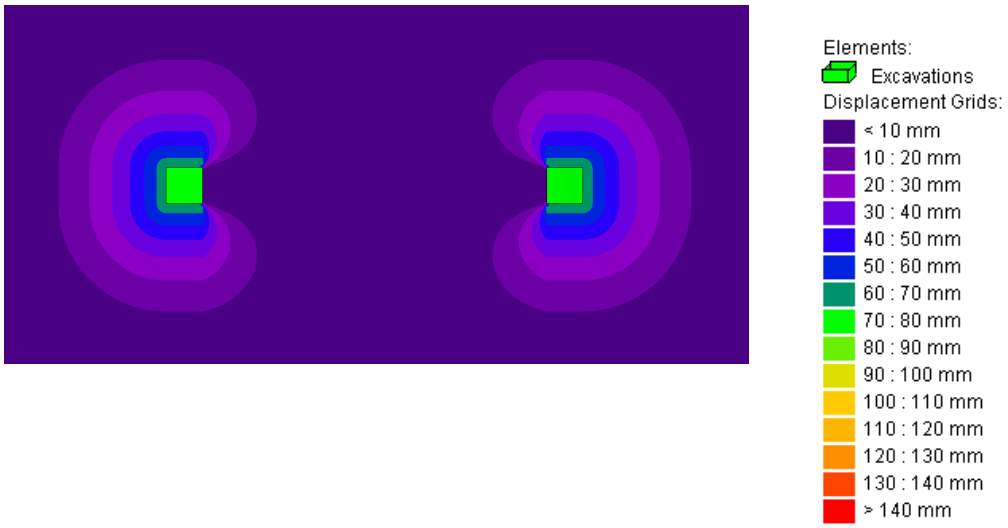


(3) Twin excavations with dimensions as (2), but with no ground movement assigned to the walls that will form the attachment...

(3.1) ... widely detached:



(3.2) ... attached:

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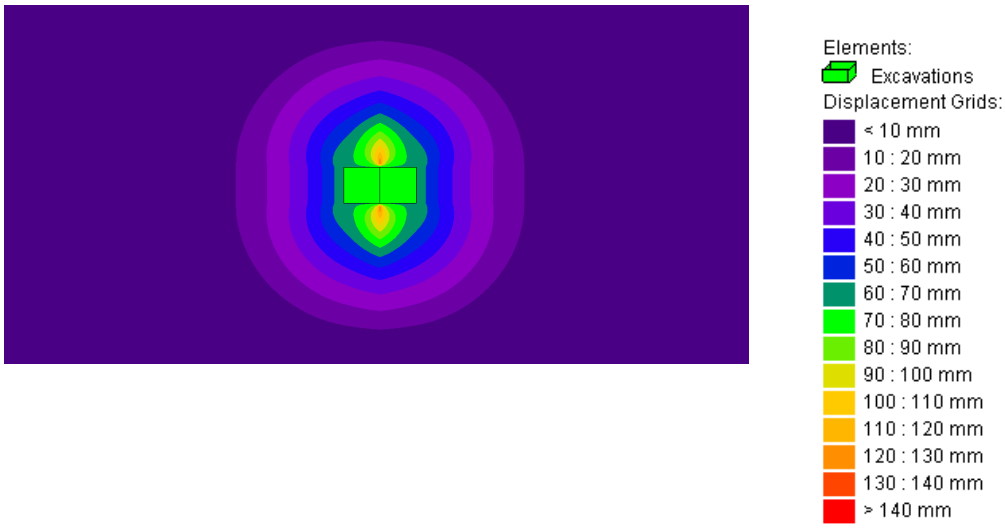
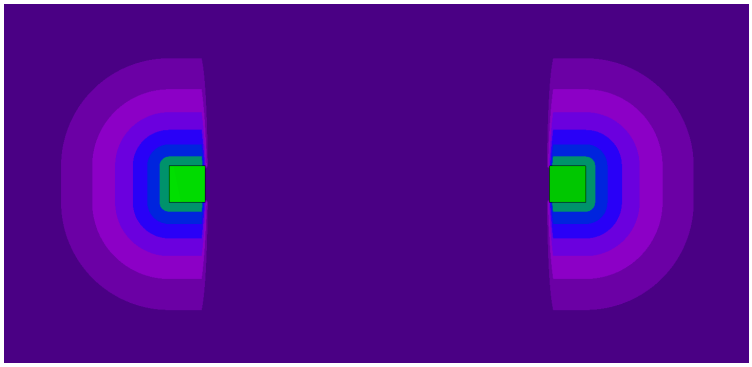


The effect of Xdisp's calculation of ground movements around corners is to produce higher ground movements adjacent to the junctions of the two excavations in both cases (2) and (3) above, than along the sides. Such movements can be reduced by assigning ground movement curves with no movements to those sides of the excavations that form the attachment, but they cannot be yet be eliminated.

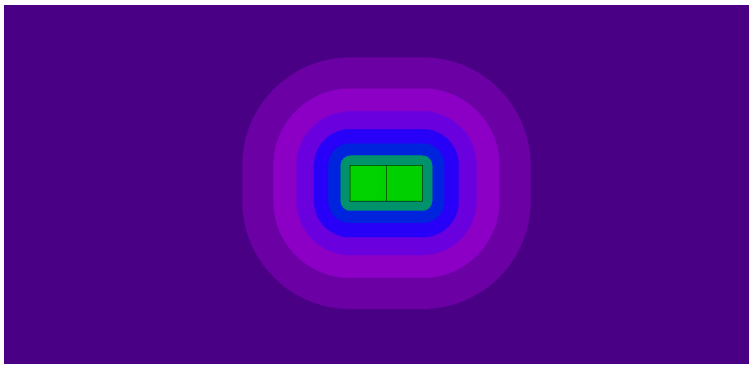
The plot in (1) can now be obtained by disabling those corner effects by setting "Corner Arcs Enabled" to "No" for the corners of the two excavations that are coincident.

(4) Twin excavations as (3) but now with "Corner Arcs Enabled" set to "No" for the corners of the two excavations that are coincident...

(4.1) ...widely detached:



(4.2) ... attached:



See Re-entrant Corners for cautionary text if modelling composite excavations resulting in re-entrant corners.

2.2.5 Re-entrant Corners

Re-entrant corners of excavations are corners with internal angles greater than 180º.

The use of re-entrant corners is permitted in XDisp but not recommended. A warning will be output if single excavations which have re-entrant corners are input or analysed. However, no warning will be given if re-entrant corners are modelled by assembling a complex excavation by joining excavations together (see Conjoined Excavations).

CIRIA C580/C760, on which XDisp's method for modelling ground movements behind walls of excavations is based, considers only movements for points lying at right angles behind single walls. It does not consider how movements should be calculated within the zone of influence of re-entrant corners, i.e. where movements would be influenced by two walls adjacent to the re-entrant corner. XDisp will merely sum the effects from both walls, making no allowance for interaction or stiffening of the corner.

Re-entrant corners should be used with caution. Results in their vicinity should be validated independently.

If corner stiffening is applied in the polygonal excavation input data then re-entrant corners will be prohibited since the stiffening method suggested by Fuentes and Devriendt makes no allowance for re-entrant corners.

2.3 Mining Analysis Method

Mines are taken as being excavations of rectangular cross-section in rock.

XDisp calculates the subsidence at ground level, due to deformation within the mine cavity, at every specified displacement grid point. Subsidence contours are then determined from the values at each point to define the whole area of the settlement trough. The spacing of the displacement grids is therefore fundamental to the accuracy of any contour plots.

The subsidence calculations are divided into vertical and horizontal displacement at each point. A single method of calculation exists in each case.

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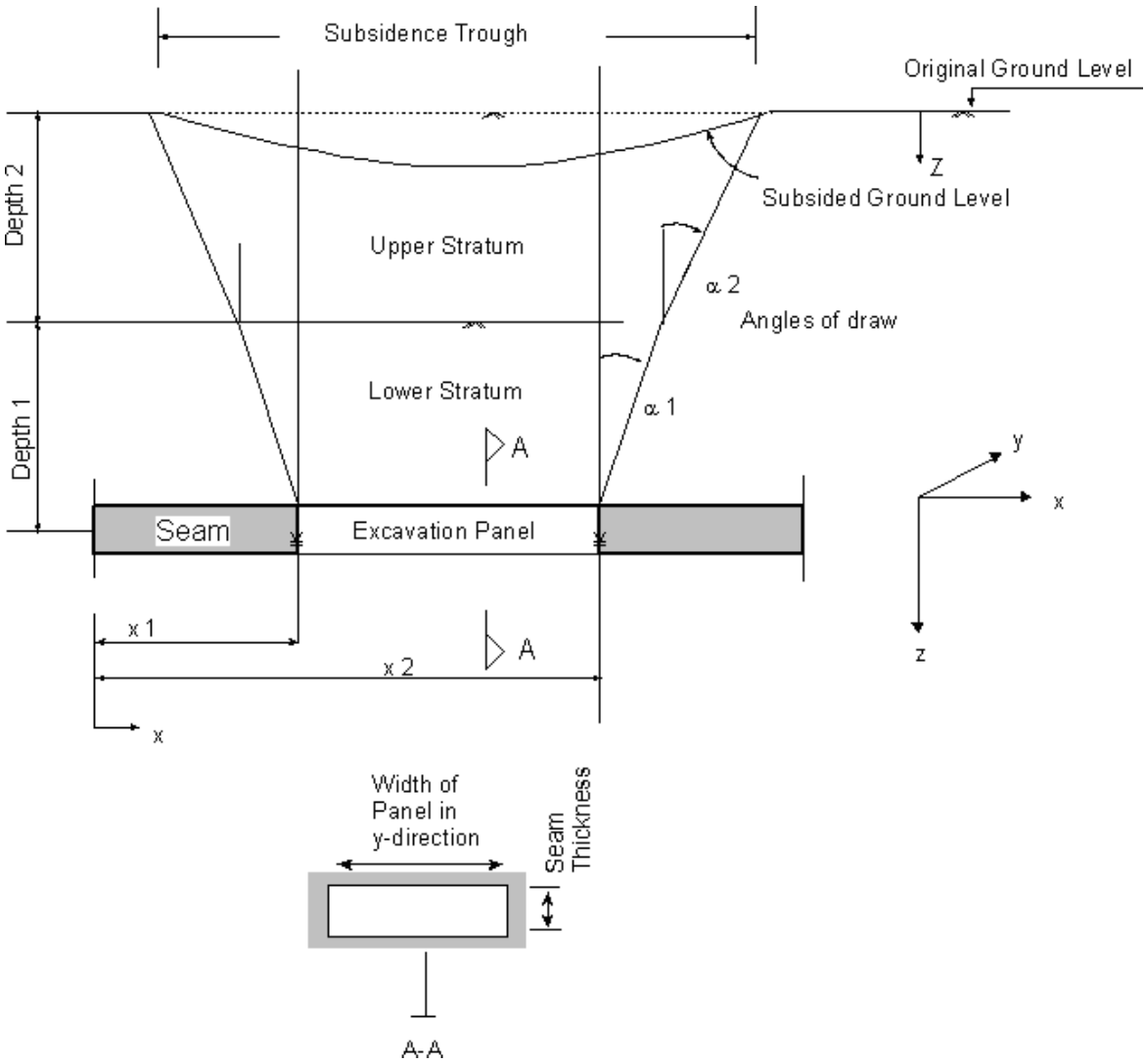
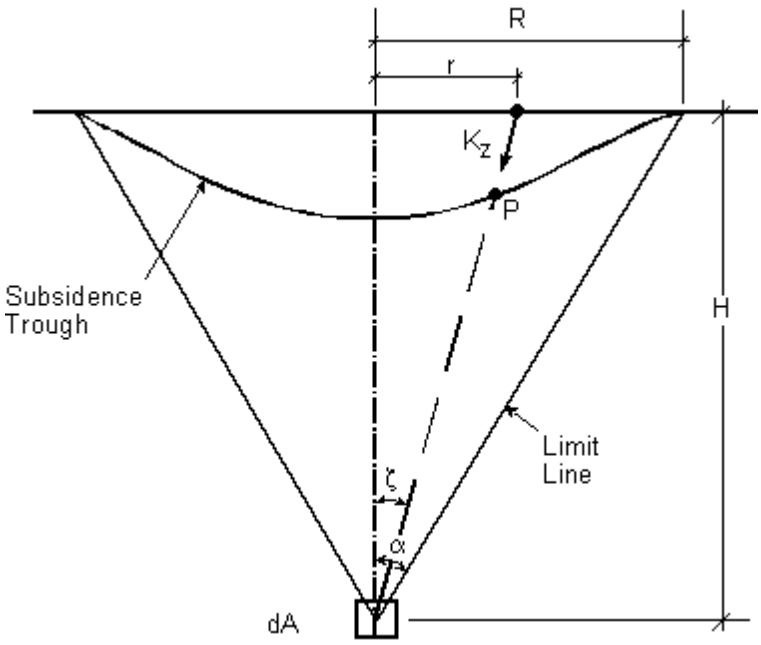


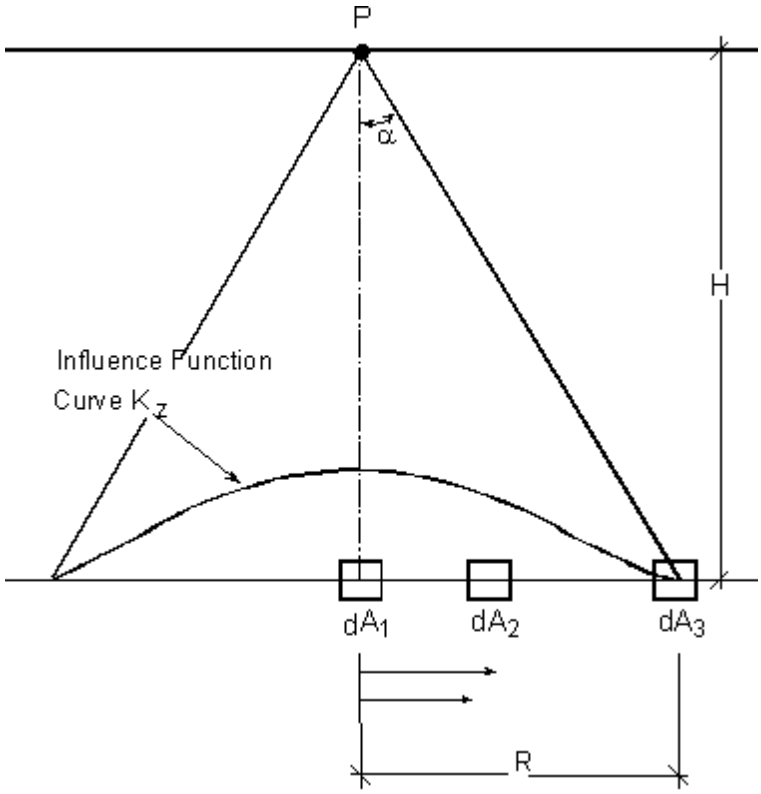
2.3.1 Vertical Displacement

The method of calculation of vertical displacement is based on the use of an influence factor (K_z). The area of subsidence created due to the extraction of an element dA at the same depth of the mine is calculated. The factor then defines the influence of the subsidence trough on the displacement grid points located at the surface.



Full details of the derivation of the influence factor can be found in Ren et al (1987).

The following describes the calculation procedure taken by **XDisp**.



Here the above statement is reversed. Each displacement grid point (P) is deemed to be over a point of maximum displacement. The influence of the actual area of extraction within the mine is then determined.

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1. The vertical displacement at each displacement grid point is taken as:

   $S = S_p S_0$

   where:

   S_0 is the maximum possible subsidence above the excavation.
   = (Subsidence Factor)x(Seam Thickness)

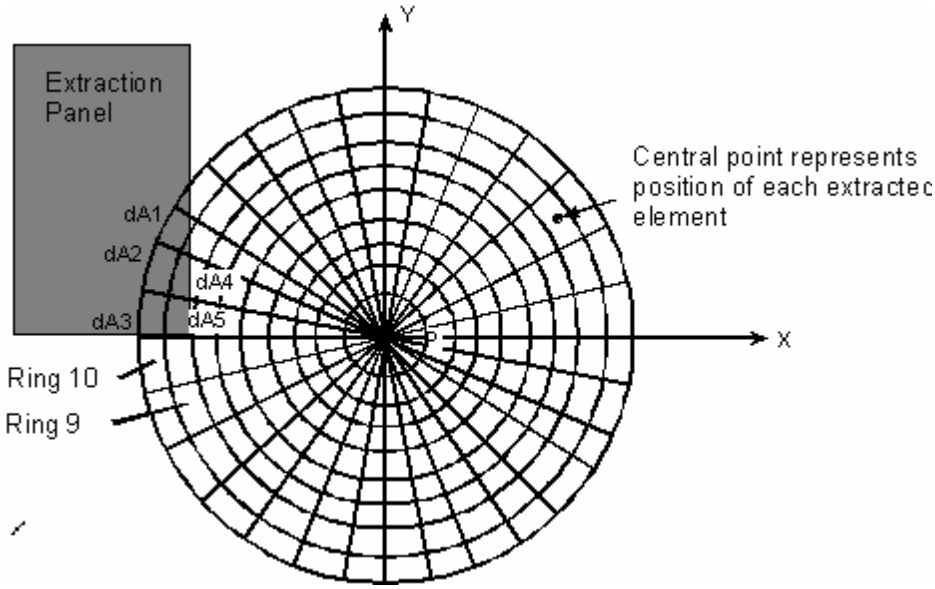
   S_P is the influence of the mine subsidence on the displacement grid point.

2. A circle of influence is defined around each grid point (P).

   The radius (R) of this circle is taken as;

   $R = H\tan\alpha$

   where H = depth to the centre of the seam



   α = Angle of draw

3. The circle is divided into 10 rings, increasing in size around the centre. The displacement at the central point is then determined by calculating the influence on the centre if extraction is made of each encircling ring.

   e.g. Each ring has an area A and width r_i to r_{i+1}. The amount of relative subsidence at the central point P after the ring is extracted is taken as $S_{(i)}$, the Annular Influence Factor. Where:

$$S_{(i)} = \left\{ \exp\left[-\pi \left(\frac{r_{i-1}}{R} \right)^2 \right] - \exp\left[-\pi \left(\frac{r_i}{R} \right)^2 \right] \right\}$$

4. Each ring is divided into 64 sectors. Each sector has an individual sector element influence factor $S_{(i)s} = S_{(i)}/64$. This indicates the amount of influence, extraction beneath that sector

exerts on the central point P at the surface.

In the example figure above the calculated values of $S_{(i)s}$ for each sector are:

Ring No.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
$S_{(i)s}$ x 10-6	505	1423	2094	2430	2433	2195	1767	1315	905	577

5. **XDisp** then calculates which sectors lie over the extracted panel. If a sector is within the area of the panel then its element influence factor $S_{(i)s}$ is summed to obtain the variable S_p.

   $Sp = \Sigma S_{(i)s}$

   e.g. for the above example where two sectors in ring 9 and three in ring 10 are extracted:

   $S_p = (2S_{(9)s} + 3S_{(10)s}) = (2 \times 905 + 3 \times 577) \times 10^{-6} = 0.003541$

6. Then settlement S at point P is:

   $S = S_p S_0$.

   e.g. $S = 0.003541 \times S_0$

2.3.2 Horizontal Displacement

XDisp calculates the horizontal movement of each displacement grid point due to subsidence in the mine. The calculation uses focal point theory and the same division of circles and sectors derived for the calculation of vertical displacement.

Focal point theory assumes that each extracted sector area dA exerts an influence on the surface point P by attracting P towards A by an amount dV. This movement can be defined in terms of a horizontal radial vector dH_{xy}, and vertical vector dV_z .

Using this assumption it is possible to calculate the horizontal displacements in conjunction with the subsidence. Where focal point theory provides the **direction** of movement and influence functions provide the **magnitude** of subsidence.

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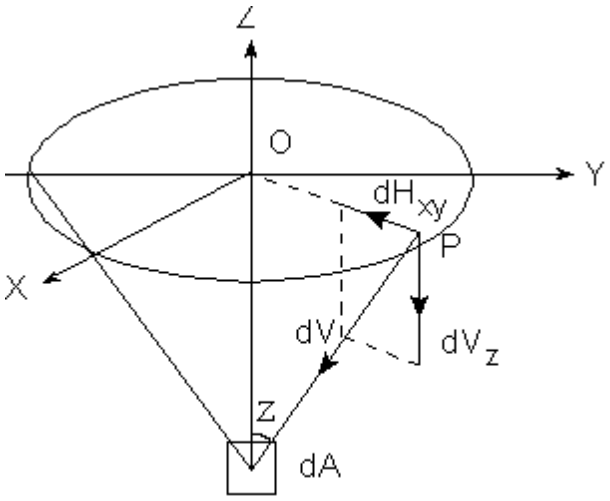

Extraction Element

The use of these two components allows the amount of horizontal movement to be determined: $dH_{xy} = \tan \zeta dV_z$

where:

ζ = angle between the vertical and the line joining the surface point P with the extraction element dA

dV = vertical displacement.

The total horizontal displacement at point P is the summation of the horizontal movement vectors dH caused by extraction at each individual element.

In order to allow summation, each movement vector is divided into its horizontal components x and y where:

$dH_x = dH_{xy} \cos \alpha$

$dH_y = dH_{xy} \sin \alpha$

Therefore the total horizontal displacement at point P is:

$H_x = \Sigma dH_x$

$H_y = \Sigma dH_y$

These values are resolved to give the total movement vector $H_{xy(p)}$ at point P.

2.4 Building Damage Method

An approach to assessing the risk of damage to buildings and structures was described by Burland (1995). This approach is adopted by **XDisp**.

For the purposes of this section, the term "building" signifies a building's facade, i.e. a "sub-building" in XDisp.

The methodology of considering the building being assessed to act as a linear elastic beam and using the concept of limiting tensile strain derives from the approach proposed by Burland and Wroth (1974) and Boscardin and Cording (1989). This guide briefly describes the approach. Interaction diagrams are plotted based upon definable building characteristics and parameters. These relate contours of limiting tensile strain (corresponding to boundaries between damage categories) to imposed deflection ratio and horizontal ground strain determined from a ground movement assessment.

XDisp assumes that the calculated average horizontal ground strain is transferred directly into the building that is being assessed. The XDisp user should note that this is potentially an onerous assumption where:

- horizontal compressive ground strains are not completely transferred from ground to the building (ie a stiffened response to horizontal compressive strains); and
- a greenfield response of the building results from vertical ground movements (ie resulting in a greenfield deflection ratio structural response).

2.4.1 Specific Building Damage Assessment

If building locations and properties are known then Specific Building Damage Assessment may be performed to calculate damage categories for precise locations. If precise locations and properties are not known, or a rapid general assessment of likely building damage across an area is required, without the need to input precise locations and properties, then Generic Building Damage Assessment may be performed.

2.4.1.1 Limiting Tensile Strain and Linear Elastic Isotropic Beams

Cracking in masonry walls and finishes usually, but not always, results from tensile strain. Burland and Wroth (1974) noted the following.

(i) The average values of strain at which visible cracking occurs, ε_{crit} are very similar for a variety of types of brickwork and blockwork and are in the range of 0.05% to 0.1%.
(ii) For reinforced concrete beams, the onset of visible cracking occurs at lower values of tensile strain in the range 0.03% to 0.05%.
(iii) The values of ε_{crit} in (i) and (ii) are much larger than the local tensile strains corresponding to tensile failure.
(iv) The onset of visible cracking does not necessarily represent a limit of serviceability. Provided the cracking is controlled, it may be acceptable to allow deformations well beyond the initiation of visible cracking.

Burland et al (1977) introduced the concept of limiting tensile strain, ε_{lim} as a serviceability parameter which can be varied to take account of differing material and serviceability limit states. Boscardin and Cording (1989) developed this concept assessing 17 case records of damage due to excavation induced subsidence. They related the ranges of ε_{lim} to the likely severity of damage. Burland et al (1977) had previously assigned categories of damage severity to descriptions of typical damage. The

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table below is the commonly used building/structure damage risk classification table summarising the above.

Building / Structure Damage Risk Classification (Burland (1997))

Damage Category	Category of damage	Description of typical damage+ (Ease of repair is underlined)	Approx. crack width* (mm)	Limiting tensile strain (%)
0	Negligible	Hairline cracks	< 0.1	< 0.05
1	Very Slight	Fine cracks that can easily be treated during normal decoration. Perhaps isolated slight fracture in buildings. Cracks in external brickwork visible on inspection.	< 1	0.05 - 0.075
2	Slight	Cracks easily filled. Redecorating probably required. Several slight fractures showing inside of building. Cracks are visible externally and some repointing may be required externally to ensure weather tightness. Doors and windows may stick slightly.	< 5	0.075 - 0.15
3	Moderate	The cracks require some opening up and can be patched by a mason. Recurrent cracks can be masked by suitable linings. Repointing of external brickwork and possibly a small amount of brickwork to be replaced. Doors and windows sticking. Service pipes may fracture. Weather tightness often impaired.	5 - 15 or a number of cracks > 3	0.15 – 0.3
4	Severe	Extensive repair work involving breaking out and replacing sections of walls, especially over doors and windows. Windows and door frames distorted, floor sloping noticeably. Walls leaning and bulging noticeably, some loss of bearing in beams. Service pipes disrupted.	15 - 25 but also depends on number of cracks	> 0.3
5	Very Severe	This requires a major repair job involving partial or complete rebuilding. Beams lose bearing, walls lean badly and require shoring. Windows broken due to distortion. Danger of instability.	Usually > 25 but depends on number of cracks.	-

Notes
+ In assessing the degree of damage, account must be taken of its location in the building or structure.
* Crack width is only one aspect of damage and should not be used on its own as a direct measure.

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2.4.1.2 Linear Elastic Isotropic Beams

Burland and Wroth (1974) and Burland (1995) used the concept of limiting tensile strain to study the onset of cracking in simple weightless elastic beams undergoing sagging and hogging modes of deformation. Burland (1974) demonstrated that the criteria for initial cracking of simple beams are in very good agreement with the case records of damaged and undamaged building. Therefore, in many circumstances, it is reasonable to represent the façade of a building by means of a simple rectangular beam.

2.4.1.3 Sagging and Hogging

The approach adopted by Burland and Wroth (1974) is illustrated in the figure below where the building is represented by a rectangular beam of length L and height H. The problem is to calculate the tensile strains in the beam for a given deflected shape of the building foundations and hence obtain the deflection ratio Δ/L at which cracking is initiated. It is immediately obvious that little can be said about the distribution of strains within the beam unless we know its mode of deformation. Two extreme modes are bending only about a neutral axis at the centre and shearing only. In the case of bending only, the maximum tensile strain occurs in the bottom fibre and that is where cracking will initiate as shown. In the case of shear only, the maximum tensile strains are inclined at 45° giving rise to diagonal cracking. In general both modes of deformation will occur simultaneously and it is necessary to calculate both bending and diagonal tensile strains to ascertain which type is limiting.

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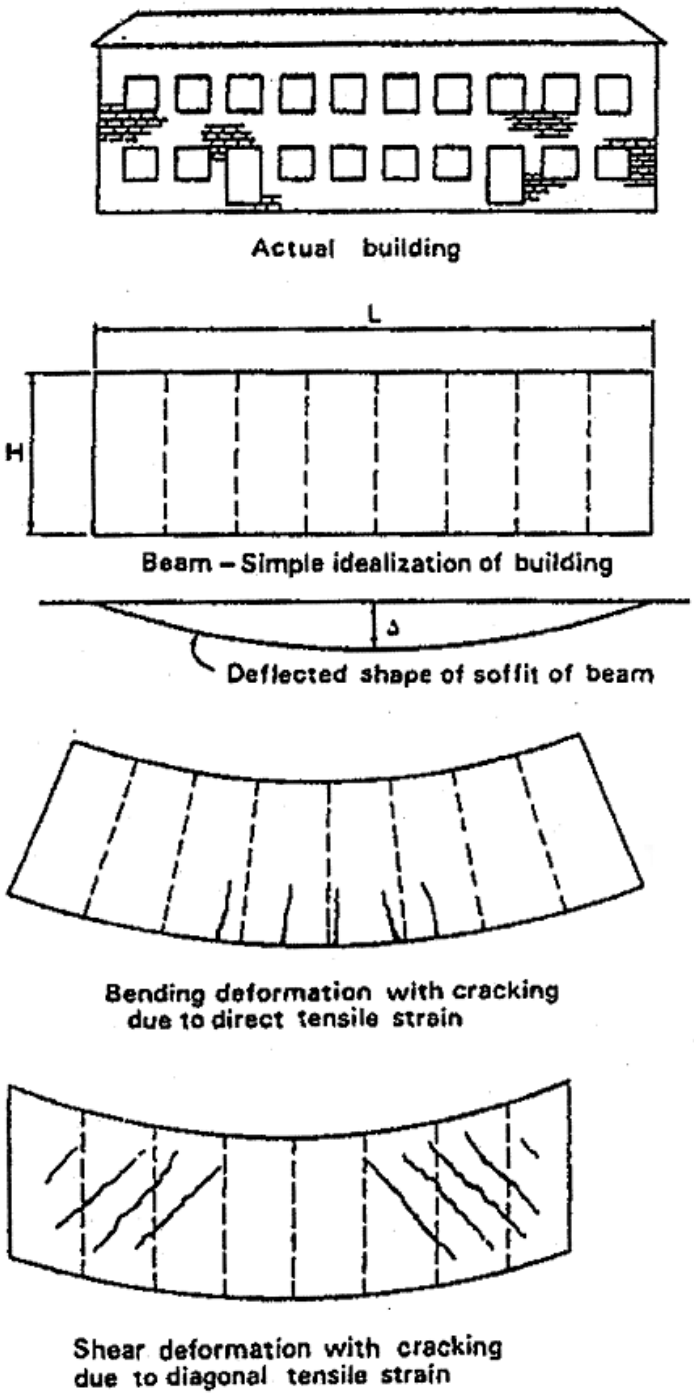
Hogging and Sagging Deformations and Definitions of Δ, L and H (Burland 1995)



The expression for the total mid-span deflection Δ of a central point loaded beam having both bending and shear stiffness is given by Timoshenko (1957) as:

$$\Delta = \frac{PL^3}{48EI}\left(1 + \frac{18EI}{L^2HG}\right)$$

where:

E = Young's modulus
G = shear modulus
I = second moment of area
P = point load.

Burland (1974) established that, considering structures behaving in pure bending, "the limiting relationship between Δ/L and L/H is not very sensitive to the form of load distribution".

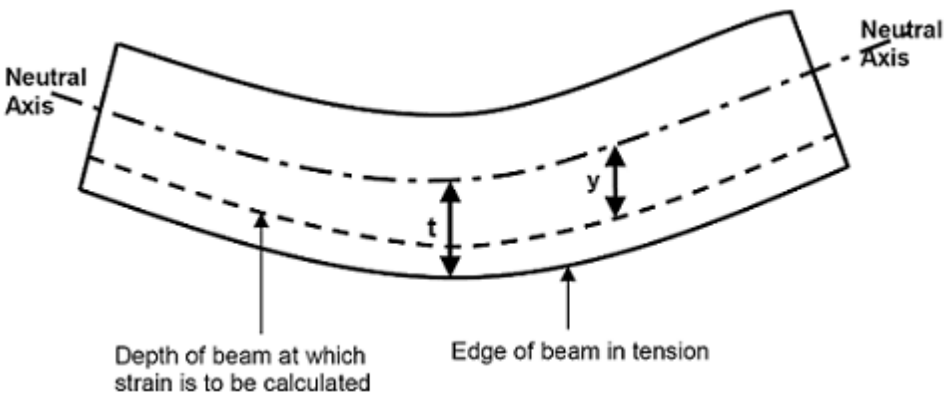
The equation for Δ above can be re-written in terms of the deflection ratio Δ/L and the maximum extreme fibre strain ε_{bmax} as follows:

$$\frac{\Delta}{L} = \left(\frac{L}{12t} + \frac{3IE}{2yLHG}\right)\varepsilon_{bmax}$$

where:

t = distance of the neutral axis from the edge of the beam in tension
y = distance from the neutral axis to the position where strain is to be calculated (see figure below for diagram illustrating y and t).

Definitions of y and t



Similarly, for the maximum diagonal strain ε_{dmax}, the equation for Δ becomes:

$$\frac{\Delta}{L} = \left(1 + \frac{HL^2G}{18IE}\right)\varepsilon_{dmax}$$

Expressions are also obtained for the case of a uniformly distributed load with the diagonal strains calculated at the quarter points. Therefore the maximum tensile strains are much more sensitive to the value of Δ/L than to the distribution of loading.

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By setting the value of ε_{dmax} or $\varepsilon_{bmax} = \varepsilon_{lim}$, in the two equations for Δ/L above, the limiting values of Δ/L for the deflection of simple beams are defined. It is evident that, for a given value of ε_{lim}, the limiting value of Δ/L (whichever is the lowest in the two equations) depends on L/H, E/G and the position of the neutral axis. For example, during hogging the foundations are likely to offer considerable restraint causing the neutral axis to move downwards. Burland and Wroth (1974) showed that hogging with the neutral axis at the bottom edge is much more damaging than sagging with the neutral axis in the middle – a result that is well borne out in practice and illustrated by Burland and Wroth (1974) in a sequence of model brick wall diagrams given in their paper.

2.4.1.4 The Influence of Horizontal Strain

Ground movements associated with tunnelling and excavation not only involve sagging and hogging profiles but significant horizontal strains as well. Boscardin and Cording (1989) included horizontal tensile strain ε_h in the above analysis using simple superposition, i.e. it is assumed that the deflected beam is subjected to uniform extension over its full depth. The resultant extreme fibre strain ε_{br} is given by:

$$\varepsilon_{br} = \varepsilon_{bmax} + \varepsilon_h$$

In the shearing region, the resultant diagonal tensile strain ε_{dr} can be evaluated using the Mohr's circle of strain. The value of ε_{dr} is then given by:

$$\varepsilon_{dr} = \varepsilon_h\left(\frac{1-v}{2}\right) + \sqrt{\varepsilon_h^{\,2}\left(\frac{1+v}{2}\right)^2 + \varepsilon_{dmax}^{\,2}}$$

where:

v = Poisson's ratio.

The maximum tensile strain is the greater of ε_{br} and ε_{dr}. Thus, for a beam of length L and height H, it is a straight-forward matter to calculate the maximum value of tensile strain ε_{max} for a given value of ε_h, in terms of t, E/G and v, where ε_{max} is the lesser of ε_{dmax} or ε_{bmax}. This value can then be used in conjunction with the table in Limiting Tensile Strain and Linear Elastic Isotropic Beams to assess the potential associated damage.

2.4.1.5 Interaction Charts

By adopting the values of ε_{lim} associated with the various categories of damage given in the table in Limiting Tensile Strain and Linear Elastic Isotropic Beams, and by using the equations for Δ/L, ε_{br} and ε_{dr} (given in Sagging and Hogging and The Influence of Horizontal Strain), an Interaction Diagram can be developed showing the relationship between Δ/L and ε_h for appropriate values of L/H, E/G, I, v, y and t selected for the building being assessed. XDisp calculates Δ/L and ε_h parameters for the building (or each hogging or sagging segment) and determines damage categories by comparing these values with the category boundaries of the Interaction Chart. This method is based on a prediction of the deformation of the building, which may differ from the 'green field' deformation of the ground. As a conservative initial assumption it is often assumed that the deformation of the building will be the same as that assessed for the 'green field' situation. More rigorous analyses may take

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account of the stiffness of the building in reducing the deformation, allowing appropriately for the effects of the development of cracking in the building on its stiffness.

2.4.1.6 Points of Inflexion, Gradient and Radius of Curvature

For building damage assessment calculations **XDisp** must first determine the hogging and sagging zones along the length of a building. **XDisp** relies on the ground movement results for the displacement line that is associated with the building. It uses horizontal displacements that are calculated at the position of the displacement line, and vertical displacements that are calculated for three vertical offsets of this line. It therefore performs building damage assessments for three sets of vertical displacements. It fits a cubic spline to these results and, by differentiation, determines the curvature and points of inflexion which demarcate hogging and sagging zones. Building damage calculations then proceed using these zones. Points of inflexion, and therefore the segment lengths that are used in calculating deflection ratios and building damage categories, take account of imposed horizontal strains. Points of inflexion are based upon vertical displacements on the offset lines. Horizontal strains are calculated using the horizontal displacements at zero vertical offset, between these points of inflexion.

Increasing or decreasing the number of intervals at which ground movement calculations are to be performed on a displacement line will affect the definition of the cubic spline that is fitted to the results, and so will affect the building damage assessment results too.

Curvature:

$$k = \frac{d^2 y}{dx^2}$$

where y = settlement of beam
x = location of the displacement point

Radius of curvature:

$$R = \frac{1}{k}$$

Adjacent hogging or sagging zones, or segments, may be combined so that building damage calculations are performed for the aggregated zone. This can only be specified after an analysis has been performed to determine the curvature of the displacement line. See Segment Combinations.

2.4.2 Generic Building Damage Assessment

Generic Building Damage Assessment allows a rapid assessment of likely building damage over an area without the need to specify precise building locations or properties.

A polyline is input whose transects are treated as plan alignments of sub-buildings.

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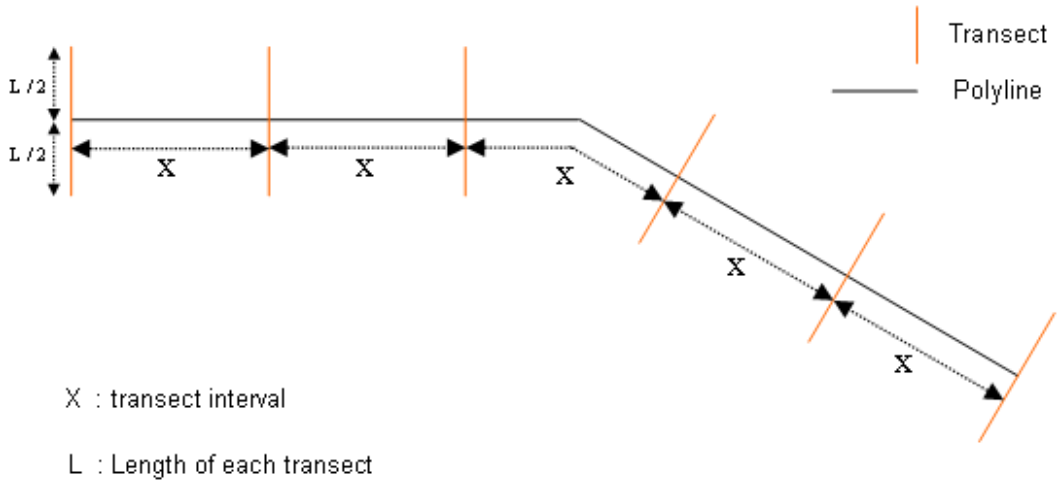

Transects

- These are perpendicular lines to the polyline created at an interval specified by the user in the Polylines input table.
- The length and number of displacement points of these transects are specified by the user in the Polylines input table.
- By default a transect is provided at the start point of the polyline.
- All transects are bisected by the polyline.

Building Damage Assessment of each transect is performed for all L/H values (input in the Generic Building Damage Assessment Table) following the Burland calculation method described in Specific Building Damage Assessment and the results reported in the Text Output.

2.5 Utility Damage Method

Two types of utility damage assessment can be performed. These are:

- Specific Utility Damage Assessment
- Generic Utility Damage Assessment

If utility locations and properties are known then Specific Utility Damage Assessment may be performed to calculate utility damage for precise locations. If precise locations and properties are not known, or a rapid general assessment of likely utility damage across an area is required without the need to input precise locations and properties, then Generic Utility Damage Assessment may be performed.

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2.5.1 Specific Utility Damage Assessment

Specific Utility Damage Assessment provides an assessment of utility damage along a specific displacement line. It therefore differs from Generic Utility Damage Assessment, which allows a rapid assessment of likely utility damage over an area without the need to specify precise locations or properties of utilities.

Assessments are performed for

- pullout
- rotation
- strain

Utilities are specified to be either jointed or unjointed. Pullout and rotation assessment calculations are performed only for jointed utilities, which require the assignment of a pipe length. Strain assessment calculations are performed for both jointed and unjointed utilities, with both types then considered as a continuum.

The determination of assessment locations for pullout and rotation differs from that for strain. See Assessment Locations for Pullout and Rotation and Strain Calculations.

In the discussions that follow the terms "upstream" and "downstream" are used to distinguish the part of the utility to one side of an assessment location from the part to the other side, when describing the calculations performed. Their use does not imply a direction of flow within a utility.

2.5.1.1 Ground Movements Along Utilities

The location of utilities is specified by each referring to a displacement line or a displacement polyline. These are divided by displacement intervals into a series of displacement locatins at which ground movements are calculated directly by the program using the methodologies described for tunnels and embedded wall excavations. However, the calculation of pullout, rotation and strain along a utility may require estimation of ground movements at locations between these displacement points. XDisp therefore fits a cubic spline to the displacements that are calculated directly by the program at all the displacement points of the utility's displacement line. It then uses that spline to estimate the displacements anywhere along the utility - whether at the location of a displacement point, or between displacement points. The spline will give the same ground movements at the displacement points as the program calculates directly, but additionally enables the estimation of ground movements at locations between those displacement points.

2.5.1.2 Assessment Locations for Pullout and Rotation

See Ground Movements Along Utilities for a discussion of the specification of a utility's location using displacement lines or displacement polylines, and for the significance of displacement intervals and displacement locations.

Utilities are made up of pipes, each of which has a pipe length.

A discussion follows regarding XDisp's determination of assessment locations.

Consider assessment locations to be defined as those displacement points on a utility which have a pipe length of utility both upstream and downstream. Therefore the first and last displacement points along a utility will not qualify as assessment locations, neither will other displacement points near

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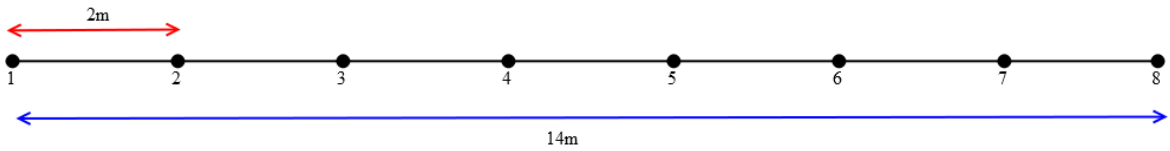
the start and end of a utility if the pipe length is greater than one displacement interval.

Pullout and rotation assessment calculations are performed at assessment locations in a series of iterations. Each of these iterations contains a group of assessment locations.



Consider the utility of 14m length shown above. The displacement interval is 2m. 1, 2, 3, 4, 5, 6, 7 and 8 are the displacement points along the displacement line.

There are 2 possible cases for the determination of assessment locations. Case 1 applies if the pipe length is a multiple of the displacement interval. Case 2 applies if the pipe length is not a multiple of the displacement interval.

Case 1

Assume the pipe length is 4m and the displacement interval is 2m. Since the pipe length is a multiple of the displacement interval Case 1 applies.

Only displacement points 3, 4, 5 and 6 are assessment locations. Displacement points 1, 2, 7 and 8 are ignored as they do not satisfy the condition of having a pipe length of utility both upstream and downstream.

Iteration 1 (assessments at displacement points 3 and 5)

The first iteration starts at the first available assessment location, i.e. at displacement point 3. The next and last assessment location in this iteration is one pipe length away from displacement point 3, i.e. at displacement point 5.

Iteration 2 (assessments at displacement points 4 and 6)

The second and last iteration starts with an assessment location at displacement point 4. The next and last assessment location in this iteration is one pipe length away from displacement point 4, i.e. at displacement point 6.

There are no more iterations carried out for this case as all the possible assessment locations along the utility have now been considered.

Case 2

Assume the pipe length is 3m and the displacement interval is 2m. Since the pipe length is not a multiple of the displacement interval this case applies.

Only displacement points 3, 4, 5 and 6 are assessment locations. Displacement points 1, 2, 7 and 8 are ignored as they do not satisfy the condition of having a pipe length of utility both upstream and downstream.

Iteration 1 (assessments at displacement points 3 and 5)

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The first iteration in this case also starts at the first available assessment location, i.e. at displacement point 3. Since there is no displacement point exactly one pipe length downstream from displacement point 3, the next displacement point beyond is taken as the next assessment location, i.e. displacement point 5.

Iteration 2 (assessments at displacement points 4 and 6)

The second and last iteration starts with an assessment location at displacement point 4. Since there is no displacement point exactly one pipe length downstream of point 4, the next displacement point beyond is taken as the next assessment location, i.e. displacement point 6.

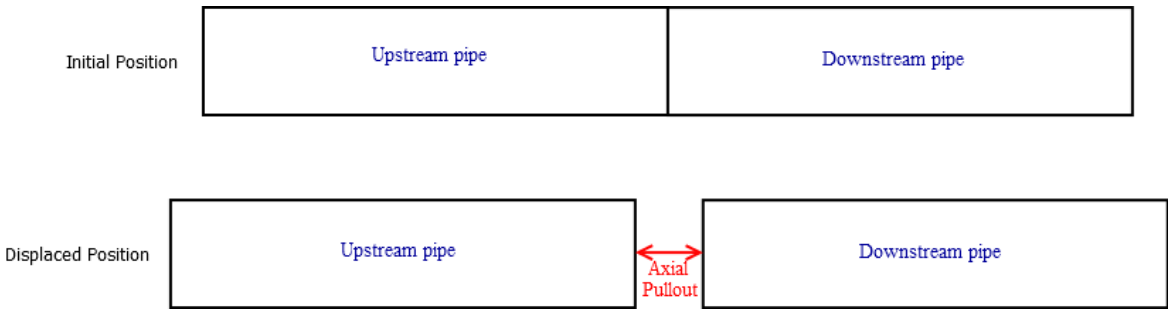
There are no more iterations carried out for this case as all the possible assessment locations along the utility have now been considered.

2.5.1.3 Pullout

An assessment of pullout, comprising axial and flexural pullout, is performed for jointed utilities only, and uses Ground Movements Along Utilities. For the determination of assessment locations see Assessment Locations for Pullout and Rotation.

Pullout calculations are performed by considering the relative movements of the pipes upstream and downstream of an assessment location. Pipes are considered to be infinitely rigid. The movement of the upstream and downstream pipes with respect to the assessment location is the average of the horizontal component of ground movements parallel to (i.e. along) the pipe's axis, for all displacement points within one pipe length of the assessment point, multiplied by a coefficient to take into account the soil-pipe interaction. The contraction of the upstream pipe is then added to the contraction of the downstream pipe to obtain the total pullout at the assessment location. Neither friction between pipes nor interlocking due to the rotation of joints are considered.

Axial Pullout



If the assessment location is displacement point 'n' along the utility, then the contributions to axial pullout from the upstream and downstream pipes are considered to be given by:

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$$POaxial\text{-}upstream = -\left(\frac{D_{//(n)} + D_{//(n-1)} + D_{//(n-2)} + \ldots\ldots\ldots + D_{//(n-Lp)}}{N}\right)$$

$$POaxial\text{-}downstream = \left(\frac{D_{//(n)} + D_{//(n+1)} + D_{//(n+2)} + \ldots\ldots\ldots + D_{//(n+Lp)}}{N}\right)$$

where:

$PO_{axial\text{-}upstream}$ = contribution to axial pullout from the upstream pipe
$PO_{axial\text{-}downstream}$ = contribution to axial pullout from the downstream pipe
$D_{//(n)}$ = horizontal component of ground movement that is along the utility at the nth displacement point
$D_{//(n\text{-}1)}$ = horizontal component of ground movement that is along the utility at $(n - 1)^{th}$ displacement point, i.e. the point that is immediately upstream of 'n'
$D_{//(n\text{-}Lp)}$ = horizontal component of ground movement that is along the utility at a point a distance L_p upstream of 'n'
N = number of points in the numerator

The factored values of these pullouts are given by:

$$POaxial\text{-}upstream\text{-}factored = f_{pullout\text{-}axial} * POaxial\text{-}upstream$$

$$POaxial\text{-}downstream\text{-}factored = f_{pullout\text{-}axial} * POaxial\text{-}downstream$$

where:

$f_{pullout\text{-}axial}$ = axial pullout factor as specified in the Factors table

The total axial pullout at an assessment location (PO_{axial}) is then given by:

$$PO_{axial} = PO_{axial\text{-}downstream} + PO_{axial\text{-}upstream}$$

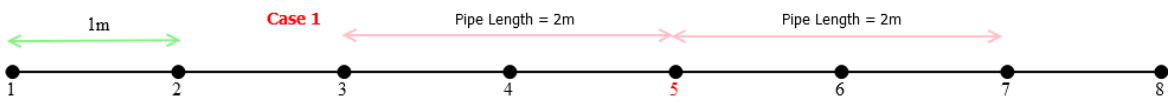
The factored total axial pullout is given by:

$$PO_{axial\text{-}factored} = PO_{axial\text{-}downstream\text{-}factored} + PO_{axial\text{-}upstream\text{-}factored}$$

However when later combined with flexural strain to calculate total strain, this axial component (PO_{axial}) is included only if it is positive, i.e. if it represents pullout of a joint at the assessment location. If it represents compression of a joint at the assessment location then it is ignored.

Examples are given below. The distinction between Case 1 and Case 2 is clarified in Locations of Assessment Calculations.

Case 1 (if pipe length is a multiple of displacement interval)

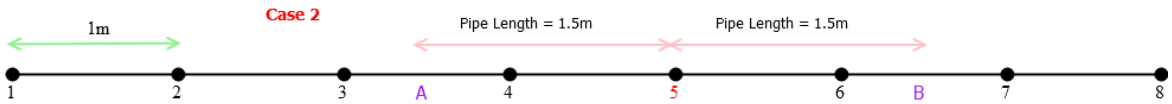


Contributions to axial pullout for the assessment location at displacement point 5 are given as:

$$POaxial\text{-}upstream = -\left(\frac{D_{///(5)} + D_{///(4)} + D_{///(3)}}{3}\right)$$

$$POaxial\text{-}downstream = \left(\frac{D_{///(5)} + D_{///(6)} + D_{///(7)}}{3}\right)$$

Case 2 (if pipe length is not a multiple of displacement interval)



In this case there are no displacement points available at locations A and B, which are a pipe length upstream and a pipe length downstream of displacement point 5. However, the cubic spline discussed in Ground Movements Along Utilities is available to provide an estimate of displacements at A and B.

Contributions to axial pullout for the assessment location at displacement point 5 are given as:

$$POaxial\text{-}upstream = -\left(\frac{D_{///(5)} + D_{///(4)} + D_{///(A)}}{3}\right)$$

$$POaxial\text{-}downstream = \left(\frac{D_{///(5)} + D_{///(6)} + D_{///(B)}}{3}\right)$$

Flexural Pullout

When considering flexural pullout at the assessment location any bending in the adjacent pipes is ignored. Pipes are assumed to remain straight and all ground movements are accommodated by rotation of a nominal joint at the assessment location.

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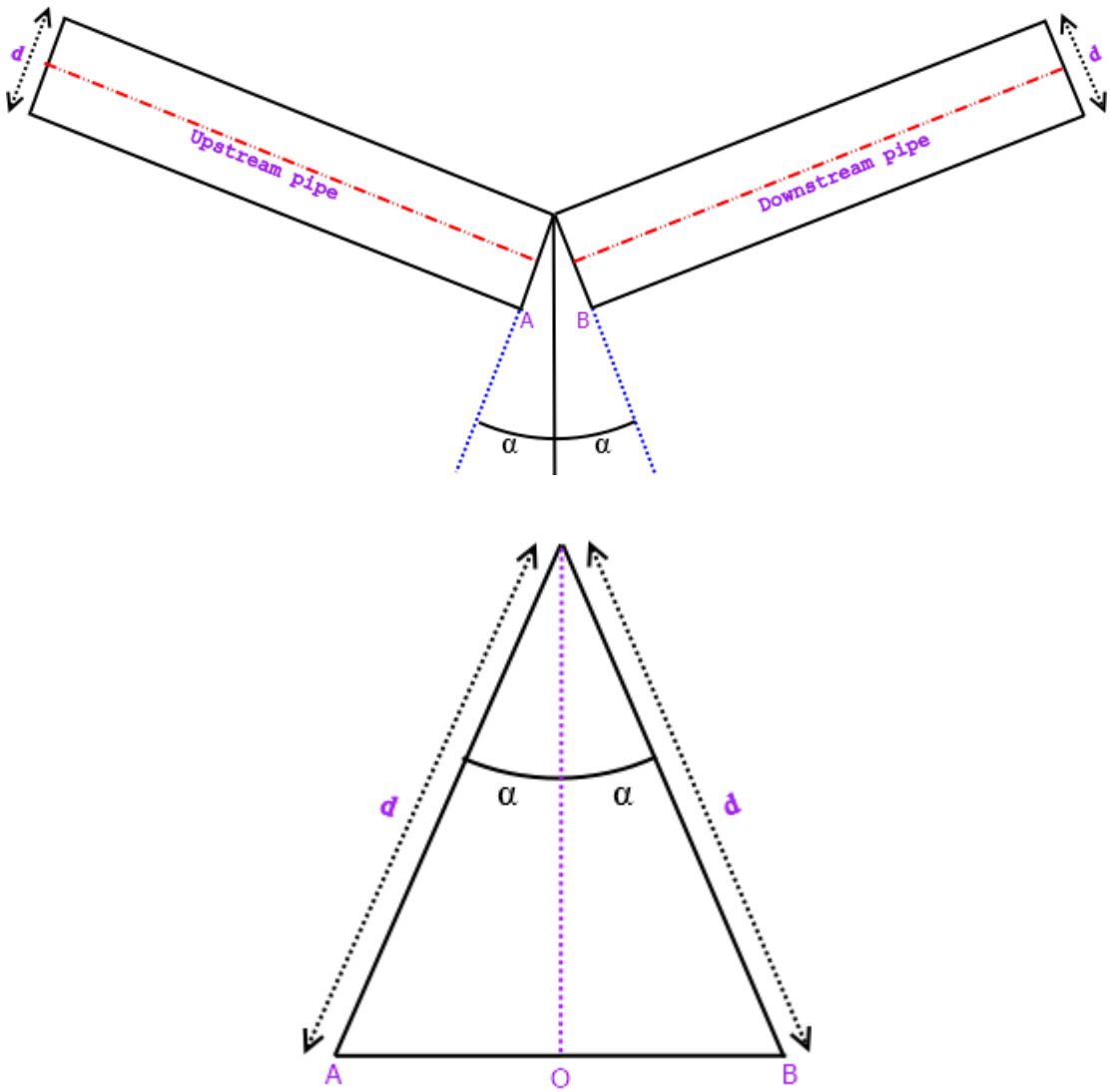

Figures illustrating flexural pullout

If 2α is the rotation of the joint then the total flexural pullout at the joint is given by:

$$PO_{flexural} = PO_{flexural\text{-}upstream} + PO_{flexural\text{-}downstream}$$

where

$PO_{flexural\text{-}upstream}$ = contribution to flexural pullout from upstream pipe
= AO
= $d \; x \; sin \; \alpha$

and

$PO_{flexural\text{-}downstream}$ = contribution to flexural pullout from downstream pipe
= OB
= $d \times \sin \alpha$

where

α = half the rotation of the angle at the joint
d = the external diameter of the utility given by
= $P_{dia} + 2P_{wt}$
where
P_{dia} = internal diameter of the utility
P_{wt} = wall thickness of the utility

The factored values of flexural pullout are given by:

$$PO_{flexural\text{-}upstream\text{-}factored} = f_{pullout\text{-}flexural} * PO_{flexural\text{-}upstream}$$
$$PO_{flexural\text{-}downstream\text{-}factored} = f_{pullout\text{-}flexural} * PO_{flexural\text{-}downstream}$$
$$PO_{flexural\text{-}factored} = PO_{flexural\text{-}upstream\text{-}factored} + PO_{flexural\text{-}downstream\text{-}factored}$$

As for axial pullout, in cases where the displacement interval is not a multiple of the pipe length, XDisp fits a cubic spline to the displacements that are calculated at all the displacement points of the utility's displacement line and uses that to estimate the displacements at the far ends of the upstream and downstream pipes.

Note : Users may be familiar with the term “reduction factor”. Pullout reduction factors are achieved by setting the factor of pullout to less than 1.

Total Pullout

The total pullout at the assessment location 'n' is then given by:

$$PO = PO_{axial} + PO_{flexural}$$

where

PO_{axial} = total axial pullout (considered only if it is positive)
$PO_{flexural}$ = total flexural pullout

The total factored pullout is given by

$$PO_{factored} = PO_{axial\text{-}factored} + PO_{flexural\text{-}factored}$$

2.5.1.4 Rotation

An assessment of rotation is performed for jointed utilities only, and uses Ground Movements Along Utilities. For the determination of assessment locations see Assessment Locations for Pullout and Rotation.

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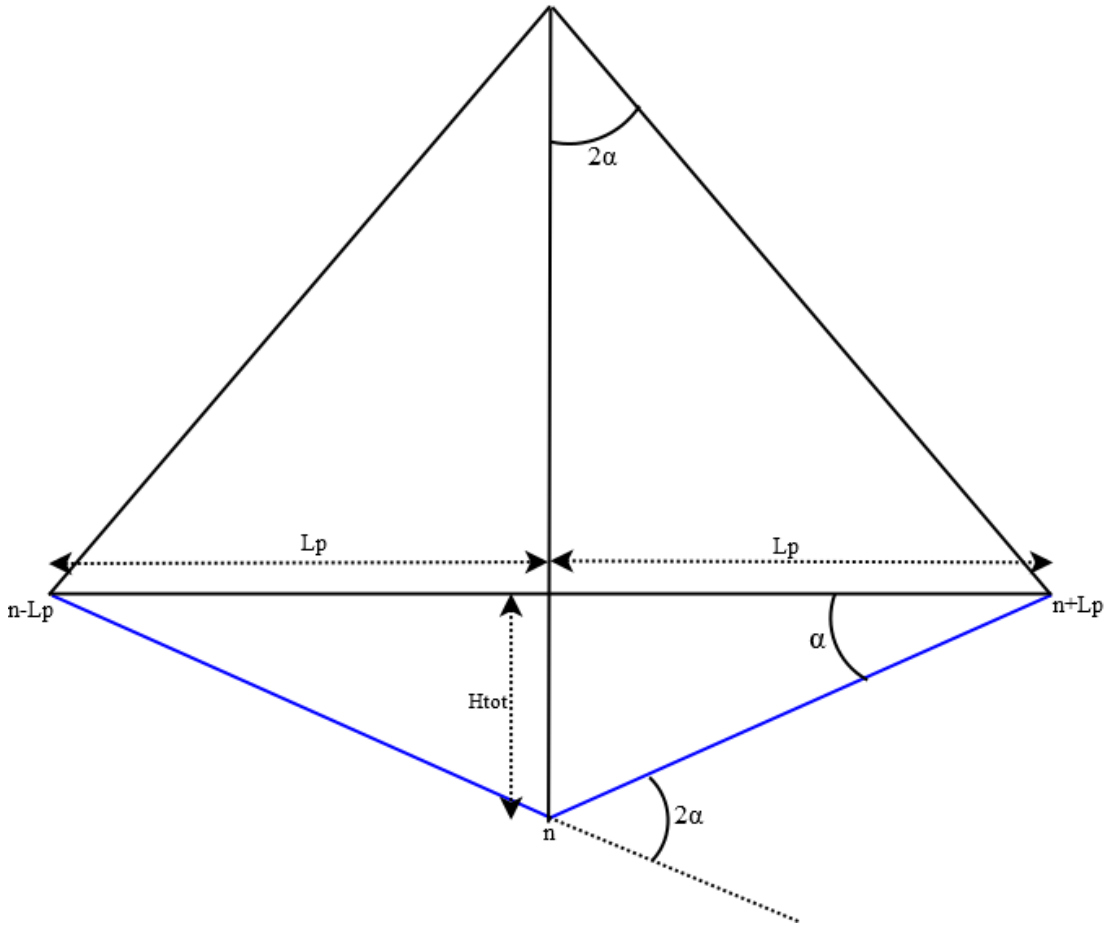
When considering rotation at the assessment location any bending in the adjacent pipes is ignored. Pipes are assumed to remain straight and all ground movements are accommodated by rotation of a nominal joint at the assessment location.

The rotation angle, 2α, between the upstream pipe and the downstream pipe at each assessment location is calculated as follows.



Rotation at an Assessment Location

Consider an assessment location at displacement point 'n'.

L_p	= length of the pipe
$n\text{-}L_p$	= point at a distance of L_p upstream of the assessment location
$n+L_p$	= point at a distance of L_p downstream of the assessment location

The horizontal offset in the perpendicular direction $H_{\perp}$ between the ends of the pipe is given by:

$$H_{\perp} = D_{\perp(n)} - \left(\frac{D_{\perp(n-Lp)} + D_{\perp(n+Lp)}}{2} \right)$$

where:

$D_{\perp(n)}$ = displacement perpendicular to the utility at the assessment location

$D_{\perp(n-Lp)}$ = displacement perpendicular to the utility at a distance L_p upstream of the assessment location

$D_{\perp(n+Lp)}$ = displacement perpendicular to the utility at a distance L_p downstream of the assessment location

Similarly, replacing H with V, the vertical offset V between the ends of the pipe is given by:

$$V = V_{(n)} - \left(\frac{V_{(n-Lp)} + V_{(n+Lp)}}{2} \right)$$

where:

$V_{(n)}$ = vertical displacement at the assessment location

$V_{(n-Lp)}$ = vertical displacement at a distance L_p upstream of the assessment location

$V_{(n+Lp)}$ = vertical displacement at a distance L_p downstream of the assessment location

Positive V indicates hogging and negative V indicates sagging

The total offset H_{tot} is given by:

$$H_{tot} = \sqrt{(H_{\perp})^2 + (V)^2}$$

The rotation in the pipe at the assessment location is 2*α*, where *α* is given by:

$$\alpha = tan^{-1}\left(\frac{H_{tot}}{L_p} \right)$$

Rotation = 2α

Factored rotation = $f_{rotation}$ * 2α

where:

$f_{rotation}$ = rotation factor as specified in the Factors table

2.5.1.5 Strain

An assessment of total strain, comprising axial and bending strains, is performed for all utilities - i.e. both jointed and unjointed, and uses Ground Movements Along Utilities. Strains are calculated and reported for every displacement point on the utility that has another displacement point both upstream and downstream, so not the first and last.

The assumptions made are described by Bracegirdle et al. (1996). Bending strains along the utility are calculated assuming the utility follows the movement of ground.

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Axial Strain

Axial strain is calculated as the ratio of change in length between adjacent mid-points of displacement intervals, to original length.

Given that:

d	= displacement interval
1…5	= displacement points
A	= the mid-point between displacement points 2 and 3
B	= the mid-point between displacement points 3 and 4
AB	= the portion of utility used to calculate the axial strain at displacement point 3

The axial strain for the utility at displacement point 3 is given by:

change in length of AB / original length of AB

The original distance between the points A and B is given by:

$$L_{iAB} = \sqrt{(X_{iA} - X_{iB})^2 + (Y_{iA} - Y_{iB})^2 + (Z_{iA} - Z_{iB})^2}$$

where

(X_{iA}, Y_{iA}, Z_{iA}) = initial position of point A

(X_{iB}, Y_{iB}, Z_{iB}) = initial position of point B

The final distance between the points A and B is given by:

$$L_{fAB} = \sqrt{(X_{fA} - X_{fB})^2 + (Y_{fA} - Y_{fB})^2 + (Z_{fA} - Z_{fB})^2}$$

where

(X_{fA}, Y_{fA}, Z_{fA}) = final position of point A

(X_{fB}, Y_{fB}, Z_{fB}) = final position of point B

The change in length, DL, is given by:

$$DL = L_{fAB} - L_{iAB}$$

The axial strain in the ground over the given interval AB is given by:

$$\varepsilon_{axial} = \frac{DL}{L_i}$$

The factored axial strain is given by:

$$\varepsilon_{axial-factored} = f_{axial} * \frac{DL}{L_i}$$

where

if axial strain is tensile in nature

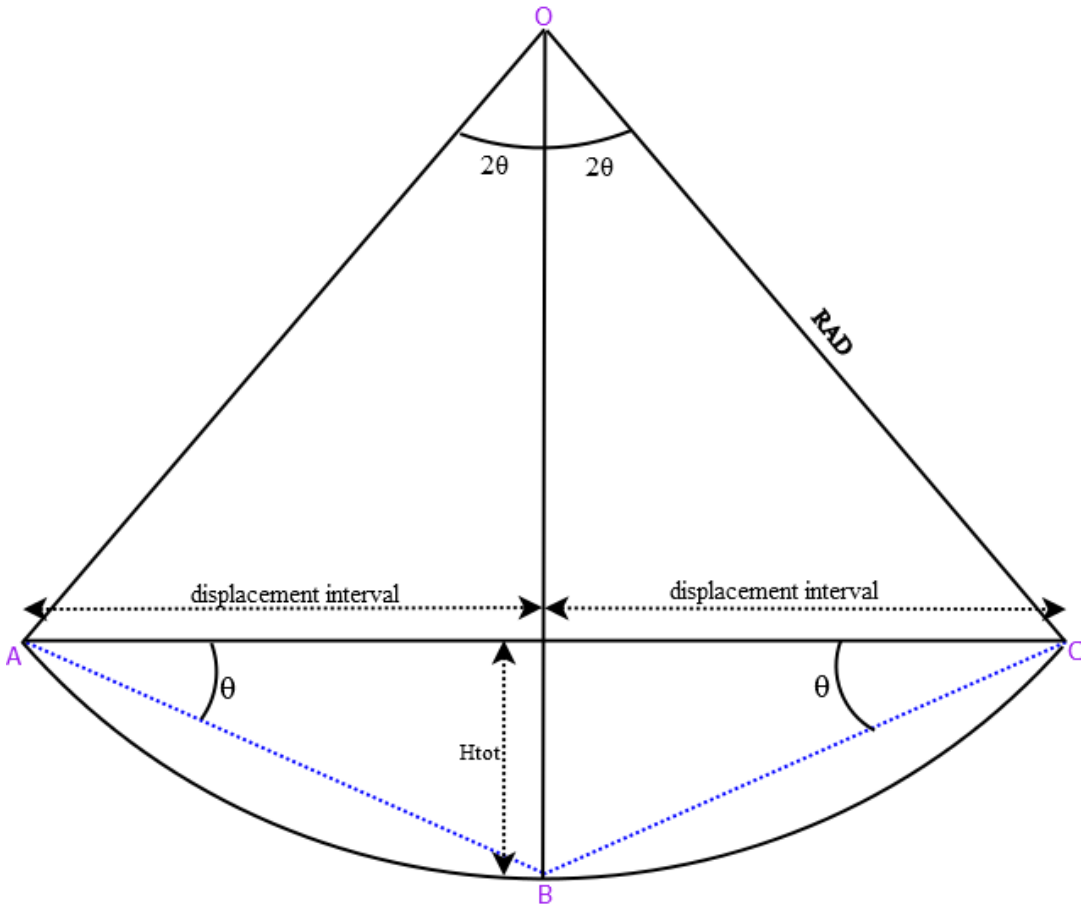
f_{axial} = Axial strain factor in tension as specified in the Factors table

if axial strain is compressive in nature

f_{axial} = Axial strain factor in compression as specified in the Factors table

The factor applied to axial strain might be a reduction factor to account for the slippage between pipe and the surrounding soil.

Bending Strain



Schematic Representation of Utility Bending

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For illustrative purposes the above diagram is shown in two dimensions. However, the calculations are performed for three dimensional movements with horizontal and vertical movements separated as discussed below.

When considering bending strain, any rotation that arises from the asymmetric opening of joints at the displacement points being used for assessment (e.g. B in the figure above) is ignored. Ground movements are considered to induce flexural bending only. So the pipes are considered continuous at B.

The horizontal offset at displacement point B, perpendicular to the utility's axis and relative to AC, is given by:

$$H_{\perp} = D_{\perp(B)} - \left(\frac{D_{\perp(A)} + D_{\perp(C)}}{2} \right)$$

where:

$D_{\perp(B)}$ = displacement perpendicular to the utility at the displacement point B.

$D_{\perp(A)}$ = displacement perpendicular to the utility at the displacement point A.

$D_{\perp(C)}$ = displacement perpendicular to the utility at the displacement point C.

Similarly the vertical offset V of displacement point B relative to AC is given by:

$$V = V_{(B)} - \left(\frac{V_{(A)} + V_{(C)}}{2} \right)$$

where:

$V_{(B)}$ = vertical displacement at the displacement point B.

$V_{(A)}$ = vertical displacement at the displacement point A.

$V_{(C)}$ = vertical displacement at the displacement point C.

Positive V indicates hogging and negative V indicates sagging.

The total offset of B relative to AC is given by:

$$H_{tot} = \sqrt{(H_{\perp})^2 + (V)^2}$$

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Considering the diagram above, let ∠BCA = θ, then ∠BOA = 2θ, ∠BAC = θ and ∠BOC = 2θ - from

the angle at centre theorem and from symmetry.
θ can be calculated as:

$$\theta = tan^{-1}\left(\frac{H_{tot}}{displacement\ interval}\right)$$

The bending strain is proportional to the distance from the centre line to the outer edge of the pipe and inversely proportional to the radius of curvature.

The effective radius of curvature RAD of the deformed pipes is given by:

$$RAD = \left(\frac{displacement\ interval}{sin2\theta}\right)$$

The bending strain in the utility is given by:

$$\varepsilon_{bending} = \left(\frac{y_p}{RAD}\right)$$

where y_p is external radius of the utility:

$$y_p = \frac{P_{dia}}{2} + P_{wt}$$

The factored bending strain in the utility is given by:

$$\varepsilon_{bending-factored} = f_{bending} * \left(\frac{y_p}{RAD}\right)$$

where:

for total tensile strain calculations
$f_{bending}$ = the bending strain factor (tension) as specified in the Factors table
for total compressive strain calculations
$f_{bending}$ = the bending strain factor (compression) as specified in the Factors table

Bending Strain Factor and Lever Arm

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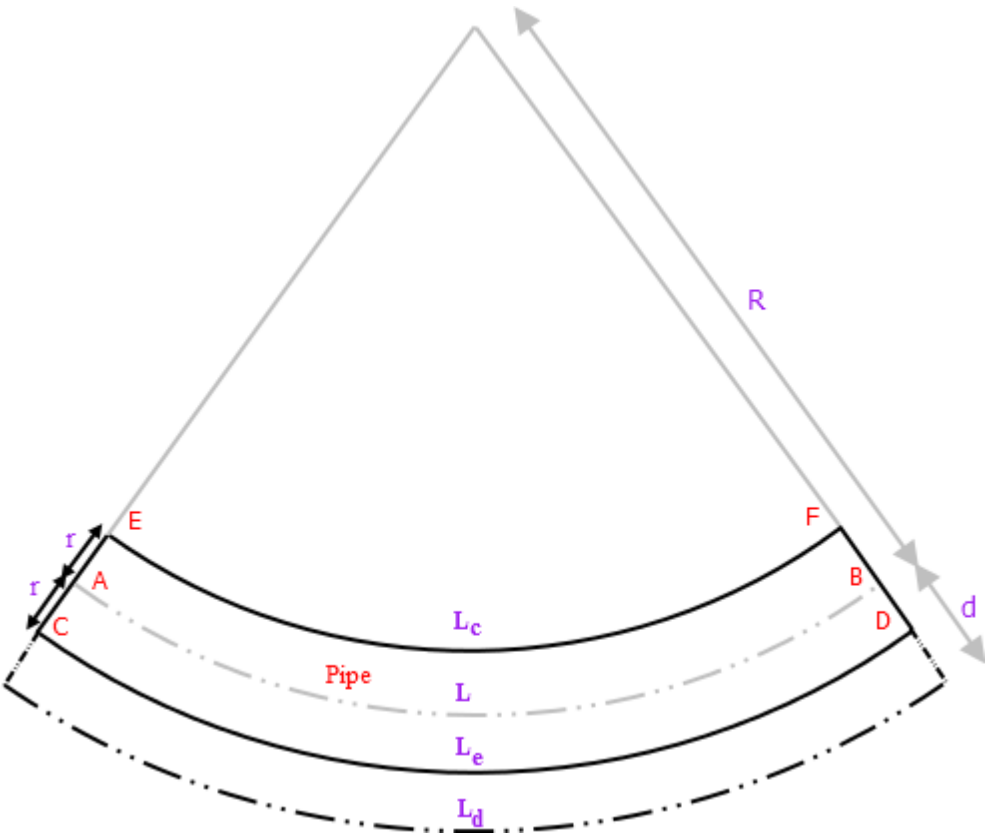


The figure above illustrates a pipe bending.

where:

AB = neutral axis whose length (L) remains the same before and after bending.
r = radius of the utility.
R = radius of curvature.
d = diameter of the utility.
L_c = length of external fibre (in compression) most shortened by bending.
L_e = length of external fibre (in tension) most lengthened by bending.
L_d = length of imaginary fibre at a distance 'd' from the neutral axis.

Bending strain in the extreme fibre (CD) under tension = $(L_e - L)/L = +r/R$

Bending strain in the extreme fibre (EF) under compression = $(L_c - L)/L = -r/R$

Factored Bending Strain = $f_{\text{bending}} * r/R$

The factor on bending strain could be interpreted as determining what some users may term "lever arm". A factor of 2 would represent a lever arm of pipe diameter, i.e. with factored bending strain being that for L_d, whereas a factor of 1 would represent a lever arm of pipe radius, with a factored bending strain being that for L_e.

Total Strain

The axial strain is combined with the positive value of the flexural bending strain in the extreme fibre under tension, and with the negative value of the flexural bending strain in the extreme fibre under

compression to give the total strain.

The total strain is therefore given by:

$$\varepsilon_{total} = \varepsilon_{axial} + \varepsilon_{bending}$$

The factored total strain is given by:

$$\varepsilon_{total-factored} = \varepsilon_{axial-factored} + \varepsilon_{bending-factored}$$

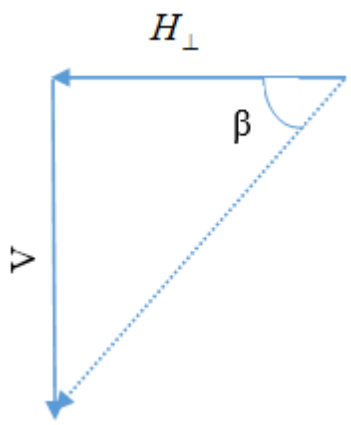
If "Neglect beneficial contribution of axial strains" is checked in the Utility strain calculation options dialog, then the calculation of total strains, both factored and unfactored, is influenced as below:

- Total tensile strain : If axial strain is compressive, then ε_{axial} is assumed to be zero.
- Total compressive strain : If axial strain is tensile, then ε_{axial} is assumed to be zero.

The factored total strain values are verified against their limiting values specified in the Criteria table.

Strain Orientation Angle

The strain orientation angle β gives the direction in which peak flexural strain occurs. It is the resultant of V and $H_{\perp}$.



$$\beta = \tan^{-1}\left(\frac{V}{H_{\perp}}\right)$$

This is reported as 90°+ β, and so is the angle from the global Z axis

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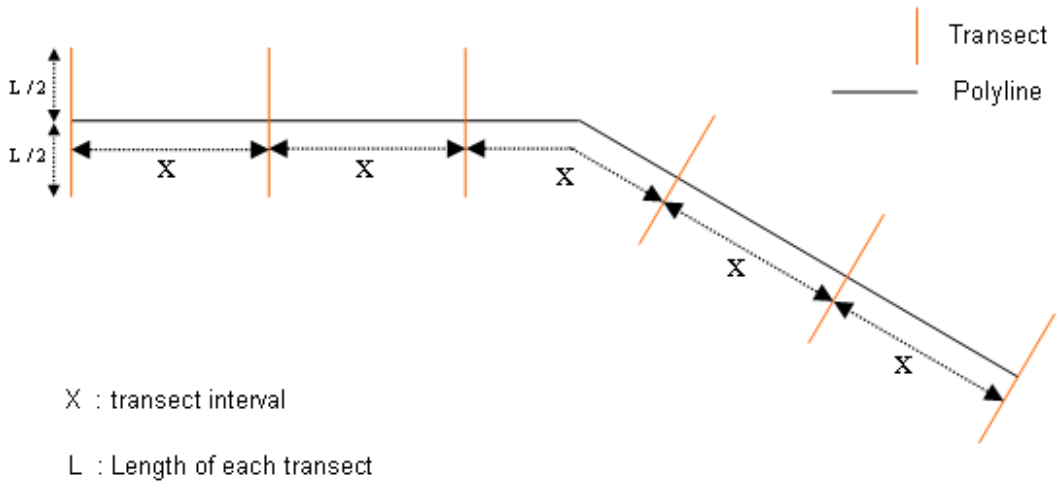
2.5.2 Generic Utility Damage Assessment

Generic Utility Damage Assessment allows a rapid assessment of likely utility damage over an area without the need to specify precise utility locations or properties. It therefore differs from Specific Utility Damage Assessment, which provides an assessment of utility damage along a specific displacement line.

The plan area for Generic Utility Damage Assessment is specified by a polyline with equally spaced transects. Each of these transacts represents the alignment of a utility which is used for assessment purposes. Generic Utility Damage Assessment will therefore not give accurate assessment results for locations of utilities that differ from these transects. Specific Utility Damage Assessment is recommended for such utilities whose precise location is known.



Transects

- These are perpendicular lines to the polyline created at an interval specified by the user in the Polylines input table.
- The length and number of displacement points of these transects are specified by the user in the Polylines input table.
- By default a transect is provided at the start point of the polyline.
- All transects are bisected by the polyline.

Utility damage assessment is then performed for each transect following the procedure for Specific Utility Damage Assessment, but with the specific utility now located along each and every transect rather than along a single specific displacement line. The results are reported in the Text Output.

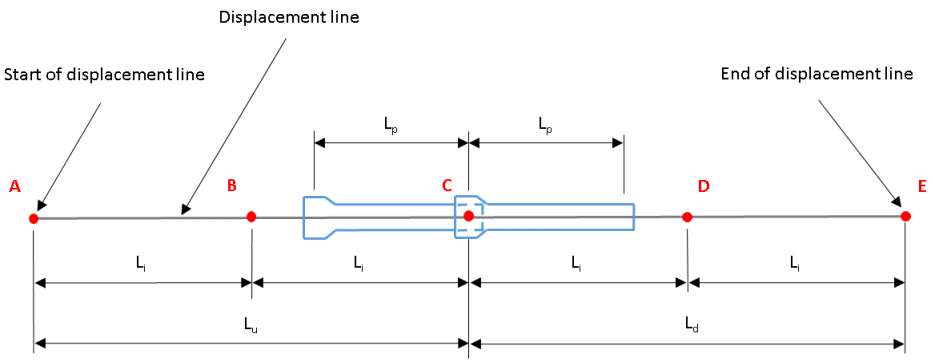
2.5.3 No Results or Extreme Results

From Assessment Locations for Pullout and Rotation and Strain Calculations it can be seen that pullout and rotation assessments are performed only at those displacement locations along a Specific Utility's Displacement Line or Displacement Polyline, or along a Generic Utility's Transects, which have a displacement location at least one pipe length both upstream and downstream of the assessment location and within any segment of a Specific Utility's Displacement Polyline. Strain assessment is performed at every displacement location along a Specific Utility's Displacement Line, or along a Generic Utility's Transects, except the first and last, or the first and last within any segment of a Specific Utility's Displacement Polyline. Therefore for strain assessment there must be at least 3 displacement locations within a Specific Utility's Displacement Line, within any a segment of a Specific Utility's Displacement Polyline, or within a Generic Utility's Transect.

Hence the Text Output and Chart Output may display no results at all for a Specific Utility or for a Transect of a Generic Utility, or results only for portions of a Specific Utility or portions of a Transect of a Generic Utility.

From Assessment Locations for Pullout and Rotation and Strain Calculations it can also be seen that pullout, rotation and strain results depend a relationship between the difference in ground movement compared and a span. In the case of pullout and rotation the span is determined by the pipe length. In the case of strain the difference is determined by the displacement interval. Extreme results may arise for very small differential movements, which might be otherwise considered insignificant, in cases where those small differential movements relate to short spans. Increasing the span (i.e. increasing the pipe length for pullout and rotation, or the displacement interval for strain) may avoid such extreme but insignificant results.

Specific Utility on Displacement Line
(or Generic Utility Transect)



Specific Utility on Displacement Polyline

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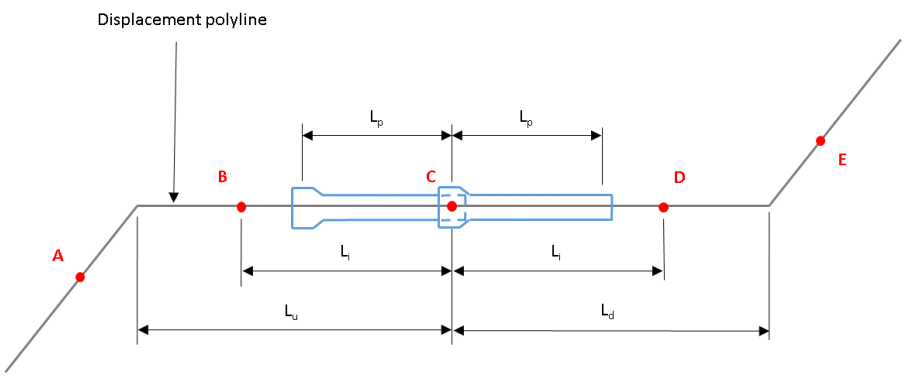


A, B, C, D, E - displacement/assessment locations

L_p - pipe length

L_i - displacement/assessment location interval

L_u - distance from displacement/assessment location to upstream end of displacement line or polyline segment

L_d - distance from displacement/assessment location to downstream end of displacement line or polyline segment

Pullout/ rotation

No result at B:

if $L_p > L_u$

or if $L_p > L_d$

or if $L_i > L_u$[1]

or if $L_i > L_d$[2].

Risk of extreme results if L_p is very small.

Strain

No result at B:

if $L_i > L_u$[1]

or if $L_i > L_d$[2].

Risk of extreme results if L_i is very small.

Notes

[1] i.e. no A or B

[2] i.e. no D or E

2.5.4 Displacement Intervals, Pipe Lengths and the Cubic Spline

Increasing or decreasing the number of intervals at which ground movement calculations are to be performed on a Specific Utility's Displacement Line or Displacement Polyline, or along a Generic Utility's Transects, will affect the definition of the cubic spline that is fitted to the results, and so will affect the utility damage assessment results in cases where ground movements are required to be estimated for locations between displacement points (i.e. for pullout and rotation assessment if the pipe length is not set to be a multiple of the displacement interval, or for strain assessment).

If pullout and rotation assessments are to be reliant only on the ground movements calculated directly by the program at the displacement locations, and not on estimates between those locations using the spline, then the pipe length and the displacement interval of the utility's displacement line must be specified so that the pipe length is a multiple of the displacement interval.

2.6 Rail Damage Assessment

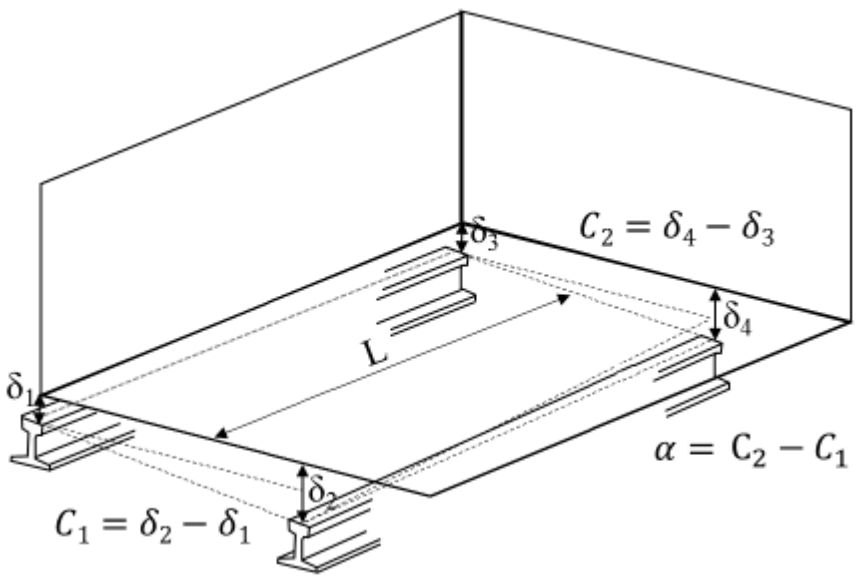
The calculation of cant and twist for a rail track is illustrated in the diagram below, where:

L = span (base) for twist calculations

δ = vertical ground movement at centre-line of each rail (left and right) and at each assessment interval

C = cant

α = twist (the change in cant over the base distance, reported in units of displacement)



Rail Damage Assessment - Cant and Twist

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Two spans, or bases, one short and one long, may be specified for twist calculations.

Assessment intervals define how frequently along a rail track calculations of cant and twist are performed.

The alignments of rail tracks are described by polylines. Acceptance Criteria specify thresholds and limits for cant and twist results. Text results and line charts report whether calculated values exceed these.

2.7 Staged Construction

Stages may be used to model construction changes over time, or to model different design options/ analysis cases. Tunnels or excavations may be specified for inclusion or exclusion in different stages, which may also specify varying tunnel diameters or excavation depths. Stages can therefore be used to model the advance or a tunnel, to model a pilot tunnel later expanded to the full tunnel diameter, or to model the deepening of excavations.

A Base Model, which does not need stage data, is first set up containing all locations of tunnels and excavations, with a particular set of tunnel diameters and excavation depths. The Base Model refers to all the tunnels and excavations that are specified in the Tunnel Data, the Polygonal Excavation Data, and the Circular Excavation Data.

Stages and Stage Properties are not needed if that Base Model describes the only state of construction for which analysis is required.

However, Stages may be defined to select a subset of the Base Model's tunnels or excavations for analysis. If tunnel diameters or embedded wall excavation depths are to vary from those specified in the Base Model, then Stage Properties may then be used to specify the diameters and depths of each tunnel and embedded wall excavation that are included in any stage.

A sample file is provided with the program to demonstrate the specification of stages and stage properties. It can be opened and viewed, and the input data compared with the model image in the 3D Graphics, to understand most easily how stages are specifie and how Stage Properties relate to Stages.

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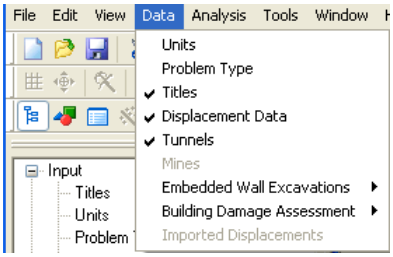
Part III

3 Data Input

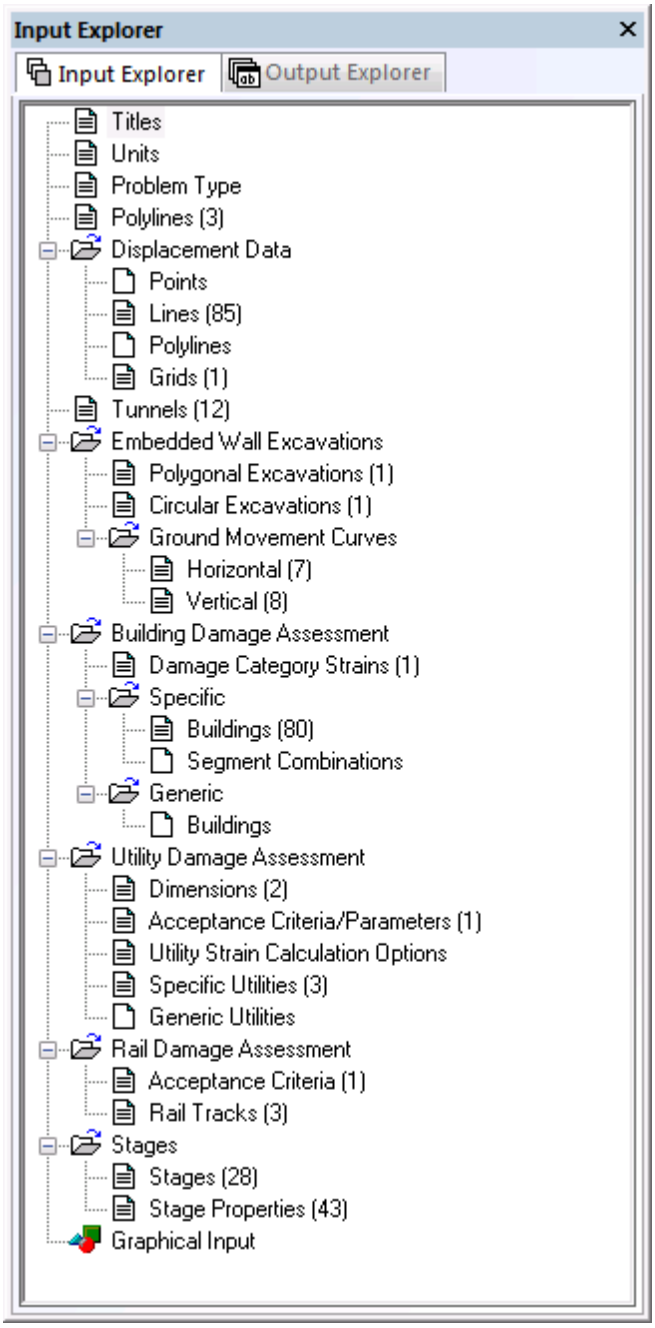
Data is input via options that are available from the Data menu, or from the Gateway.



The information can be entered in any order though it is advisable to enter displacement lines before the buildings which refer to them. Once the data has been entered the program places a tick against that item in the menu list. The section for entry of Mining Data only becomes available on selection of a mining problem in Problem Type.

3.1 Input Explorer

The Input Explorer is accessible from the 'View' menu, or via the 'Explorers' button on the XDisp Toolbar. It allows access to all input data.



A context menu, to expand or collapse individual or all items, is available by right-clicking in the window.

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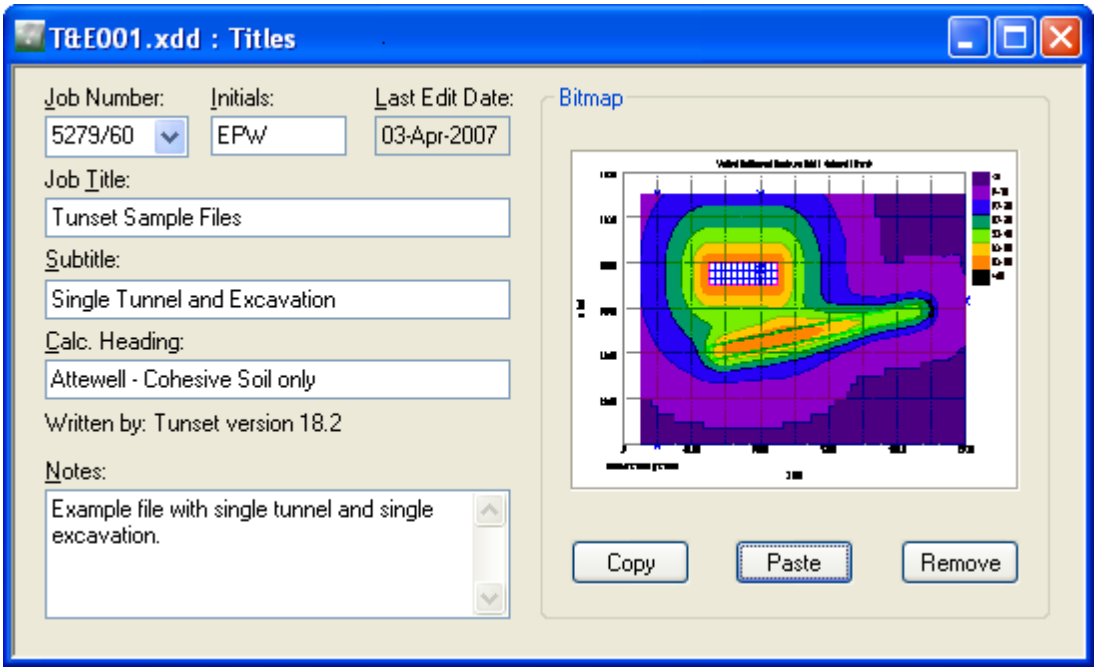
3.2 Titles

Upon creating a new file or opening an existing one the first window to appear, for entry of data into **XDisp**, is the Titles window.



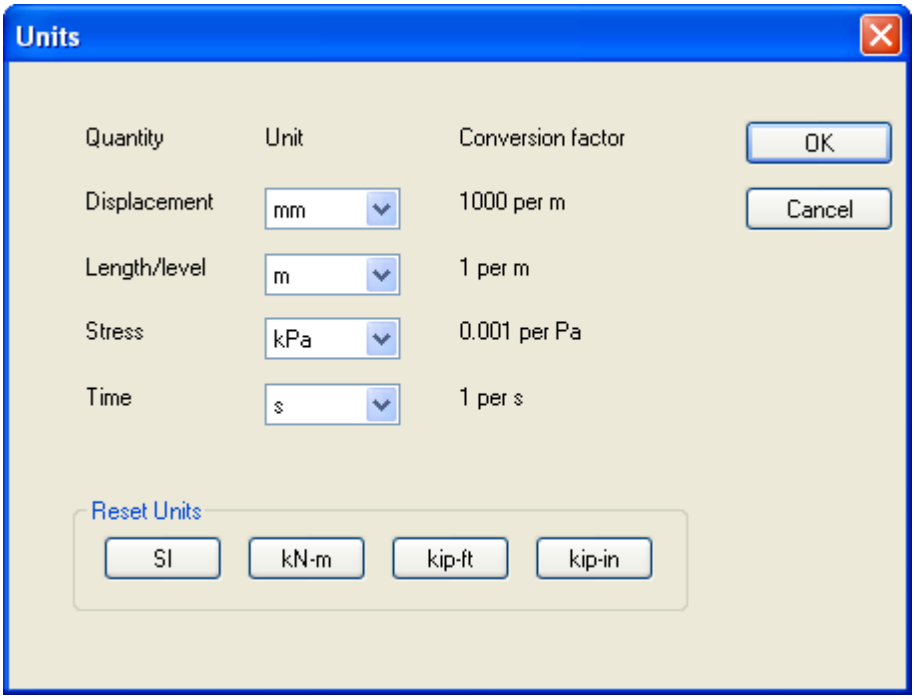
This window allows entry of identification data for each program file. The following fields are available:

Job Number	allows entry of an identifying job number
Initials	for entry of the user's initials
Last Edit Date	this field is set by the program at the date the file is saved
Job Title	allows a single line for entry of the job title
Subtitle	allows a single line of additional job or calculation information
Calculation Heading	allows a single line for the main calculation heading
Notes	allows the entry of a detailed description of the calculation

The titles are reproduced in the title block at the head of all printed information for the calculations. The fields should therefore be used to provide as many details as possible to identify the individual calculation runs.

3.3 Units

The Units dialog is accessible via the Gateway, or by choosing Data | Units from the program's menu. It allows the user to specify the units for entering the data and reporting the results of the calculations. These choices are stored in, and therefore associated with, the data file.



Default options are the Système Internationale (SI) units - kN and m. The drop down menus provide alternative units with their respective conversion factors to metric.

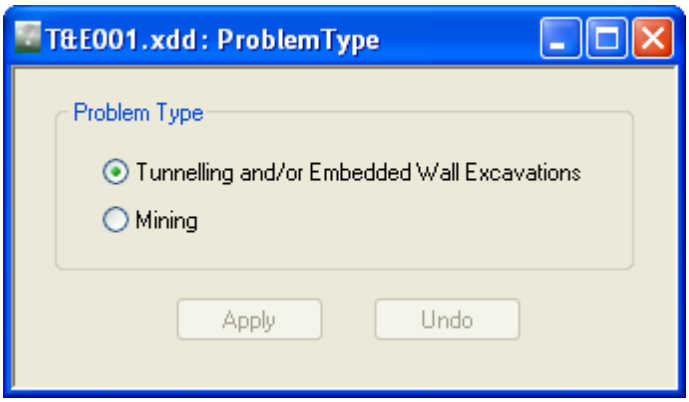
Standard sets of units may be set by selecting any of the buttons: SI, kN-m, kip-ft kip-in.

Once the correct units have been selected then click 'OK' to continue.

SI units have been used as the default standard throughout this document.

3.4 Problem Type

The Problem Type dialog is accessible via the Data menu, or via Problem Type in the Input Explorer. It defines whether the data model is to calculate ground movements arising from tunnels and/or embedded wall excavations, or from mines.



Depending on the Problem Type selected, certain features will be enabled or disabled, as described in Program Features.

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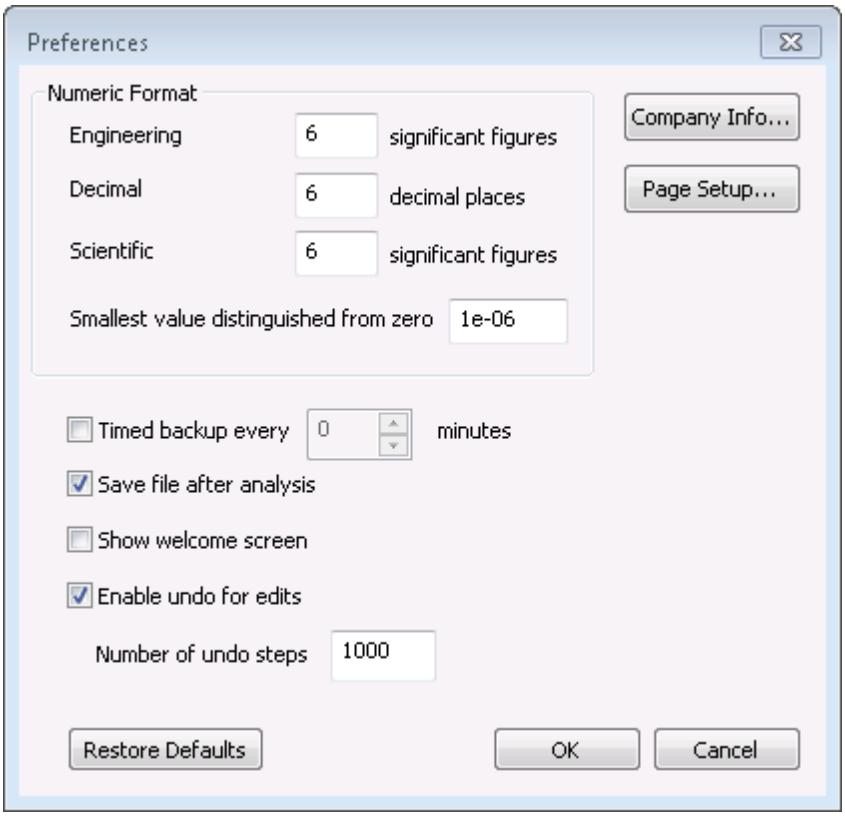
3.5 Preferences

The Preferences dialog is accessible by choosing Tools | Preferences from the program's menu. It allows the user to specify the numeric format for the reporting of results and of text on the Plan View. These choices are stored in the computer's registry and are therefore associated with the program rather than the data file. All data files will adopt the same choices.



Numeric Format controls the output of numerical data in the Text Output. The Text Output presents input data and results in a variety of numeric formats, the format being selected to suit the data. Engineering, Decimal, and Scientific formats are supported. The numbers of significant figures or decimal places, and the smallest value distinguished from zero, may be set here by the user.

Timed backup every allows the automatic backup of the active data file at the stated intervals. See File Backups for more information and the location of the backup folder. If files are large, particularly with extensive results, then the backup process may cause a delay to the operation of the user interface at the moment the file is being backed up. Under such circumstances it may be helpful to deselect this option.

Save file after analysis saves the data file upon completion of analysis, with results, to the location from which it was opened. If files are large, particularly with extensive results, then the saving process may take a considerable time, so this option may be deselected and the file saved manually at moments of their choosing.

Show welcome screen enables or disables the display of the Welcome Screen. The Welcome Screen will appear on program start-up, and give the option for the user to create a new file, to open an existing file by browsing, or to open a recently used file.

Enable undo for edits and **Number of undo steps** enable and specify the extent of the undo/redo history for data tables.

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Company Info allows the user to change the company name and logo on the top of each page of print out. To add a bitmap enter the full path of the file. The bitmap will appear fitted into a space approximately 4cm by 1cm. The aspect ratio will be maintained. For internal Arup versions of the program the bitmap option is not available.

Page Setup opens a dialog which allows the user to specify the calculation sheet style for graphical and textual printing e.g. whether it has borders and a company logo.

Restore Defaults resets the above settings to program defaults.

3.6 Polylines

Polylines are used to:

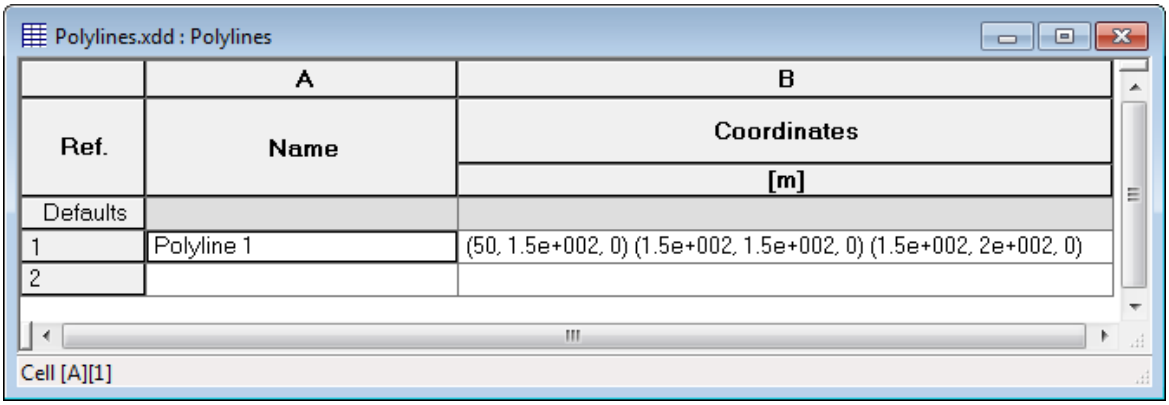
a) define areas over which generic building damage assessment and generic utility damage assessment are to be performed

b) define displacement polylines; which in-turn may be used to perform specific utility damage assessment

c) define alignments for rail tracks in order to perform rail damage assessment.

The following input data is required to define a polyline.

Data may be input in dialog form by double-clicking within a cell of the Polylines input table.



Name specifies the name of the polyline.

Coordinates specify the end points of the segments that make up the polyline.

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3.7 Displacement Data

The locations at which displacement results are required can be specified using grids, lines, polylines or individual points.

3.7.1 Displacement Points

Displacement Points specify single point locations for which ground movement results are required.

Staged construction.xdd : Displacement Points

Ref.	Name	X	Y	Z(level)	Surface type for tunnels	Calculate
		[m]	[m]	[m]		
Defaults	Displacement Point #	0.000	0.000	0.000	Surface	No
1	Point 1	10.000	10.000	100.000	Surface	Yes
2						

Name is the name of the point.

X, **Y** and **Z(level)** are the coordinates of point.

Surface Type specifies whether displacements due to tunnelling are to be calculated for this displacement data item using the Surface or Sub-surface method. For more information see Tunnels - Analysis Parameters and Tunnel Settlement Trough Width.

Calculate specifies whether displacement calculations are to be performed for the point.

3.7.2 Displacement Lines

Displacement Lines specify a series of point locations on a straight line, for which ground movement results are required. Displacement Lines may be entered in any orientation by specifying the co-ordinates of the end point locations.

Staged construction.xdd : Displacement Lines

Ref.	Name	Start			End			Intervals	Surface type for tunnels	Calculate
		X	Y	Z(level)	X	Y	Z(level)			
		[m]	[m]	[m]	[m]	[m]	[m]	[No.]		
Defaults	Displacement Line #	0.000	0.000	0.000	1.000	1.000	0.000	10	Surface	No
1	Northern Buildings #1, South Face	60.000	120.000	100.000	90.000	120.000	100.000	10	Surface	Yes
2	Northern Buildings #1, East Face	90.000	120.000	100.000	90.000	150.000	100.000	10	Surface	Yes
3	Northern Buildings #1, North Face	90.000	150.000	100.000	60.000	150.000	100.000	10	Surface	Yes
4	Northern Buildings #1, West Face	60.000	150.000	100.000	60.000	120.000	100.000	10	Surface	Yes
5	Northern Buildings #2, South Face	100.000	120.000	100.000	140.000	120.000	100.000	10	Surface	Yes
6	Northern Buildings #2, East Face	140.000	120.000	100.000	140.000	150.000	100.000	10	Surface	Yes
7	Northern Buildings #2, North Face	140.000	150.000	100.000	100.000	150.000	100.000	10	Surface	Yes

Name is the name of the line.

Start and **End** points of the line are specified by entering their **X, Y** and **Z (level)** coordinates**.**

Intervals specify the number of intervals at which intermediate point locations will be created for ground movement results.

Surface Type specifies whether displacements due to tunnelling are to be calculated for this

displacement data item using the Surface or Sub-surface method. For more information see Tunnels - Analysis Parameters and Tunnel Settlement Trough Width.

Calculate specifies whether displacement calculations are to be performed for the point.

3.7.3 Displacement Polylines

Displacement Polylines specify a series of point locations on a 3D polyline, for which ground movement results are required.

Generic utility damage.xdd : Displacement Polylines

Ref.	Name	Polyline	Intervals	Surface type for tunnels	Calculate
			[No.]		
Defaults	Displacement Polyline #	Polyline 1	10	Surface	No
1	Displacement Polyline 1	Polyline 1	25	Surface	Yes
2					

Name is the name of the Displacement Polyline.

Polyline is the name of the Displacement Polyline.

Intervals specify the number of intervals at which intermediate point locations will be created for ground movement results.

Surface Type specifies whether displacements due to tunnelling are to be calculated for this displacement data item using the Surface or Sub-surface method. For more information see Tunnels - Analysis Parameters and Tunnel Settlement Trough Width.

Calculate specifies whether displacement calculations are to be performed for the point.

3.7.4 Displacement Grids

Displacement Grids specify a planar grid of point locations for which ground movement results are required. They may be horizontal, vertical, or inclined.

Staged construction.xdd : Displacement Grids

Ref.	Name	Direction of extrusion	Base line to be extruded							Extrusion		Surface type for tunnels	Calculate
			Start			End			Intervals	Distance	Intervals		
			X	Y	Z(level)	X	Y	Z(level)					
			[m]	[m]	[m]	[m]	[m]	[m]	[No.]	[m]	[No.]		
Defaults	Displacement Grid #	Global X	0.000	0.000	0.000	1.000	1.000	0.000	10	100.000	10	Surface	No
1	Surface	Global X	0.000	0.000	100.000		200.000	100.000	40	500.000	100	Surface	Yes
2													

Displacement Grids are specified by extruding a base line which is parallel to the XY, YZ, or ZX plane. The **Direction of extrusion** is specified as one of the Global axes (X, Y or Z). The **Base line to be extruded** must be entered by specifying its end coordinates. For example, if 'Global X' is the direction of extrusion then the base line will be parallel to the YZ plane.

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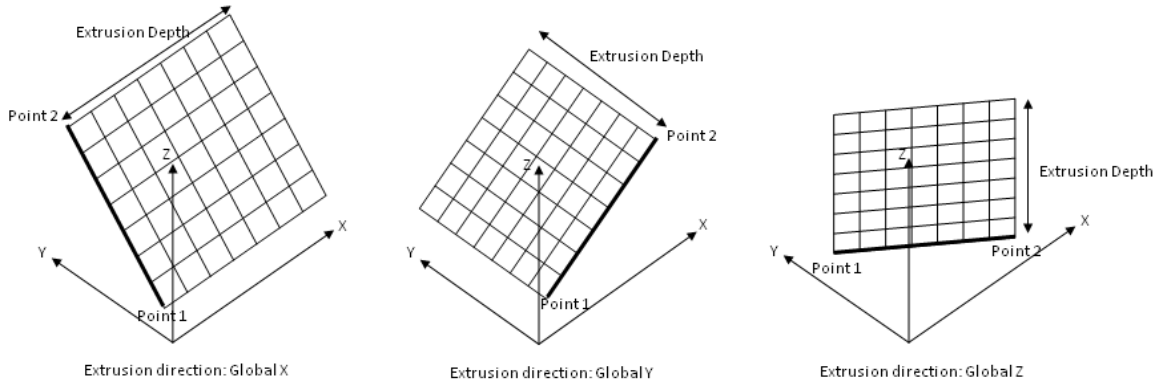
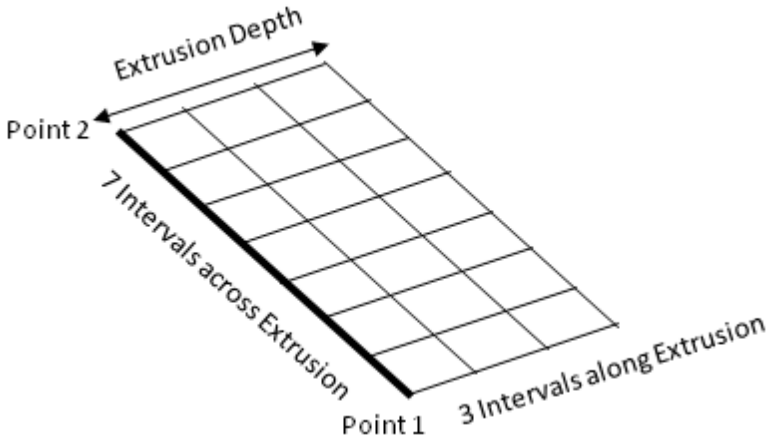


The extrusion depth should not be zero. Negative extrusion depth extrudes in the opposite direction to the global directions.

The number of intervals is specified across and along the extrusion as shown below.



Surface Type specifies whether displacements due to tunnelling are to be calculated for this displacement data item using the Surface or Sub-surface method. For more information see Tunnels - Analysis Parameters and Tunnel Settlement Trough Width.

Calculate specifies whether displacement calculations are to be performed for the displacement data item.

3.8 Tunnels

The following input data is required for the analysis of tunnels. Data may be input in dialog form by double-clicking within a cell of the Tunnel input table.

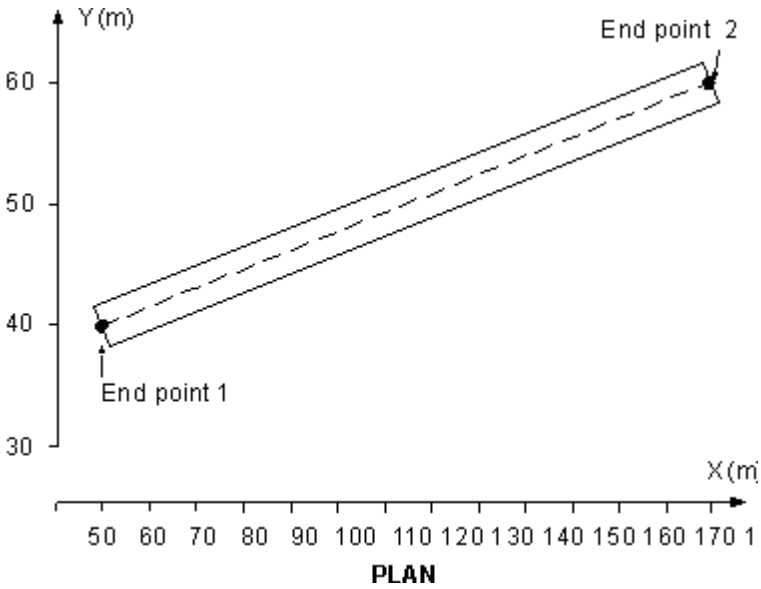
B001.xdd : Tunnels

	A	B	C	D	E	F	G	H	I	J	K	L	M
Ref.	Name	Diameter	Endpoint 1			Endpoint 2			Ground Loss	Surface Displacement Calculations			
			x	y	z	x	y	z		k Derivation	Layers	Interface Level	
												End 1	End 2
		[m]	[m]	[m]	[m]	[m]	[m]	[m]	[%]			[m]	[m]
Defaults	Tunnel #	5.00	0.00	0.00	0.00	10.00	10.00	0.00	1.00	O'Reilly and New	Single	50.000	50.000
1	Tunnel 1	5.00	75.00	100.00	-20.00	75.00	200.00	-20.00	5.00	User-specified k	Single		
2	Tunnel 2	5.00	125.00	100.00	-20.00	125.00	200.00	-20.00	5.00	User-specified k	Single		
3													

Cell [K][1]

J	K	L	M	N	O	P	Q	R	S	T	U
Surface Displacement Calculations					Sub-surface Displacement Calculations						Soil at Tunnel Level
k Derivation	Layers	Interface Level		k	Analysis Method	k Derivation	k	m	Ground Level		
		End 1	End 2						End 1	End 2	
		[m]	[m]						[m]	[m]	
O'Reilly and New	Single	50.000	50.000	0.40	New and Bowers	User-specified	0.40	0.50			Cohesive
User-specified k	Single			0.40	New and Bowers	User-specified	0.40				
User-specified k	Single			0.40	New and Bowers	User-specified	0.40				

The parameters which define the geometry of the the tunnel are as follows:



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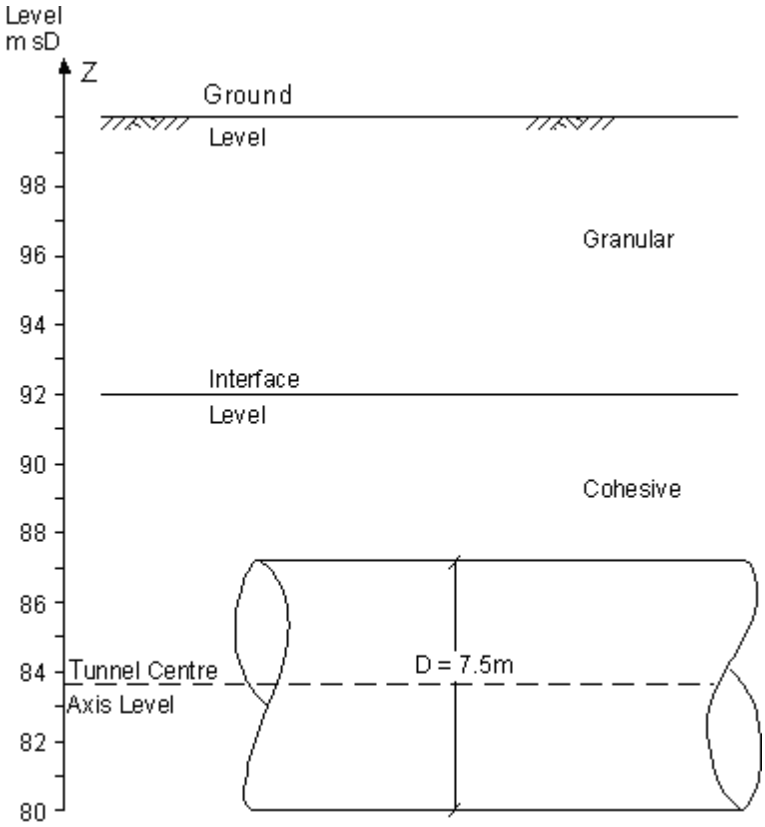

ELEV ATION

Tunnel diameter (m) specifies the diameter of the tunnel.

Endpoint 1 and **Endpoint 2** (**x**, **y**, **z**) specify the locations of the end points of the tunnel's centre-line (m). The tunnels may be skewed or inclined.

The parameters which define the anticipated volumetric ground loss due to tunnel collapse are as follows:

Ground Volume Loss Factor (V_L), see Volume Loss.

Soil at Tunnel Level specifies the soil type (cohesive or granular) at the level of the tunnel. If dual-layered soils are specified i.e. the Selby k Derivation method is used to calculate surface movements, then the soil in the layer above this is assumed to be of different type.

k Derivation specifies the choice of k derivation method that is to be applied to this tunnel. Different methods may be chosen for surface and sub-surface displacements. See Tunnel Analysis Methods and k Derivation Methods. If the Mair et al analysis method is chosen for sub-surface displacements, then a k derivation method is not required.

Layers specifies whether the tunnel lies beneath single or dual-layered soil (for surface displacement calculations only). This field is not editable. It is dependent on the k derivation method since only the Selby k derivation method is applicable to dual-layered soil. Other methods are applicable to single layer soils only.

Interface Level specifies the levels of the interface between the two possible layers of cohesive and granular soil. These levels are specified directly above the tunnel end points. They are only applicable if the Selby k derivation method is chosen.

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k specifies the k value of the settlement trough. See Tunnel Settlement Trough Width and Analysis Methods for further information.

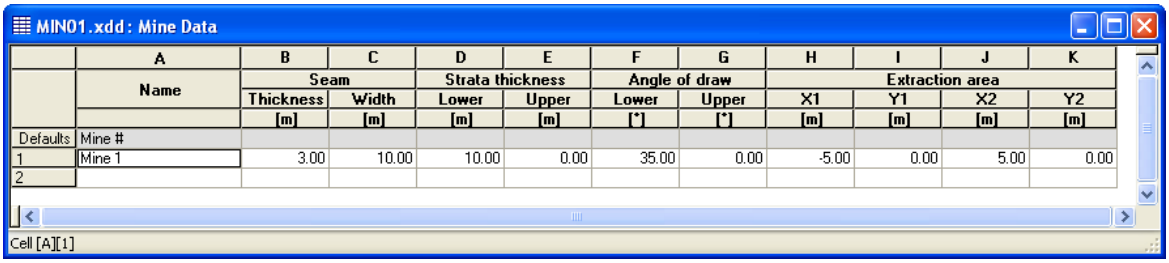
Analysis Method specifies whether the New and Bowers or Mair et al method is to be used for calculation of sub-surface displacements. Surface displacements are calculated using the O'Reilly and New method. See Analysis Methods for further information.

m specifies Harris and Alvarado's exponent 'm'. See Tunnel Settlement Trough Width and Analysis Methods for further information.

Ground Level specifies the level of the ground surface directly above each of the tunnel end points. Ground levels are required only if the Mair et al analysis method is chosen for the calculation of sub-surface displacements.

3.9 Mines

The following data is required for input of a mine:



MIN01.xdd : Mine Data

	A	B	C	D	E	F	G	H	I	J	K
	Name	Seam		Strata thickness		Angle of draw		Extraction area			
		Thickness	Width	Lower	Upper	Lower	Upper	X1	Y1	X2	Y2
		[m]	[m]	[m]	[m]	[°]	[°]	[m]	[m]	[m]	[m]
Defaults	Mine #										
1	Mine 1	3.00	10.00	10.00	0.00	35.00	0.00	-5.00	0.00	5.00	0.00
2											

Cell [A][1]

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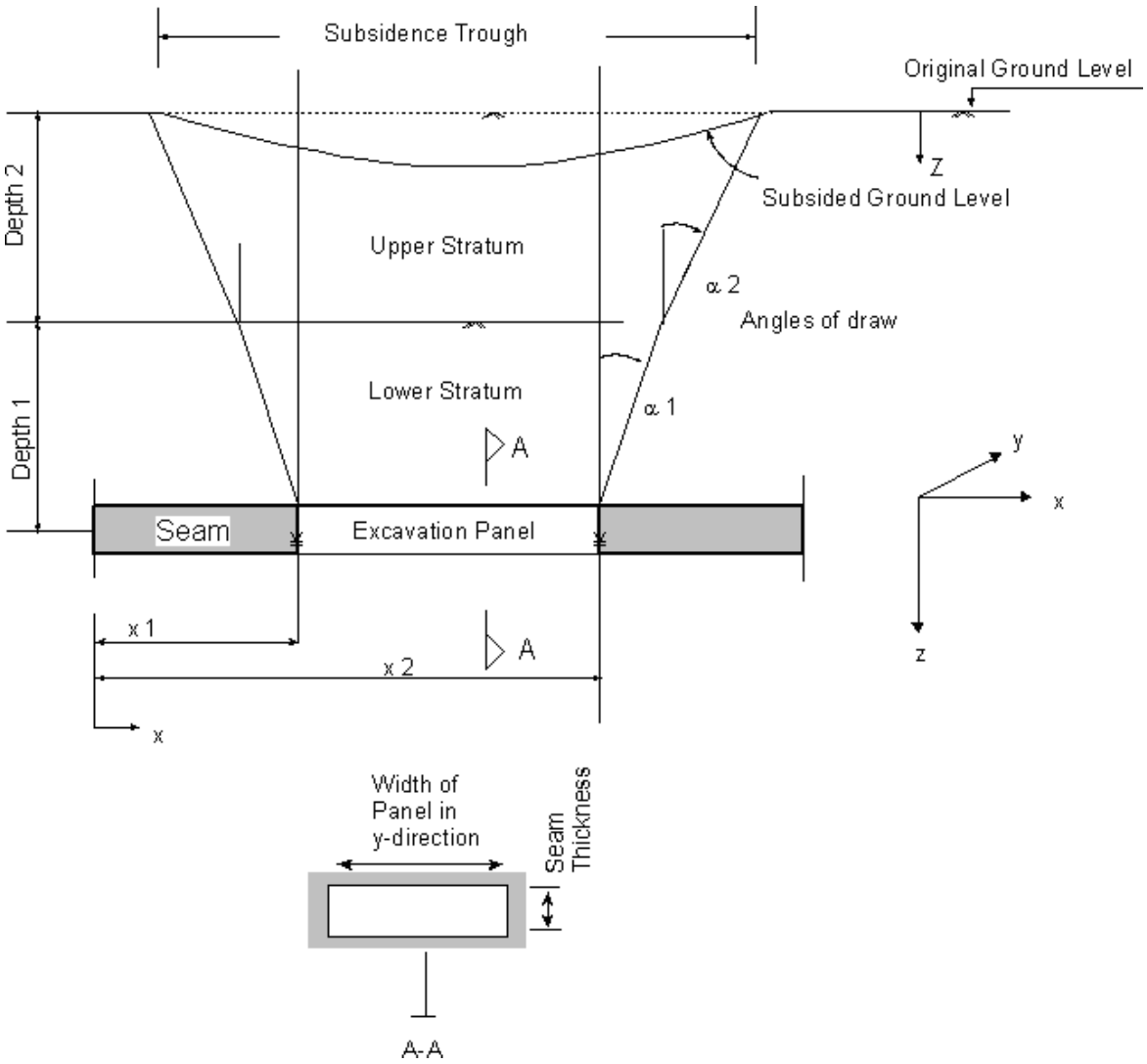
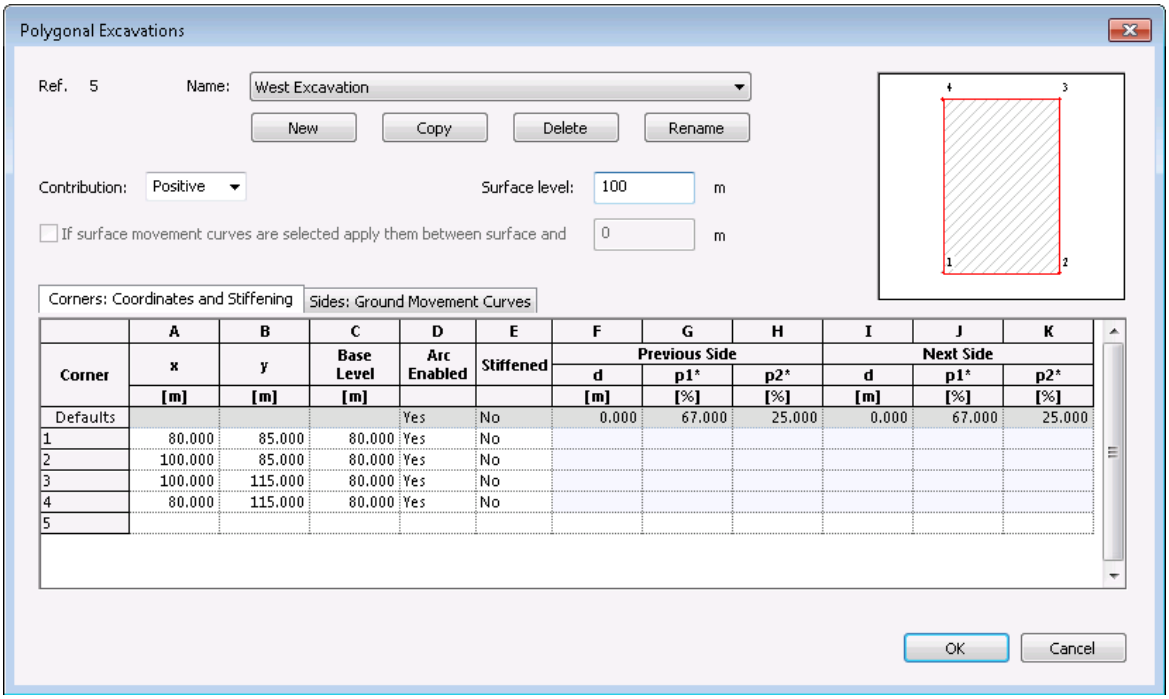


- Seam **thickness** on the z axis.
- Seam **width** along the y axis. This should extend beyond the proposed extracted area specified below.
- The thickness (or depth) of the **upper** and **lower** layers of strata. The lower layer of strata is deemed to reach the centre of the mined layer.
- The **angle of draw** (α) in degrees for the upper and lower layers of strata.
- The **horizontal dimensions** to the edges of the extracted area X1, Y1, X2 and Y2. These are measured from the origin (0) on the x and y axis.

3.10 Embedded Wall Excavations

3.10.1 Polygonal Excavations

A polygonal excavation defines the volume of a polygonal embedded wall excavation together with the ground movement curves that are to be associated with it.



	A	B	C	D	E	F	G	H	I	J	K
Corner	x	y	Base Level	Arc Enabled	Stiffened	Previous Side			Next Side		
						d	p1*	p2*	d	p1*	p2*
	[m]	[m]	[m]			[m]	[%]	[%]	[m]	[%]	[%]
Defaults				Yes	No	0.000	67.000	25.000	0.000	67.000	25.000
1	80.000	85.000	80.000	Yes	No						
2	100.000	85.000	80.000	Yes	No						
3	100.000	115.000	80.000	Yes	No						
4	80.000	115.000	80.000	Yes	No						
5											

Name - specifies the name of the excavation.

New - creates a new excavation.

Copy - copies the excavation currently displayed.

Delete - deletes the excavation currently displayed.

Rename - renames the excavation currently displayed.

Contribution - specifies whether the excavation is considered to contribute (positive) to the displacements or to detract (negative) from them. See Irregularly Shaped Excavations for further details.

Surface level - specifies the ground surface level at this excavation. If any of the Ground Movement Curves that are associated with this excavation are of surface-only type, then displacements will be calculated only for displacement points, or points within displacement lines or grids, that are at this level. A warning will be given otherwise. See the Embedded Wall Excavations method for more information.

If surface movement curves are selected... - this option is enabled only if any of the Ground Movement Curves that are associated with this excavation are of surface-only type. For such cases the displacements can be calculated for displacement entities below the surface too, by checking this option and specifying the level up to which the curves are to be applied. Displacements that are calculated are not adjusted for the depths of displacement points. They are calculated merely based on the horizontal distance from the excavation so will be the same for a point at the surface or below

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it.

If an excavation is to be ignored in ground movement calculations then a suitable Stage should be created in which it is not included. See Staged Construction.

Corners: Coordinates and Stiffening

x and **y** - specify the plan coordinates of one corner of the excavation. Plans that specify re-entrant corners are prohibited.

Base Level - specifies the level of the base of the excavation at this corner. Base levels represent the base of the excavation (for excavation induced movements) or the toe of the Embedded Wall (for wall installation movements).

Arc Enabled - specifies whether ground movements are to be calculated around the arc of corners. This is useful when joining two excavations. By applying the ground movement curves "No vertical ground movement" and "No horizontal ground movement" to the common/internal wall, and setting **Arc Enabled** to "No", rogue concentrations of ground movement adjacent to the corners which are common to the two excavations can be avoided.

Stiffened - specifies whether stiffening effects should be applied to the corner in accordance with Fuentes and Devriendt. If "yes" then the stiffening parameters in the following columns must be entered. For further discussion of the use of these parameters see Corner Stiffening.

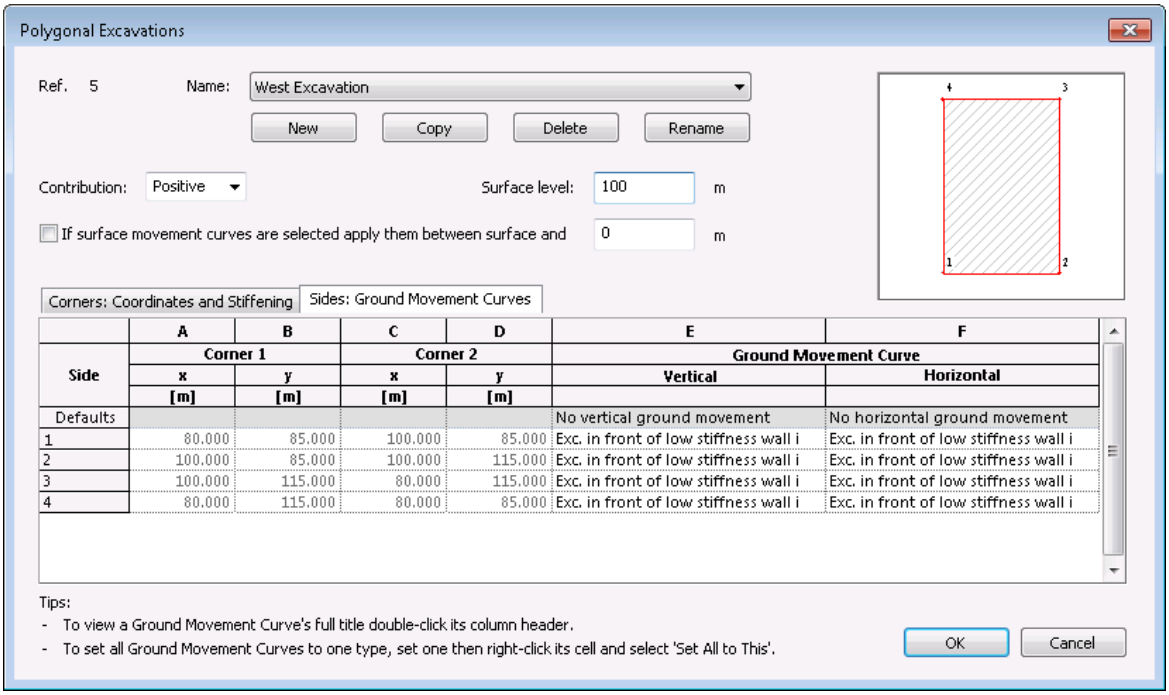
d - the distance from the corner to the centre point of the side in plan, or the distance to where plane strain movements start to occur, whichever is the lesser.

p1* - calibrated value of p1 for given ground conditions for corners that form a 90º angle - where p1 is the percentage of the ground movements for the previous and next sides' d, in a section that passes through the corner and is perpendicular to the side.

p2* - calibrated value of p2 for given ground conditions for corners that form a 90º angle - where p2 is the percentage of $100\%_{previous}$ and $100\%_{next}$ in a section that bisects the excavation at the given corner, and where $100\%_{previous}$ and $100\%_{next}$ are plane strain ground movements perpendicular and behind the previous and next sides respectively.

The values of **p1* and p2*** may change for different ground conditions and should be calibrated for those for each particular predominant soil. This calibration should be made by comparing the calculated corner movements to the observed movements at the corner. However, Fuentes and Devriendt shows, values of p_1 = 67% and p_2 =25% are reasonable for the case histories considered. [1]

Sides: Ground Movement Curves



Ground Movement Curves - specify the vertical and horizontal ground movement curves that are to be associated with this side of the excavation. Their columns may be widened to view their titles better by double-clicking the column header ("E", "F", "Vertical" or "Horizontal" or the blank units cells beneath). Double-clicking the spanning header "Ground Movement Curve" returns those columns to their original sizes. To set all Ground Movement Curves to one type, set one then right-click and select 'Set All to This'.

Notes

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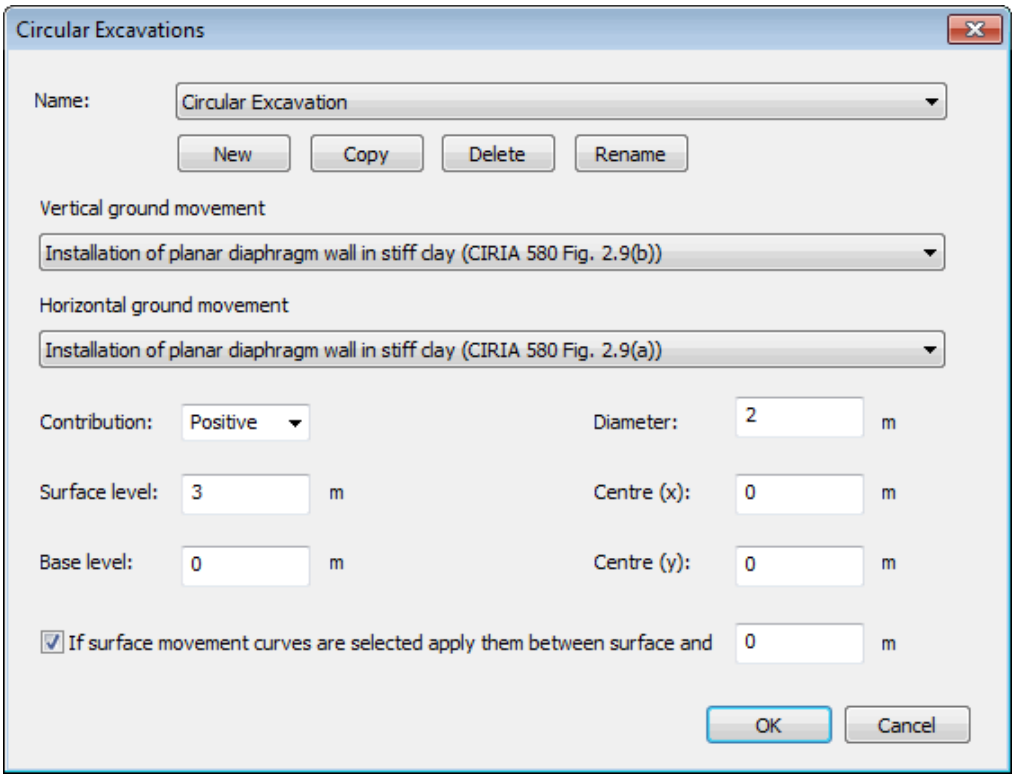
3.10.2 Circular Excavations

A circular excavation defines the volume of a circular embedded wall excavation together with the ground movement curves that are to be associated with it.



Name - specifies the name of the excavation.

New - creates a new excavation.

Copy - copies the excavation currently displayed.

Delete - deletes the excavation currently displayed.

Rename - renames the excavation currently displayed.

Vertical and Horizontal ground movement curves - specify the vertical and horizontal ground movement curves that are to be associated with this excavation.

Contribution - specifies whether the excavation is considered to contribute (positive) to the displacements or to detract (negative) from them. See Irregularly Shaped Excavations for further details.

Surface level - specifies the ground surface level at this excavation. If either of the Ground Movement Curves that are associated with this excavation are of surface-only type, then displacements will be calculated only for displacement points, or points within displacement lines or grids, that are at this level. A warning will be given otherwise. See the Embedded Wall Excavations method for more information.

If surface movement curves are selected... - this option is enabled only if any of the Ground Movement Curves that are associated with this excavation are of surface-only type. For such cases

the displacements can be calculated for displacement entities below the surface too, by checking this option and specifying the level up to which the curves are to be applied. Displacements that are calculated are not adjusted for the depths of displacement points. They are calculated merely based on the horizontal distance from the excavation so will be the same for a point at the surface or below it.

Base level - specifies the level at the base of this excavation. Circular excavations are assumed to have horizontal bases.

Diameter - diameter of the excavation.

Centre (x) and (y) - coordinates of the plan centre of the excavation.

If an excavation is to be ignored in ground movement calculations then a suitable Stage should be created in which it is not included. See Staged Construction.

3.10.3 Ground Movement Curves

Ground Movement Curve input data is accessible via the Gateway or by choosing "Data | Ground Movement Curves" from the program's menu.

Ground Movement Curves describe the horizontal or vertical movement of a point adjacent to the side of an embedded wall excavation. They may be defined for both ground surface and sub-surface movements, or for ground surface movements only. The former are functions of distance from the wall/excavation, depth below the top of the wall/excavation and the wall/excavation's depth. The latter are functions of distance from the wall/excavation and the wall/excavation's depth only.

A number of ground movement curves for surface movement are provided by **XDisp** to represent Figures 2.8 to 2.12 of CIRIA C580 and Figures 6.8 to 6.16 of CIRIA C760. However, users may add their own surface movement curve data to supplement this set, or add their own surface and sub-surface data. In order for **XDisp** to perform movement calculations for displacement points in the model, it will use, in its calculations, either a polynomial curve fit to these points (derived by the least squares method) or linear interpolation between them. If a polynomial is required, then the x and y orders must be specified. A graph of the resulting curve that is to be used is available by clicking the 'View Graph' button. **XDisp** uses these curves to calculate soil movements that result from whichever embedded wall excavations refer to them in the Excavation Details dialog.

Included with the program is a sample file which contains an example data set named "Subsurface" for surface and sub-surface movements. This data has been sourced form a 3 dimensional finite element model for ground movements around an embedded wall excavation. Ground conditions modelled comprised Made Ground overlying River Terrace Deposits overlying London Clay. The finite element model used a Mohr Coulomb model to model the Made Ground overlying River Terrace Deposits and the BRICK soil model (Simpson (1992)) to model the London Clay. The plan dimension of the basement was approximately rectangular in shape and 120m by 100m in plan dimension. Displacements were taken normal to the secant pile retaining wall at 60m along one of the boundaries. It provides an example only for illustrative purposes and should not be used by 3rd parties for carrying out analysis. It is recommended that surface and sub-surface movement curves' data for use in **XDisp** be sourced either from field data, or by finite element analysis. Further details of the analyses performed to create this data can be found in Sample Sub-surface Ground Movement Curve.

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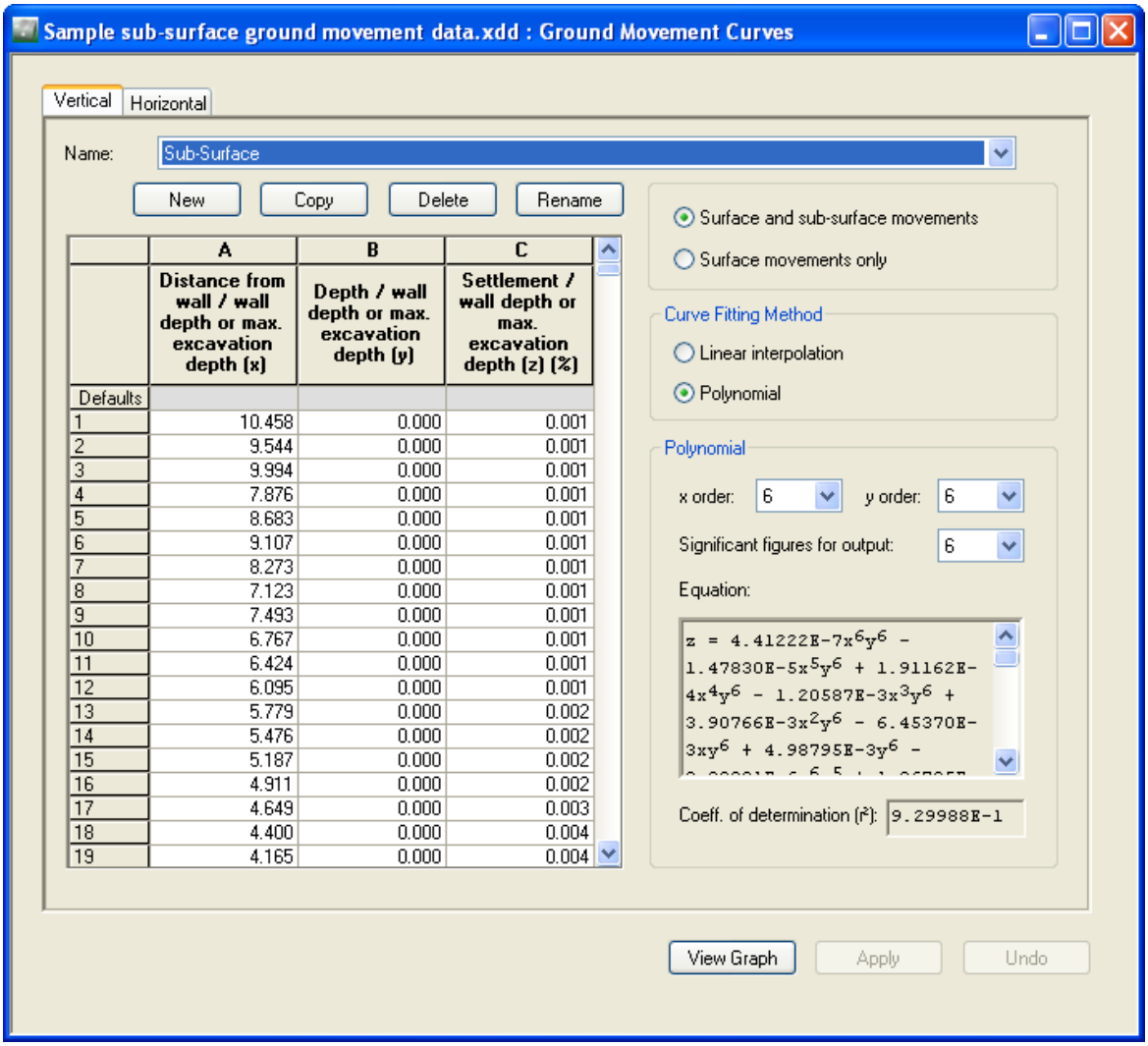

	A	B	C
	Distance from wall / wall depth or max. excavation depth (x)	Depth / wall depth or max. excavation depth (y)	Settlement / wall depth or max. excavation depth (z) (%)
Defaults			
1	10.458	0.000	0.001
2	9.544	0.000	0.001
3	9.994	0.000	0.001
4	7.876	0.000	0.001
5	8.683	0.000	0.001
6	9.107	0.000	0.001
7	8.273	0.000	0.001
8	7.123	0.000	0.001
9	7.493	0.000	0.001
10	6.767	0.000	0.001
11	6.424	0.000	0.001
12	6.095	0.000	0.001
13	5.779	0.000	0.002
14	5.476	0.000	0.002
15	5.187	0.000	0.002
16	4.911	0.000	0.002
17	4.649	0.000	0.003
18	4.400	0.000	0.004
19	4.165	0.000	0.004

Vertical/Horizontal - specifies whether the curve defines vertical or horizontal movement.

Curve Name - the title of the ground movement curve.

New - creates a new ground movement curve.

Copy - copies the currently selected ground movement curve.

Delete - deletes the currently selected ground movement curve.

Rename - renames the currently selected ground movement curve. Pre-programmed curves that are provided by **XDisp** may not be edited. In order to adjust one of those curves the curve should first be copied. The copy can then be edited.

Surface and sub-surface movements - specifies that the curve is to provide data for both surface and sub-surface ground movements, so x, y and z data will be required.

Surface movements only - specifies that the curve is to be used to calculate surface ground movements only, so x and y data only will be required.

Curve coordinates - lists the x, y, and z coordinates that define the ground movement curve.

Linear interpolation - specifies that the curve that is to be fitted to the data points is to be calculated by linear interpolation between those points.

Polynomial - specifies that the curve that is to be fitted to the data points is to be a polynomial.

Order of polynomial - specifies the order of the polynomial that is to be fitted to the curve coordinates.

Significant figures for output - defines the number of significant figures that are to be used when displaying the polynomial equation.

Polynomial equation - displays the polynomial equation that **XDisp** has calculated.

Coefficient of determination - displays the coefficient of determination (r^2) of the polynomial equation. Values closer to 1.0 than 0.0 indicate a better correlation between the coordinates that are used to create the polynomial equation, and those that would be generated by the polynomial equation.

View Graph - displays a graph of the currently selected ground movement curve.

Apply - applies, to the model's data, all changes that have been made to the set of ground movement curves.

Undo - restores, from the model's data, the set of ground movement curves - thereby undoing any changes that have been made to since 'Apply' was last executed.

3.10.3.1 Ground Movement Curve Graphs

Ground movement curves' graphs are accessible by clicking the "View Graph" button on the Ground Movement Curves' dialog. They illustrate the graph that is generated by **XDisp** as a fit a ground movement curve's data points, and that will be used in the calculations for displacement points affected by excavations/walls that refer to that curve. The style of graph that is presented depends on whether ground movement curve data has been specified for surface and sub-surface movements, or for surface movements only.

Formatting options are available by right-clicking in the view.

Surface Ground Movement Only Curves' - Chart

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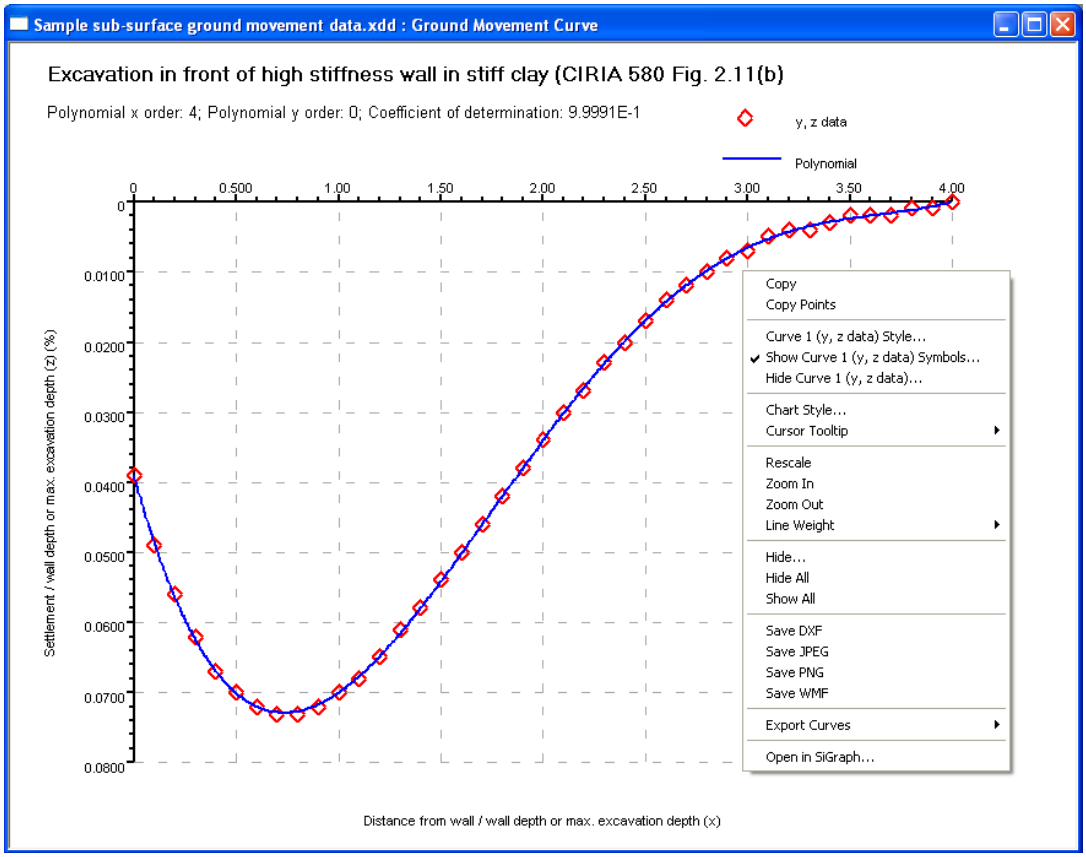
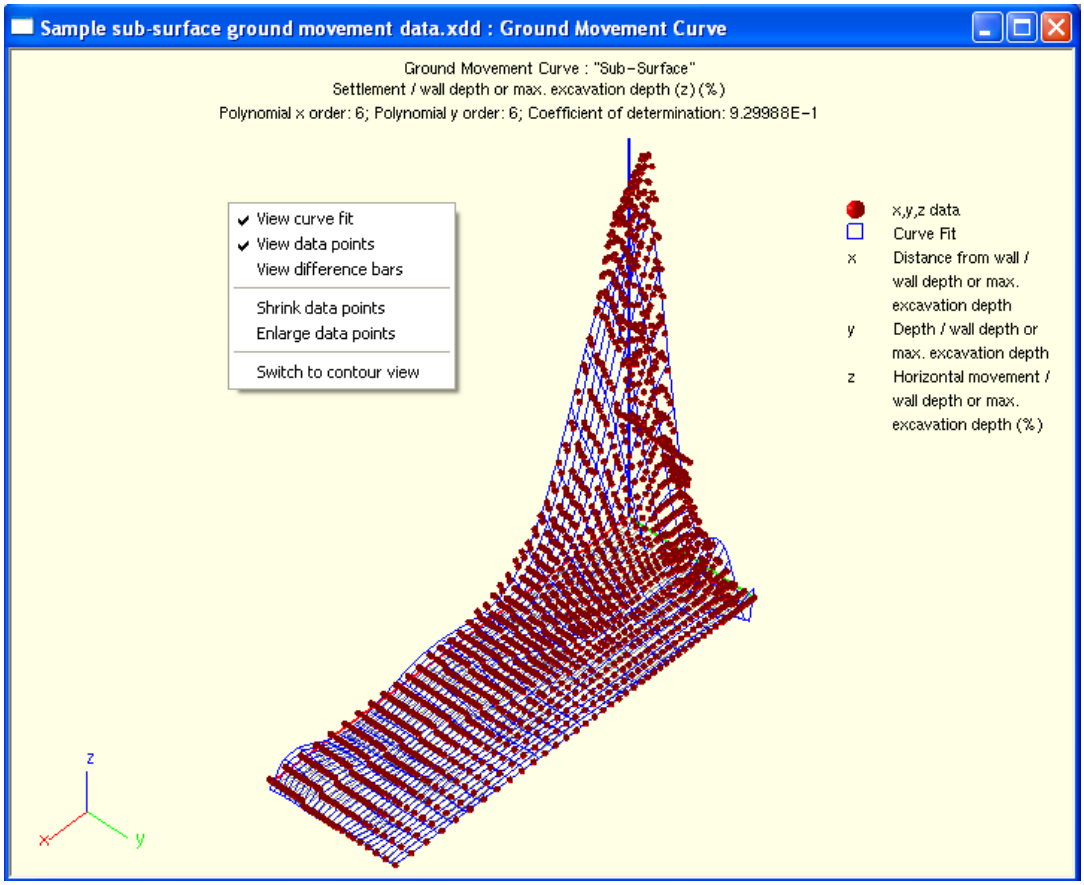
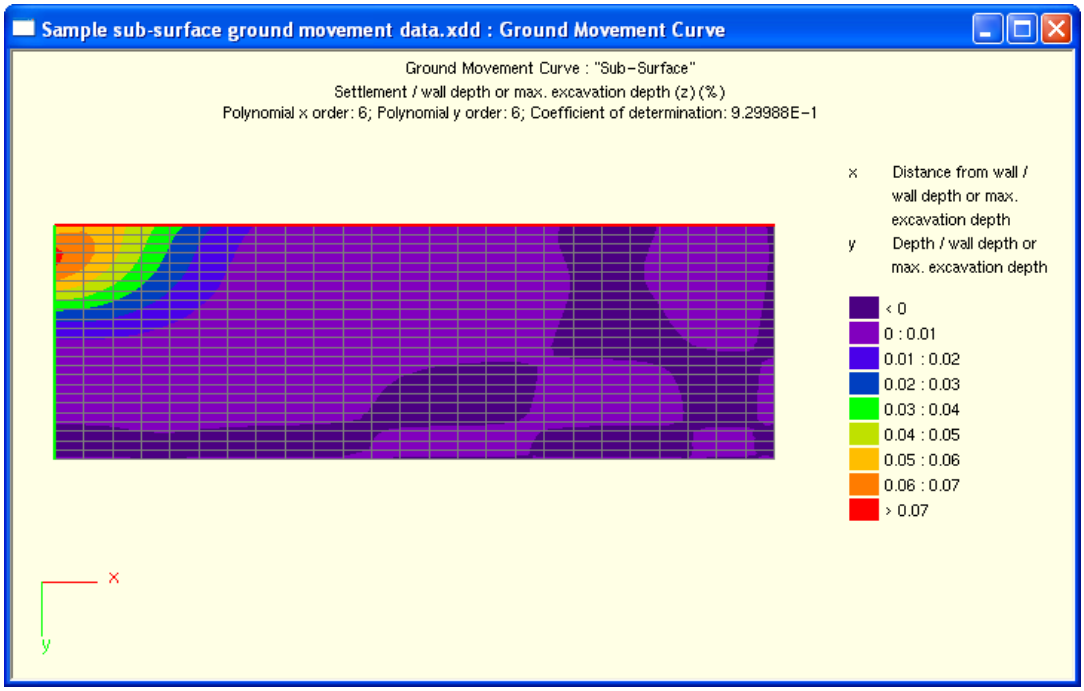


Surface and Sub-surface Ground Movement Curves' - Relief View



Surface and Sub-surface Ground Movement Curves' - Contour View



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Right-clicking in the window opens a context menu to enable formatting of the view. The following options are available for the relief view of surface and sub-surface ground movement curves' graphs.

View curve - toggles the display of the curve that has been fitted to the data points.

View data points - toggles the display of the data points that are used in deriving the curve fit.

View difference bars - toggles the display of the difference bars, illustrating the difference between the data point's z value, and the z value calculated by the curve fit.

Shrink data points - halves the size of the spheres used to display the data points.

Enlarge data points - doubles the size of the spheres used to display the data points.

Switch to contour/relief view - changes the view from a coloured, 2 dimensional, contour view of values calculated from the curve fit, and the 3 dimensional relief view of the curve fit.

3.10.3.2 Sample Sub-surface Ground Movement Curve

The following defines the modelling assumptions used for the three dimensional finite element analysis that was used to provide the displacements given in the sample data file: Sample sub-surface ground movement data.xdd.

Notation

B1 = lowest level of basement slab
c' = cohesion
E' = drained Young's Modulus
Eu = undrained Young's Modulus
G = tangent shear modulus
Gmax = maximum value of tangent shear modulus at very small strain
Gvh/Ghh = ratio of vertical to horizontal shear stiffness
Ko = coefficient of earth pressure at rest
LGF = lower ground floor slab
mOD = metres Ordnance Datum
Su = undrained shear strength
α = adhesion factor between pile and soil
γ = unit weight
λ, κ, ι, βG, and $\beta\varnothing$ = constants in the BRICK soil model
ϕpeak = peak friction angle

Introduction

The Oasys program LS-DYNA (DYNA) was used to carry out the 3D FE analysis. The modelling was used to establish ground movements around a deep basement constructed in Central London.

The site and proposed basement has maximum dimensions of approximately 105m (north to south) by 150m (east to west) and covers an area of 12,200m². Displacements in the sample file were taken at the centre of one of the basement retaining walls (at least 60m from any corner). Therefore the

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displacements approximate to a plane strain condition.

Comparisons of the surface and sub-surface displacements were carried out with the following case studies:

- British Library excavation ref Simpson (1992)
- House of Commons car park excavation, ref Burland and Hancock (1977) and St John (1975)
- 3D LS-DYNA finite element analysis of Crossrail Paddington Box in London carried out by Arup

Reasonable agreement was obtained from these comparisons between the methods. Therefore data from the FE analysis described here was used as data in the sample file. It should be noted that all of the excavations were stiffly propped excavations carried out in London Clay.

Stratigraphy

Ground and groundwater conditions were initially assessed from information compiled in a geotechnical desk study. Following this, two phases of ground investigations were carried out to gain sufficient information to allow geotechnical design of the project. On the basis of the desk study and site investigations, the table below presents the design stratigraphy adopted for the geotechnical analysis.

Geotechnical Design Stratigraphy

Stratum	Top of stratum (mOD)	Thickness (m)
Made Ground(a)	+17.5 (ground level at north of site)	5m
Brickearth(a)	+12.5	2.5m
River Terrace Deposits	+10	4m
London Clay	+6	36m
Lambeth Clay	–30	12m

(a) Assumed not to be present below the majority of the former basement.

Soil Parameters

Geotechnical design parameters were derived for each stratum from the results of insitu and laboratory testing. The proposed soil parameters for each stratum, are summarised in the table below. The Made Ground, Brickearth and River Terrace Deposits were modelled in the analysis using the linear elastic perfectly plastic Mohr-Coulomb model without dilation. These materials were assumed to be drained in all stages of the analysis.

Summary of Geotechnical Parameters

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Stratum	γ (kN/m3)	c' (kN/m2)	ϕ' peak	Su (kN/m2)	E' (MN/m2) d	Eu (MN/m2) d	Kof	α
Made Ground	18	0	25	0	10	-	0.6	-
Terrace Gravel	20	0	36	0	30	-	0.4	-
London Clay	20			Modelled using BRICK				0.5
Lambeth Group (Clay)	20			Modelled using BRICK				0.4

b Su / depth profile outside secant wall (z increasing with depth from +5mOD)
c Su / depth profile inside secant wall (z increasing with depth from +2mOD) adjusted to account for excavation
d For the retaining wall analysis. Lower values were used for considering settlements from pile or raft foundations
e Eu / depth profile outside secant wall (z increasing with depth from +10mOD). Softening of the soil adopted on the passive side of the retaining wall.
f For the London Clay and Lambeth Group (Clay), the Ko profile varied with depth and was dependent upon the stress history modelled in the BRICK soil model. An approximate average value is given in this table.

The finite element analysis used the constitutive soil model, BRICK (Simpson, 1992) to model the behaviour of the London Clay and fine grained strata within the Lambeth Group. Moderately conservative soil stiffness parameters (Pillai, 1996) were adopted in the analysis for the BRICK soil model. The BRICK model is non-linear and is strain-dependent. The shear stiffness / strain soil properties used for the BRICK model are defined in the table below.

BRICK Model Material Properties for London Clay and Lambeth Clay

Strain	G/Gmax
3.04E-05	0.92
6.09E-05	0.75
0.000101	0.53
0.000121	0.29
0.000820	0.13
0.00171	0.075
0.00352	0.044

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0.00969	0.017
0.02223	0.0035
0.0646	0
λ=0.1 κ=0.02 ι=0.0019 βG=4 $\beta\varnothing$=2 Gvh/Ghh=0.5	

Groundwater Conditions

For both short and long term conditions in the London Clay and Lambeth Clay, a hydrostatic water pressure profile was adopted starting from an elevation of +8.5mOD. It was realised that a sub-hydrostatic pressure profile exists in the lower part of the London Clay and Lambeth Group (CIRIA, 1989). Given the depth of the excavation, this was considered to have a negligible effect on the design of the retaining walls and potential base heave during the proposed excavation.

Boundary Conditions

The model extends from +17.5mOD (existing ground level at Cheapside), to -42mOD (base of the Lambeth Clay). The Lambeth Sand, Thanet Sand and the Chalk layers were not included as they are stiffer materials in which little movement was expected.

The horizontal base of the model was restrained in all directions. All of the vertical boundaries were restrained in the x and y directions but are free to move vertically. The vertical boundaries were sufficiently far from the excavation to have no effect on ground movements calculated along the Central Line tunnels.

Analysis Sequence

The analysis sequence modelled the geological and historical development at the site to obtain an appropriate horizontal effective stress and strain state in the soil modelled using BRICK prior to modelling the anticipated construction sequence. Displacements were zeroed prior to the construction stages (Stage 6 onwards). For simplification a single construction sequence was adopted around the perimeter of the site to model the support of the existing wall. During the actual construction, numerous sequences were adopted to support the existing basement retaining walls, however, assuming a single sequence has a negligible effect when considering displacements at depth. The full sequence used in the DYNA finite element analysis is given in the table below.

Analysis Sequence Used in the DYNA FE Analysis

Analysis stage	Description	Remarks
Stage 1	Initialisation of the model (drained)	Model geological history of unloading to establish insitu Ko profile

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Stage 2	Excavate for Central Line tunnels (undrained)	Assume 2% volume loss
Stage 3	Place lining of tunnels (drained)	
Stage 4	Construct existing building (undrained)	“Wished” in-place existing building wall, slab and floors
Stage 5	Switch to drained	End of this stage represents current condition
Stage 6	Demolish existing building - Remove existing building surcharge, floors at +17.5mOD and +13.77mOD and place temporary prop at +16.5mOD (undrained)	Existing building wall remains in place. Displacements zeroed at this stage
Stage 7	Install secant wall for new building and fill gap between secant and existing walls (undrained)	1.18m diameter secant wall on the northern boundary and 0.88m elsewhere. Straight shafted bearing piles of up to 2.4m in diameter with plunged columns. The 1.18m secant wall on the northern boundary has male piles at 1.7m centres.
Stage 8	Install bearing piles, remove former building base slab at +10mOD, insert temporary props at +17.5mOD and +10mOD (undrained)	Install plunge columns
Stage 9	Apply percentage of new building loads on to plunge columns (undrained)	
Stage 10	Excavate to +1.9mOD, top down construction (undrained)	Bottom-up core construction not modelled
Stage 11	Place underslab drainage, construct 1m thick B1 slab and apply full new building load (undrained)	0.3m underslab drainage is placed below new building B1 slab
Stage 12	Switch to long term condition (drained)	Long term properties of concrete used

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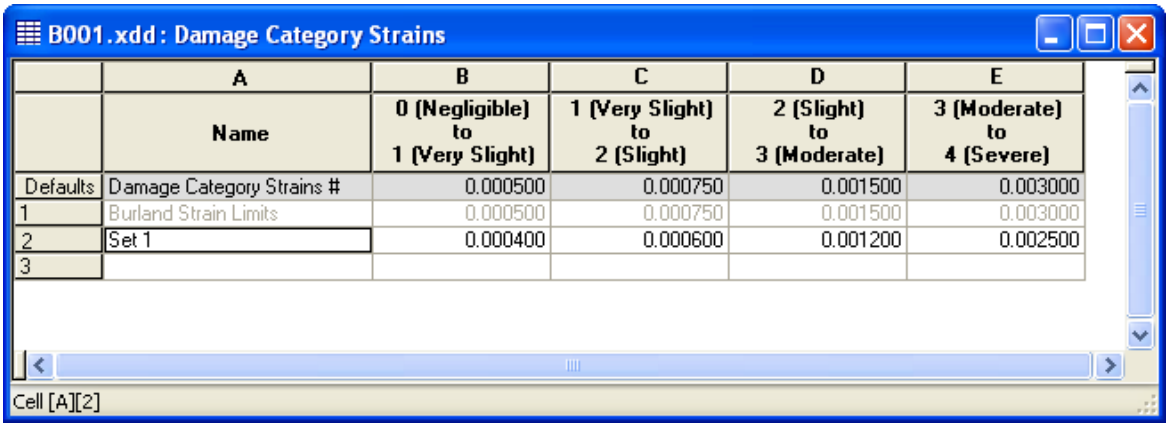
3.11 Building Damage Assessment

The two types of building damage assessment which can be performed are:

- Specific Building Damage Assessment.
- Generic Building Damage Assessment.

3.11.1 Damage Category Strains

Damage Category Strains are required to describe the relationship of damage category to deflection ratio and horizontal tensile strain for each of the four boundaries between damage categories. This data is used to determine a building segment's damage category as plotted on the Building Damage Interaction Chart.



B001.xdd : Damage Category Strains

	A	B	C	D	E
	Name	0 (Negligible) to 1 (Very Slight)	1 (Very Slight) to 2 (Slight)	2 (Slight) to 3 (Moderate)	3 (Moderate) to 4 (Severe)
Defaults	Damage Category Strains #	0.000500	0.000750	0.001500	0.003000
1	Burland Strain Limits	0.000500	0.000750	0.001500	0.003000
2	Set 1	0.000400	0.000600	0.001200	0.002500
3					

Cell [A][2]

Each sub-building is assigned a set of Damage Category Strains that will be used in the assessment of building damage. A default standard set of values is provided that represents the values provided by Burland.

0 (Negligible) to 1 (Very Slight) - the value of horizontal strain that corresponds with a deflection ratio of zero, in order to define the boundary between Damage Categories 0 and 1 etc.

3.11.2 Specific Building Damage Assessment

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3.11.2.1 Specific Buildings

Specific building damage : Specific Structures

	A	B	C	D	E	F	G	H	I
Ref.	Structure Name	Sub-Structure Name	Displacement Line	Line Length	Start Distance Along Line	End Distance Along Line	Vertical Offsets from Line for Vertical Movement Calculations	Vertical Displacement Limit Sensitivity	Damage Category Strains
				[m]	[m]	[m]	[m]	[mm]	
Defaults	Building #	Sub #	Surface		0.000	0.000	0	0.100	Burland Strain Limit
1	Building 1	Sub #	Surface	99.999	0.000	100.000	0,0,0,0	0.100	Burland Strain Limit
2									

Press <TAB> to start a new record

J	K	L	M	N	O	P	Q	R	S
				Hogging			Sagging		
Poisson's Ratio	E/G	Height	Default Properties	2nd Moment of Area (per unit width)	Distance of Bending Strain from N.A.	Distance of N.A. from Edge of Beam in Tension	2nd Moment of Area (per unit width)	Distance of Bending Strain from N.A.	Distance of N.A. from Edge of Beam in Tension
		[m]		[m³]	[m]	[m]	[m³]	[m]	[m]
0.200	2.600	10.000	Yes						
0.200	2.600	10.000	Yes	333.333	10.000	10.000	83.333	5.000	5.000

The Specific Building input table describes the location of the building and its sub-buildings, its height and settlement trough limit sensitivity. Its location is used to calculate the settlement and horizontal displacement along its length. These are then used to calculate hogging and sagging zones, deflection ratios and horizontal strains for input into the Burland Building Damage Assessment method.
Buildings contain Sub-Buildings, as buildings contain façades. Thus the varying alignments of a building's façades may be associated for reporting purpose.

The following parameters in the table define the geometry:

Building Name - a name to identify the building.

Sub-Building Name - a name to identify a sub-building e.g. one facade of a building.

Displacement Line - the Displacement Line that is to be used to describe the plan alignment of the sub-building.

Line Length - the length of the Displacement Line that is the maximum length that the sub-building can have.

Start Distance Along Line - the distance along the Displacement Line that defines the start point of the sub-building.

End Distance Along Line - the distance along the Displacement Line that defines the end point of the sub-building.

Vertical Displacement Limit Sensitivity - the minimum value that is to determine the extent of regions of settlement or heave for the sub-building's building damage assessment calculations. This is an absolute value. It allows settlement or heave profiles, that tend towards zero very gradually, to be curtailed for the purposes of establishing the end hogging or sagging zones in building damage assessment.

Height - the height of the sub-building from foundation to eaves' level.

Vertical Offsets from Line for Vertical Movement - the vertical offset to be applied to the displacement line before calculating vertical displacements for use in building damage assessments. A series of offsets may be specified in order to compare building damage results for different elevations e.g. for a piled building: basement level; equivalent pile level; and pile toe level. These vertical movements are used with horizontal movements at the level of the displacement line. See Points of Inflexion, Gradient and Radius of Curvature for further information. More than one value may be entered separated by commas ",". A negative value represents a reduction in elevation.

The Burland method of building damage assessment assumes that a building's façade behaves as a beam in bending.
The follwing parameters in the table provide the information that is required by the Burland method to effect this approximation:

Damage Category Strains - the set of Damage Category Strains that this sub-building is to adopt to describe the thresholds of each of the 5 damage categories (0 to 4)

Poisson's Ratio - the Poisson's ratio of the beam that is to represent the sub-building. Values in the range of 0.2 to 0.3 are commonly adopted.

E/G - the Youngs modulus : shear modulus ratio of the beam that is to represent the sub-building (if the sub-building is solid, isotropic, linear and elastic then a typical value would be based on Poisson's Ratio, ν, as $2(1 + \nu)$ so ranging from 2.4 to 2.6, if values of 0.2 to 0.3 are used for the Poisson's Ratio.

Burland and Wroth (1974) discuss the effect of E/G ratios but draw no conclusions about appropriate values to use for 'typical' masonry or concrete structures. Mair, Taylor and Burland (1996) state, "For the purposes of assessment of potential damage, framed buildings on shallow foundations can be considered using the same methodology as for masonry structures. It is more appropriate to adopt an E/G ratio of 12.5, rather than 2.6 used for masonry structures".

Melis and Rodríguez Ortiz (2001) suggest "for flexible buildings with big spans or steel building, the ratio E/G can be as high as 12 or 15".

Default Properties - set 'Yes' for XDisp to calculate default values for 2nd Moment of Area and neutral axis distances as discussed below, or 'No' to provide specific values.

The following data is required for hogging and sagging zones of the building.

Distance of Bending Strain from N.A. - the distance of bending strain to be calculated from the neutral axis. For sagging of a linear isotropic elastic beam a value equal to the height/2 is commonly

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used. For hogging of a building with a rigid base slab a value equal to the height is commonly used.

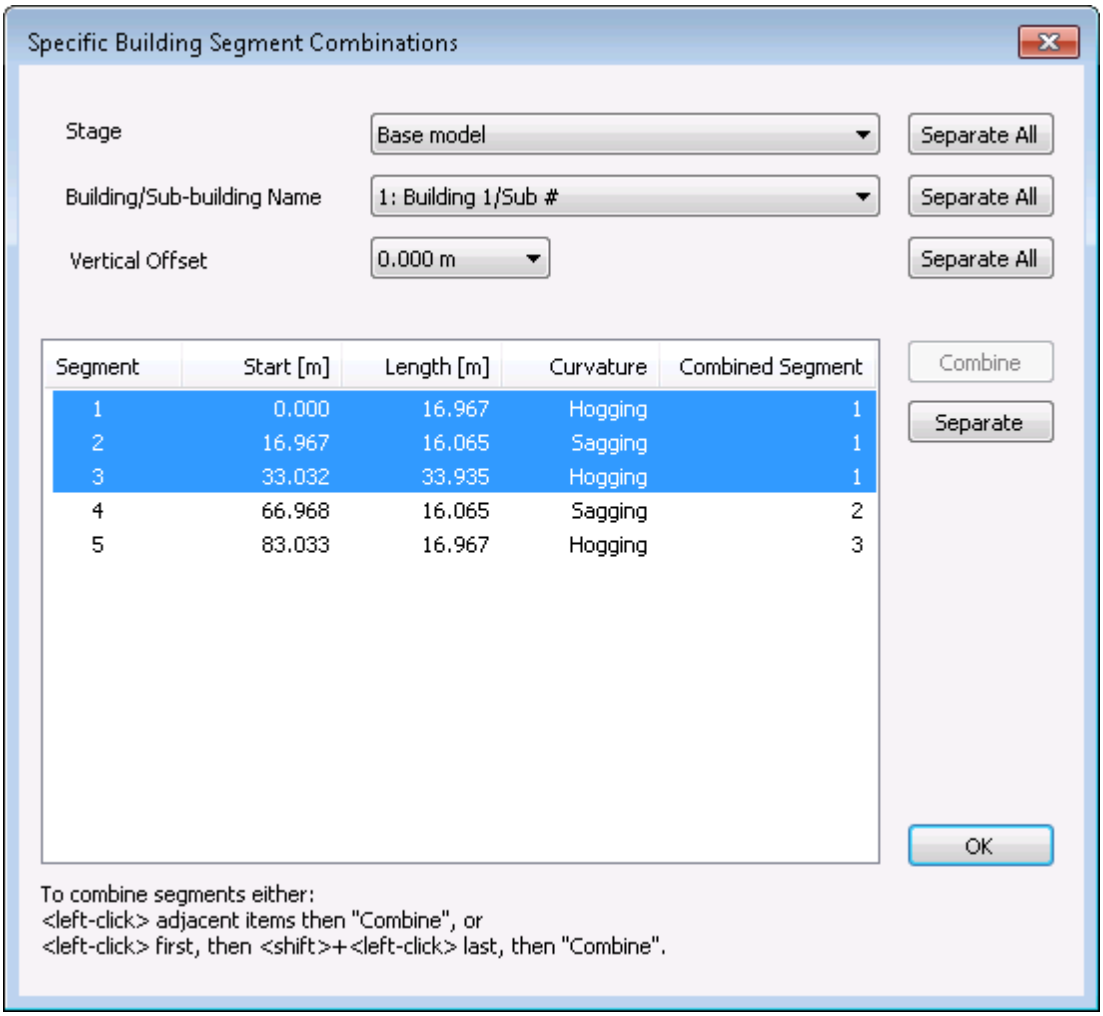
Distance of N.A. from Edge of Beam in Tension - distance of the neutral axis from the edge of the beam in tension. For sagging of a linear isotropic elastic beam a value equal to the height/2 is commonly used. For hogging of a building with a rigid base slab a value equal to the height is commonly used.

2nd Moment of Area (per unit width) - adopting the above for Distance of Bending Strain from N.A. and for Distance of N.A. from Edge of Beam in Tension - conventionally for an element of a building undergoing hogging a value of $d^3/3$ is adopted. For an element of a building undergoing sagging a value of $d^3/12$ is adopted, see Mair et al (1996).

3.11.2.2 Segment Combinations

The Segment Combinations dialog is available only if an analysis has been performed in order to determine the locations of hogging and sagging segments along a sub-building's length.

Segments may then be combined in order to force short, insignificant, lengths of hogging or sagging segments to be absorbed into longer more significant neighbouring lengths.



To combine two or more adjacent segments, click in the row of each of those segments, and then

select the 'Combine' button. Alternatively, click in the row of the segment that is to define the start the required combined segment, then <shift>+ <click> in the the row of the segment that is to define the end of the combined segment, then select the 'Combine" button. The results will be updated and available to view in the Text Output and the results' charts. The column labelled 'Combined Segment' then shows the revised index of each combined segment.

To separate combined segments select either one of the 'Separate All' buttons or the 'Separate' button.

To separate all combined segments for all vertical offsets of all sub-buildings of all stages (i.e. all combined segments in the model), click the 'Separate All' button beside the 'Stage' field.

To separate all combined segments for all vertical offsets of all sub-buildings of the displayed stage, click the 'Separate All' button beside the 'Building...' field.

To separate all combined segments for all vertical offsets of the displayed building and stage, click the 'Separate All' button beside the 'Vertical Offset' field.

To separate only the combined segments of the displayed vertical offset, building and stage, click the 'Separate' button.

3.11.3 Generic Building Damage Assessment

3.11.3.1 Generic Buildings

Generic building damage.xdd : Generic Structures

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
									Hogging			Sagging				Transects		
Ref.	Name	Polylines	L/H Values	Vertical Displacement Limit Sensitivity	Damage Category Strains	Poisson's Ratio	E/G	Default Properties	2nd Moment of Area (per unit width)	Distance of Bending Strain from N.A.	Distance of N.A. from Edge of Beam in Tension	2nd Moment of Area (per unit width)	Distance of Bending Strain from N.A.	Distance of N.A. from Edge of Beam in Tension	Vertical Offsets from Line for Vertical Movement Calculations	Interval	Length	Number of Displacement Points
				[mm]					[m³]	[m]	[m]	[m³]	[m]	[m]	[m]	[m]	[m]	
Defaults	Generic #	Polyline 1	0.1,0.16,0.25,0.4,	0.100	Burland Strain Limits	0.200	2.600	Yes							0.000	3.000	10.000	11
1	Generic 1	Polyline 1	10.	0.100	Burland Strain Limits	0.200	2.600	Yes							0.000	50.000	100.000	11
2																		

Cell [A][1]

The following parameters in the table define the geometry:

Building Name - a name to identify the generic damage assessment data.

Polyline - the polyline whose transects are used to describe the plan alignment of assessment locations.

L/H Values - the series of L/H values which make up the buildings to be analysed along each transect of the polyline. These are input as comma-separated values in the cell.

Interval - the distance that defines the spacing between transects, along the polyline.

Length - the length of each transect.

Number of Displacement Points - the number of displacement points along each transect at which displacements are to be calculated.

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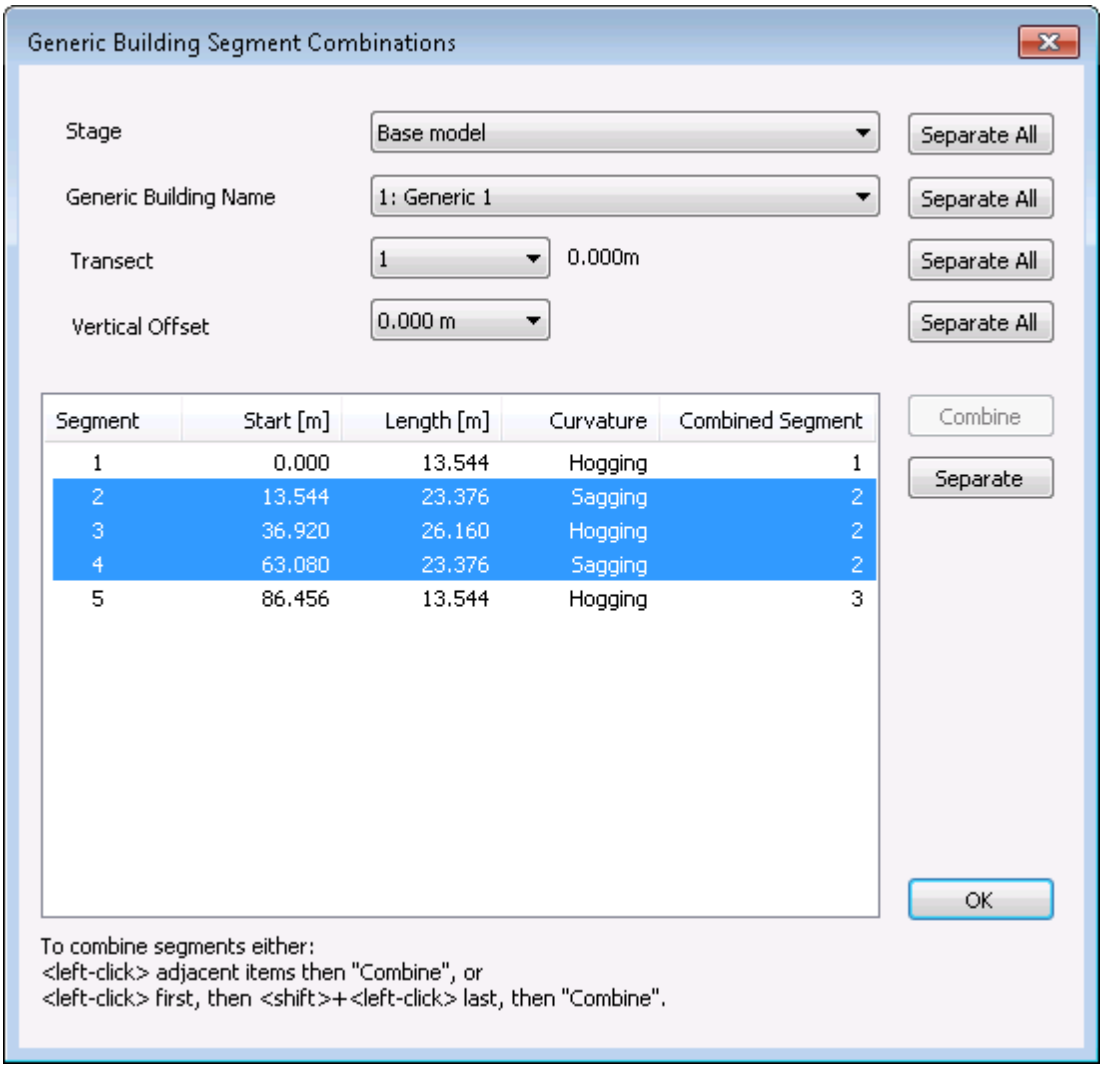
For details of other data see Specific Building Damage Assessment - Building Data.

3.11.3.2 Segment Combinations

The Segment Combinations dialog is available only if an analysis has been performed in order to determine the locations of hogging and sagging segments along a sub-building's length.

Segments of transects may then be combined in order to force short, insignificant, lengths of hogging or sagging to be absorbed into longer more significant neighbouring lengths.



To combine or separate segments follow the procedure described in Specific Building Damage Assessment - Segment Combinations.

3.12 Utility Damage Assessment

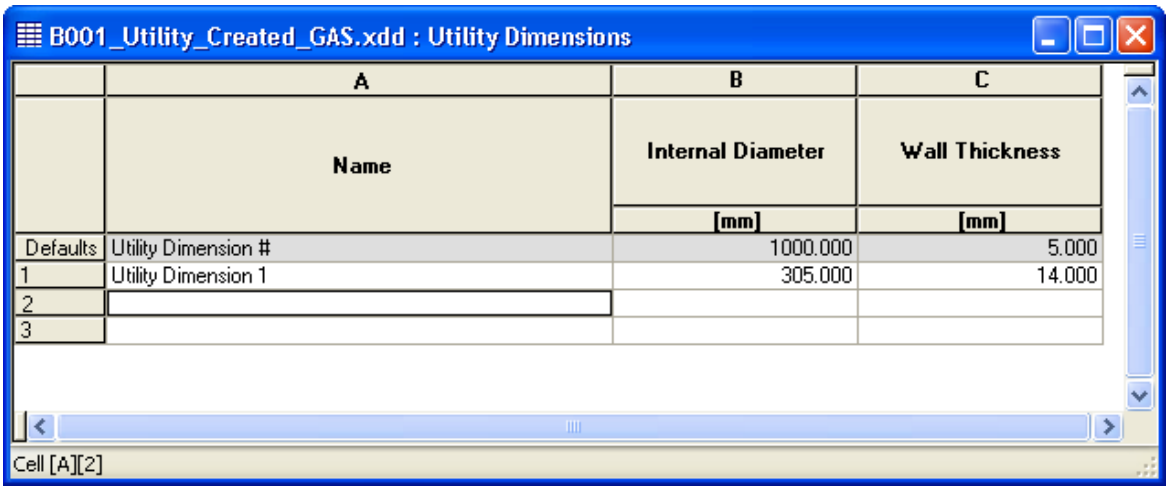
The two types of utility damage assessment that can be performed are:

- Specific Utility Damage Assessment.
- Generic Utility Damage Assessment.

See analysis methods for more information on the assessment calculations.

3.12.1 Utility Dimensions

Utility dimensions define the internal diameter and the wall thickness of a utility. Data may be input in tabular form in this input table, or in dialog form by double-clicking within a cell or by clicking the 'Wizard' button on the XDisp Toolbar.



	A	B	C
	Name	Internal Diameter	Wall Thickness
		[mm]	[mm]
Defaults	Utility Dimension #	1000.000	5.000
1	Utility Dimension 1	305.000	14.000
2			
3			

Name specifies the name of the dimension.

Internal Diameter specifies the internal diameter of the utility.

Wall Thickness specifies the wall thickness of the utility.

XDisp provides some sample dimensions via the sample file "SampleDimensionsAndCriteria.xdd'. These can be used by opening that file and copying the data from the Dimensions input table into the same table of another data file. Alternatively the sample file may be saved with a new name and opened to form the basis of a new data file. The data values should be validated before use.

3.12.2 Acceptance Criteria and Factors

The limiting criteria and factors for utility damage calculations are input into this input table either in tabular form, or in dialog form by double-clicking within a cell or by clicking the 'Wizard' button on the XDisp Toolbar.

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SampleDimensionsAndCriteria : Acceptance Criteria and Factors

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
Ref.	Name	Acceptance Criteria																Factors						
		Pullout				Rotation				Allowable Strain				Radius of Curvature				Pullout		Rotation	Axial Strain		Flexural Strain	
		Threshold		Limit		Threshold		Limit		Tension		Compression		Threshold		Limit		Axial	Flexural		Tension	Compression	Tension	Compression
		Check	[mm]	Check	[mm]	Check	[Deg]	Check	[Deg]	Check	[µε]	Check	[µε]	Check	[m]	Check	[m]							
Defaults	Acceptance Criteria #	Yes	100.000	Yes	400.000	Yes	0.025	Yes	0.150	Yes	98.000	Yes	1200.000	Yes	25000.000	Yes	25000.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1	LP, Cast Iron, <305mm, trafficked,	Yes	0.100	Yes	0.400	Yes	0.025	Yes	0.150	Yes	98.000	Yes	1200.000	Yes	25000.000	Yes	25000.000	0.216	1.000	1.000	0.400	1.000	1.000	1.000
2	LP, Cast Iron, 305mm<D<610mm,	Yes	0.100	Yes	0.600	Yes	0.020	Yes	0.120	Yes	148.000	Yes	1200.000	Yes	25000.000	Yes	25000.000	0.216	1.000	1.000	0.400	1.000	1.000	1.000
3	LP, Cast Iron, 610mm<D<914mm,	Yes	0.100	Yes	0.700	Yes	0.015	Yes	0.090	Yes	148.000	Yes	1200.000	Yes	25000.000	Yes	25000.000	0.216	1.000	1.000	0.400	1.000	1.000	1.000
4	LP, Cast Iron, >914mm, trafficked,	Yes	0.100	Yes	0.700	Yes	0.010	Yes	0.060	Yes	148.000	Yes	1200.000	Yes	25000.000	Yes	25000.000	0.216	1.000	1.000	0.400	1.000	1.000	1.000
5	MP, Cast Iron, <305mm, trafficked	Yes	0.009	Yes	0.034	Yes	0.002	Yes	0.013	Yes	98.000	Yes	1200.000	Yes	25000.000	Yes	25000.000	0.216	1.000	1.000	0.400	1.000	1.000	1.000
6	MP, Cast Iron, 305mm<D<610mm	Yes	0.009	Yes	0.051	Yes	0.002	Yes	0.010	Yes	148.000	Yes	1200.000	Yes	25000.000	Yes	25000.000	0.216	1.000	1.000	0.400	1.000	1.000	1.000
7	MP, Cast Iron, 610mm<D<914mm	Yes	0.009	Yes	0.060	Yes	0.001	Yes	0.008	Yes	148.000	Yes	1200.000	Yes	25000.000	Yes	25000.000	0.216	1.000	1.000	0.400	1.000	1.000	1.000
8	MP, Cast Iron, >914mm, trafficked	Yes	0.009	Yes	0.060	Yes	0.001	Yes	0.005	Yes	148.000	Yes	1200.000	Yes	25000.000	Yes	25000.000	0.216	1.000	1.000	0.400	1.000	1.000	1.000
9	Ductile Iron, <305mm, rubber gas	Yes	25.000	Yes	25.000	Yes	1.500	Yes	1.500	Yes	498.000	Yes	700.000	Yes	25000.000	Yes	25000.000	1.000	1.000	1.000	0.200	1.000	1.000	1.000

Cell [V][1]

Name specifies the name of the criteria/factors. This might, for instance, be the pipe type.

Pullout

- **Threshold**
  - **Check** specifies whether pullout is to be checked against a threshold value as a measure of damage to the utility.
  - **Value** specifies the pullout that is to be used as the threshold value.
- **Limit**
  - **Check** specifies whether pullout is to be checked against a limiting value as a measure of damage to the utility.
  - **Value** specifies the pullout that is to be used as the limiting value.

Rotation

- **Threshold**
  - **Check** specifies whether rotation is to be checked against a threshold value as a measure of damage to the utility.
  - **Value** specifies the rotation, in degrees, that is to be used as the threshold value.
- **Limit**
  - **Check** specifies whether rotation is to be checked against a limiting value as a measure of damage to the utility.
  - **Value** specifies the rotation, in degrees, that is to be used as the limiting value.

Allowable Strain

- **Tension**
  - **Check** specifies whether tensile strain is to be checked against a limiting value as a measure of damage to the utility.

- **Value** specifies the tensile strain, in micro strain, that is to be used as the limiting value.

- **Compression**
  - **Check** specifies whether compressive strain is to be checked against a limiting value as a measure of damage to the utility.
  - **Value** specifies the compressive strain, in micro strain, that is to be used as the limiting value.

Radius of Curvature

- **Threshold**
  - **Check** specifies whether radius of curvature is to be checked against a threshold value as a measure of damage to the utility.
  - **Value** specifies the radius of curvature, that is to be used as the threshold value.
- **Limit**
  - **Check** specifies whether radius of curvature is to be checked against a limiting value as a measure of damage to the utility.
  - **Value** specifies the radius of curvature, that is to be used as the limiting value.

Pullout Factor the factor that is used for the pullout calculations.

Rotation Factor the factor that is used for the rotation calculations.

Axial Strain Factor

- **Tension** specifies the factor that is used for the axial tensile strain
- **Compression** specifies the factor that is used for the axial compressive strain

Flexural Strain Factor

- **Tension** specifies the factor that is used for flexural strain in calculation of total tensile strain
- **Compression** specifies the factor that is used for flexural strain in calculation of total compressive strain

XDisp provides some sample criteria via the sample file "SampleDimensionsAndCriteria.xdd'. These can be used by opening that file and copying the data from the Acceptance Criteria input table into the same table of another data file. Alternatively the sample file may be saved with a new name and opened to form the basis of a new data file. The data values should be validated before use.

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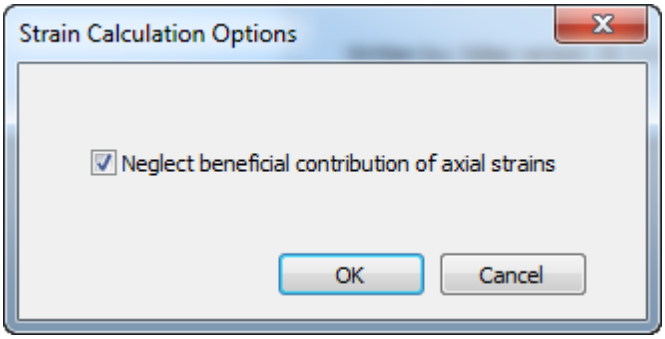
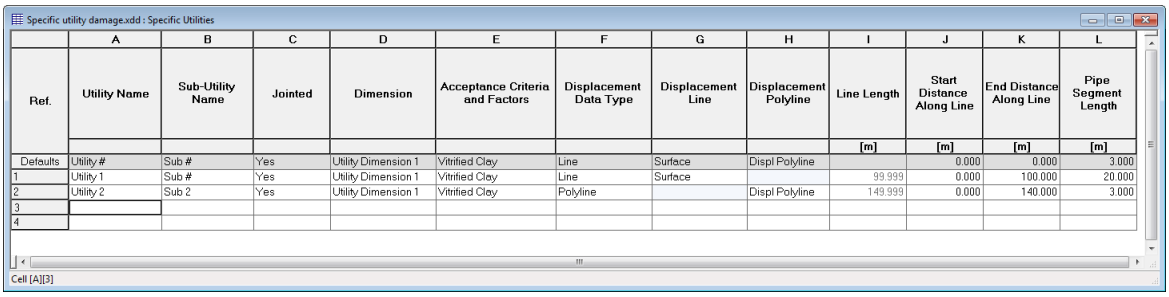
3.12.3 Strain Calculation Options



Neglect beneficial contribution of axial strains - if this option is checked, the beneficial contribution of axial strain is ignored while calculating the total strain.

3.12.4 Specific Utilities

The following data is required for the input of a utility for specific utility damage assessment. Data may be input in tabular form in this input table, or in dialog form having opened the wizard by double-clicking within a cell or by clicking the 'Wizard' button on the XDisp Toolbar.


Specific utility damage.xdd : Specific Utilities

	A	B	C	D	E	F	G	H	I	J	K	L
Ref.	Utility Name	Sub-Utility Name	Jointed	Dimension	Acceptance Criteria and Factors	Displacement Data Type	Displacement Line	Displacement Polyline	Line Length	Start Distance Along Line	End Distance Along Line	Pipe Segment Length
									[m]	[m]	[m]	[m]
Defaults	Utility #	Sub #	Yes	Utility Dimension 1	Vitrified Clay	Line	Surface	Displ Polyline		0.000	0.000	3.000
1	Utility 1	Sub #	Yes	Utility Dimension 1	Vitrified Clay	Line	Surface		99.999	0.000	100.000	20.000
2	Utility 2	Sub 2	Yes	Utility Dimension 1	Vitrified Clay	Polyline		Displ Polyline	149.999	0.000	140.000	3.000
3												
4												

Cell [A][3]

Utility Name - a name to identify a utility.

Sub-Utility Name - a name to identify a sub-utility.

If a utility has bends, then it may be specified as a series of sub-utilities, each referring to a separate displacement line. Alternatively it may be specified as a single sub-utility, referring to a single displacement polyline. However, see the Text Output section for the impact on results at bends.

Jointed - the type of utility. If yes, it is jointed, otherwise it is continuous.

Dimension - the Utility Dimension that is to be used to describe the internal diameter and the wall thickness of the utility.

Parameter Type - the Parameters and Acceptance Criteria that are to be used for the utility damage assessment.

Displacement Data Type - the type of displacement entity that is to describe the alignment of the utility, i.e. displacement line or displacement polyline

Displacement Line - the Displacement Line that is to be used to describe the alignment of the utility. The utility will therefore have no bends. This is active only when the displacement data type

selected is a displacement line.

Displacement Polyline - the Displacement Polyline that is to be used to describe the alignment of the utility. The utility will therefore have bends. This is active only when the displacement data type selected is a displacement polyline.

The Displacement Line's or Polyline's Z levels are used in calculating the levels of the centre lines of utilities. Since utilities are assumed to be circular for the purposes of those calculations, those levels also represent the levels of the neutral axes.

Line Length - the length of the Displacement Line/Displacement Polyline that is the maximum length that the utility can have.

Start Distance Along Line - the distance along the Displacement Line/Displacement Polyline that defines the start point of the utility.

End Distance Along Line - the distance along the Displacement Line/Displacement Polyline that defines the end point of the utility.

Pipe Segment Length - the length of pipes that are used in the pullout and rotation calculations of the utility damage assessment.

3.12.5 Generic Utilities

The following data is required for the input of a utility for generic utility damage assessment. Data may be input in tabular form in this input table, or in dialog form having opened the wizard by double-clicking within a cell or by clicking the 'Wizard' button on the XDisp Toolbar.

Generic utility damage.xdd : Generic Utilities

	A	B	C	D	E	F	G	H	I
							Transects		
Ref.	Name	Jointed	Dimension	Acceptance Criteria and Factors	Polyline	Pipe Segment Length	Interval	Length	Number of Displacement Points
						[m]	[m]	[m]	
Defaults	Generic Utility #	Yes	Utility Dimension 1	Vitrified Clay	Polyline 1	3.000	3.000	10.000	11
1	Generic Utility 1	Yes	Utility Dimension 1	Vitrified Clay	Polyline 1	20.000	50.000	100.000	101
2									

Cell [A][1]

Polyline - the Polyline whose transects are used to describe the alignments of utilities for damage assessment.

The polyline's Z levels are used in calculating the levels of the centre lines of utilities which are assumed to lie along transects. Since utilities are assumed to be circular for the purposes of those calculations, those levels also represent the levels of the neutral axes.

Interval - the distance that defines the spacing between transects, along the polyline.

Length - the length of each transect.

Number of Displacement Points - the number of displacement points along each transect at which displacements are to be calculated.

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For details of other data see Utility Damage Assessment - Generic.

3.13 Rail Damage Assessment Data

Enter topic text here.

3.13.1 Assessment Criteria

Rail Damage Assessment Criteria are referred to by Rail Tracks. A set of criteria specify which of cant, twist (short span) and twist (long span) are to be used for rail damage assessment of the rail track, and if so, what are the threshold and limit values which are then used in reporting of results in the Text View or Charts.

Staged construction.xdd : Rail Acceptance Criteria

Ref.	Name	Cant				Twist (short base)					Twist (long base)				
		Threshold		Limit		Base	Threshold		Limit		Base	Threshold		Limit	
		Check	[m]	Check	[m]	[m]	Check	[m]	Check	[m]	[m]	Check	[m]	Check	[m]
Defaults	Rail Acceptance Criteria #	Yes	0.020	Yes	0.030	3.500	Yes	0.010	Yes	0.015	10.000	Yes	0.020	Yes	0.030
1	Rail Acceptance Criteria 1	Yes	0.020	Yes	0.030	3.500	Yes	0.010	Yes	0.015	10.000	Yes	0.020	Yes	0.030
2															

3.13.2 Rail Tracks

Rail tracks provide details of each rail track's alignment and acceptance criteria.

Staged construction.xdd : Rail Tracks

Ref.	Rail Track Name	Sub-Rail Track Name	Polyline	Polyline Length	Distance along Polyline		Track Width	Rail Acceptance Criteria	Assessment Interval	Surface Type for Tunnels
					Start	End				
				[m]	[m]	[m]	[m]		[m]	
Defaults	Rail Track #	Sub #	Rail track 1 polyline		0.000	0.000	1.500	Rail Acceptance Criteria 1	3.000	Surface
1	Rail Track 1	Sub 1	Rail track 1 polyline	253.150	0.000	250.000	1.500	Rail Acceptance Criteria 1	3.000	Surface
2	Rail Track 2	Sub 2	Rail track 2 polyline	110.000	0.000	100.000	1.500	Rail Acceptance Criteria 1	3.000	Surface
3	Rail Track 3	Sub 3	Rail track 3 polyline	160.000	0.000	160.000	1.500	Rail Acceptance Criteria 1	3.000	Surface
4										

Rail Track Name - a name to identify the rail track

Sub-Rail Track Name - a name to identifiy a sub-rail track e.g. one portion of a rail track

Polyline - the Polyline that specifies the alignment of the rail track

Polyline Length - the lengh of the polyline that is the maximum length that the rail track can have

Distance along Polyline - **Start** and **End** - the distances along the polyline that define the start and end points of the rail track

Track Width - the distance between the centrelines of the left and right rail (i.e. gauge plus rail width)

Rail Acceptance Criteria - the set of Rail Damage Acceptance Criteria that are to be applied to the calculated cant and twist results for this rail track

Assessment Interval - the distance between each set of calculations of cant and twist

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Surface Type for Tunnels - whether displacements due to tunnelling are to be calculated for this rail track using the Surface or Sub-surface method. For more information see Tunnels - Analysis Parameters and Tunnel Settlement Trough Width.

3.14 Staged Construction

3.14.1 Lists

When working with Stages and Stage Properties there is a need to specify either collections of tunnels, polygonal excavations or circular excavations. Lists are used where the user is required to specify such collections of entities. A list is expressed as a string of text in a specific syntax. The vocabulary used is case insensitive and consists of:

- n – item number
- to – to specify a range
- all – to specify all
- none – to specify none

Examples:

- "1 11 12 to 72"
- "all"
- "none"

3.14.2 Stages

A model with no stages is the Base Model, for which analysis will consider all tunnels and excavations specified in the Tunnels Data, Polygonal Excavations Data, and Circular Excavations Data. Additional stages may be created to specify a subset of tunnels and excavations for analysis. Stage Properties may be created additionally to vary the diameters and depths of tunnels and excavations in a Stage, from the values that are specified in the Base Model.

Staged construction.xdd : Stages

Ref.	Name	Tunnels	Embedded Wall Excavations	
			Polygonal	Circular
Defaults	Stage #	none	none	none
1	Excavations 95m	none	1	1
2	Excavations 90m	none	1	1
3	Excavations 85m	none	1	1
4	Excavations 80m	none	1	1
5	North Tunnel Sec 1 Pilot	1	all	all
6	North Tunnel Sec 1 Full	1	all	all
7	North Tunnel Sec 2 Pilot	1 to 2	all	all
8	North Tunnel Sec 2 Full	1 to 2	all	all
9	North Tunnel Sec 3 Pilot	1 to 3	all	all
10	North Tunnel Sec 3 Full	1 to 3	all	all
11	North Tunnel Sec 4 Pilot	1 to 4	all	all
12	North Tunnel Sec 4 Full	1 to 4	all	all
13	North Tunnel Sec 5 Pilot	1 to 5	all	all

Name - specifies the name of the stage.

Tunnels, **Polygonal Embedded Wall Excavations**, and **Circular Embedded Wall Excavations** - specify the collections of tunnels, polygonal excavations and circular excavations that are to be included for analysis in this stage. This field uses the list syntax.

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3.14.3 Stage Properties

Stage Properties may be used to specify alternative values, to those of the Base Model, for diameters and/or depths of those tunnels and excavations that have been specified for inclusion in a Stage. They allow, for instance, an excavation's depth to be increased from one Stage to the next, or a tunnel's diameter to be increased from that of its pilot tunnel in an earlier Stage. Stage Properties are not needed if the values of tunnel diameters and excavation depths in the Base Model are appropriate for a Stage.

Staged construction.xdd : Stage Properties

Ref.	Stage	Element		Tunnel Property	Excavation Property	Units	Value(s)
		Type	Ref(s).				
Defaults	Excavations 95m	Tunnel	All	Diameter	Base Level(s)		
1	Excavations 95m	Polygonal Excavation	all		Base Level(s)	[m]	95.000
2	Excavations 95m	Circular Excavation	all		Base Level(s)	[m]	95.000
3	Excavations 90m	Polygonal Excavation	all		Base Level(s)	[m]	90.000
4	Excavations 90m	Circular Excavation	all		Base Level(s)	[m]	90.000
5	Excavations 85m	Polygonal Excavation	all		Base Level(s)	[m]	85.000
6	Excavations 85m	Circular Excavation	all		Base Level(s)	[m]	85.000
7	Excavations 80m	Polygonal Excavation	all		Base Level(s)	[m]	80.000
8	Excavations 80m	Circular Excavation	all		Base Level(s)	[m]	80.000
9	North Tunnel Sec 1 Pilot	Tunnel	1	Diameter		[m]	2.500
10	North Tunnel Sec 1 Full	Tunnel	1	Diameter		[m]	5.000
11	North Tunnel Sec 2 Pilot	Tunnel	1	Diameter		[m]	5.000
12	North Tunnel Sec 2 Pilot	Tunnel	2	Diameter		[m]	2.500
13	North Tunnel Sec 2 Full	Tunnel	1 to 2	Diameter		[m]	5.000
14	North Tunnel Sec 3 Pilot	Tunnel	1 to 2	Diameter		[m]	5.000
15	North Tunnel Sec 3 Pilot	Tunnel	3	Diameter		[m]	2.500
16	North Tunnel Sec 3 Full	Tunnel	1 to 3	Diameter		[m]	5.000
17	North Tunnel Sec 4 Pilot	Tunnel	1 to 3	Diameter		[m]	5.000
18	North Tunnel Sec 4 Pilot	Tunnel	4	Diameter		[m]	2.500
19	North Tunnel Sec 4 Full	Tunnel	1 to 4	Diameter		[m]	5.000
20	North Tunnel Sec 5 Pilot	Tunnel	1 to 4	Diameter		[m]	5.000
21	North Tunnel Sec 5 Pilot	Tunnel	5	Diameter		[m]	2.500

Stage - selects a Stage from the list of Stages in the Stages Data.

Element Type and **Ref(s).** - specify which of the elements in the specified Stage are to have their property values amended from those of the Base Model.

Tunnel Property - is active if the Element Type is "Tunnel", when it specifies which property of the referenced tunnel(s) is to have its value varied from the Base Model. Currently only diameter is available.

Excavation Property - is active if the Element Type is "Polygonal Excavation" or "Circular Excavation", when it specifies which property of the referenced excavation(s) is to have its value varied from the Base Model. Currently only base level is available.

Units - indicates the units that are relevant to the property selected.

Value(s) - specifies the value that is to be applied to the property specified. If "Polygonal Excavation" is selected as the Element Type, then either a single value or a value for each of an excavation's corners, separated by a comma ",", should be specified. A single value will be a applied to all corners of the excavation.

3.15 Graphical Input of Data

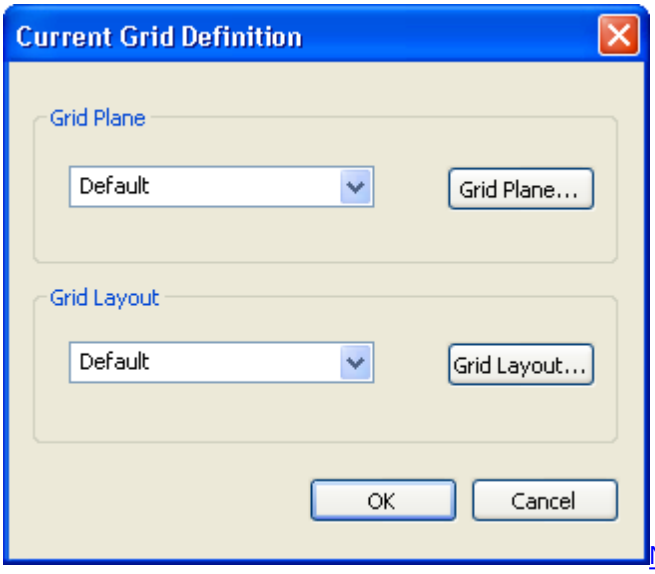
Elements may be input graphically via the 3DGraphics view which can be switched to input mode by clicking the "Input/Output" button ( ) on the Graphical Input Toolbar.

3.15.1 Defining Grids

Elements are entered on to a horizontal grid. A grid is a combination of a grid plane and a grid layout. The grid plane defines the elevation of the grid, whereas the grid layout defines the spacing between the grid points and the extent of the grid.

Grids are created using the "Current Grid Definition" dialog which may be accessed via:

- "Sculpt | Define Current Grid..." from the program's menu when the 3D Graphics View is active;
- the Define Grid button ( ) on the 3DGraphics Toolbar when the 3D Graphics View is active.



New Link

The grid plane and the grid layout for the current grid can be selected from their corresponding combo boxes, the default grid plane and default grid layout will be used otherwise.

Grid Plane

A new grid plane can be created by clicking on <new> in the grid plane combo box. The data of the new grid plane can be accessed/edited via the Grid Plane... button on the "Current Grid Definition" dialog.

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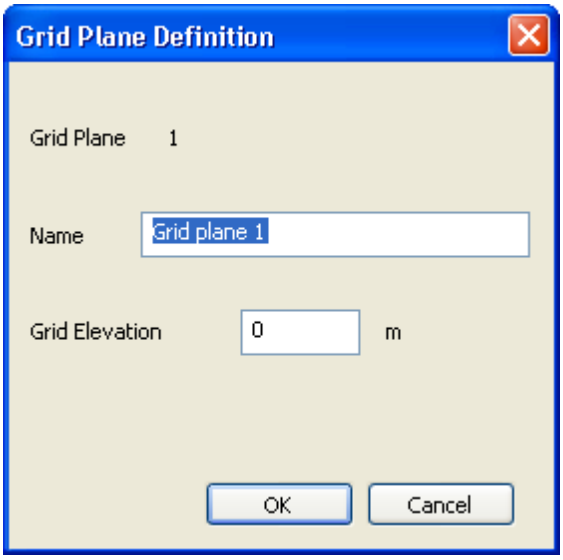


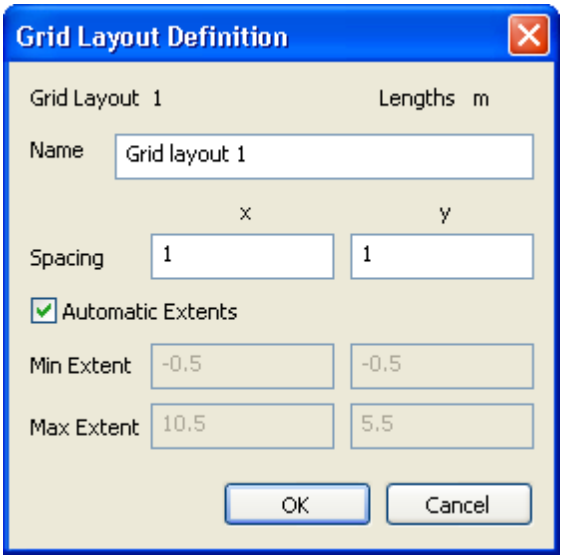
Name specifies the name of the grid plane.

Grid Elevation specifies the elevation of the grid.

The default grid plane is named "Default" and is of zero elevation.

Grid Layout

A new grid layout can be created by clicking on <new> in the grid plane combo box. The data of the new grid layout can be accessed/edited via the Grid Layout... button on the "Current Grid Definition" dialog.



Name specifies the name of the grid layout.

Spacing specifies the x spacing and y spacing of the grid.

If "Automatic Extents" is checked the program automatically extends the grid based on the elements

present in the 3D Graphics View. The user can specify his own extents by de-selecting the "Automatic Extents".

Min Extent specifies the minimum x and y extents.

Max Extent specifies the maximum x and y extents.

The default grid layout has the following values:

- Name: Default
- Spacing: (1 m, 1 m).
- Min Extent: (-0.5 m, -0.5 m).
- Max Extent: (10.5 m, 5.5 m).

3.15.2 Input of Elements

Elements may be input only when the 3DGraphics view is in the graphical input mode. The user can switch between input and the normal mode of the 3DGraphics view via the button on the Graphical Input Toolbar

3.15.2.1 Polylines

New LinkPolylines may be input graphically in the 3D Graphics View via:

- "Sculpt | Polylines..." from the program menu when the 3D Graphics View is active and is in Input Mode;
- the polylines button ( ) on the Graphical Input Toolbar when the 3D Graphics View is active and is in Input Mode.

A polyline may then be traced by left-clicking at different points in the view to specify the ends of consecutive polyline segments. The final input point is input by a double left-click. The "Polyline Data" dialog will then pop up in which the other properties of the polyline can be edited. The dialog will initially have default values.

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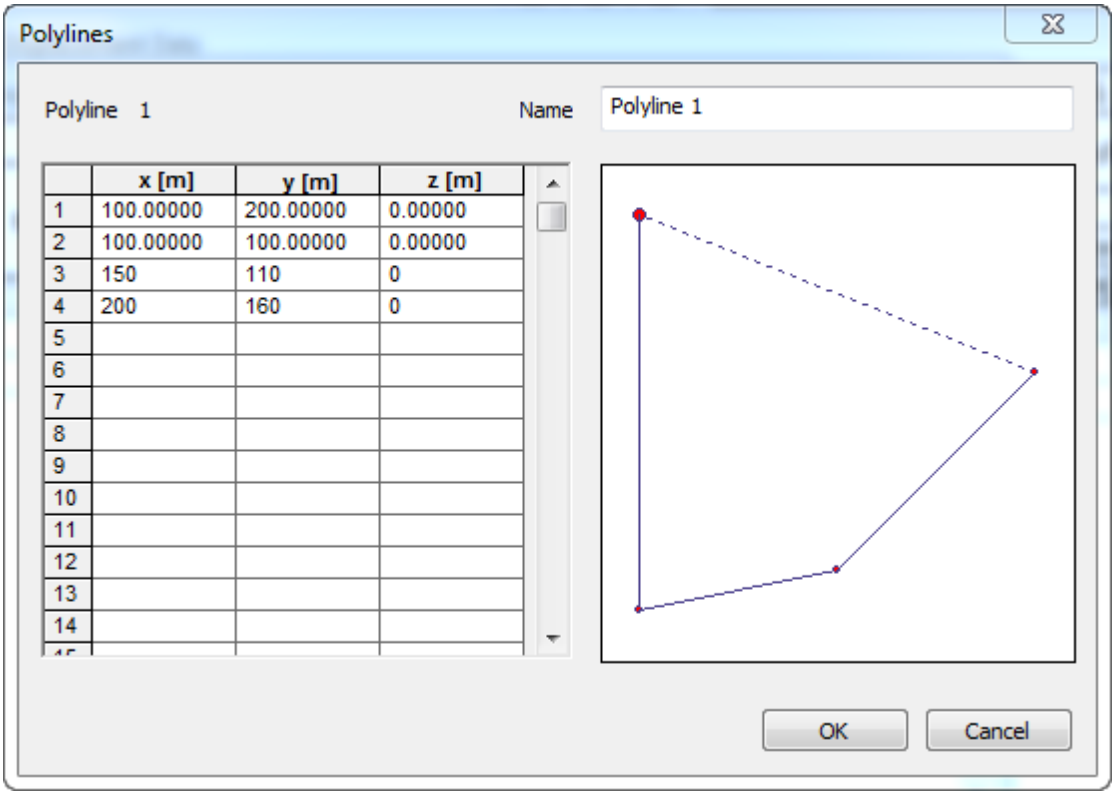


The input of polyline may be cancelled by clicking the "Cancel" button or by closing the dialog.

3.15.2.2 Tunnels

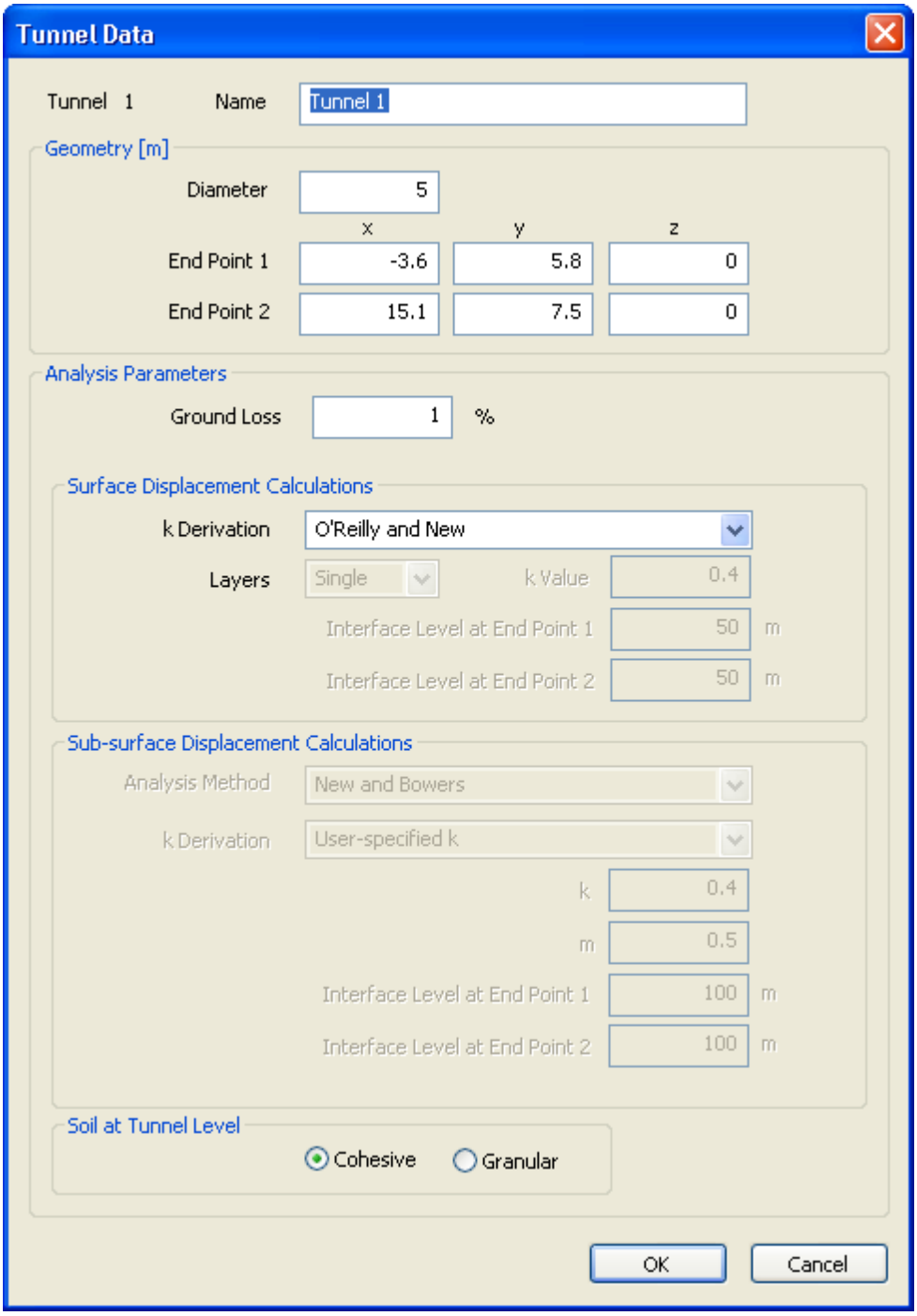
Tunnels may be input graphically in the 3D Graphics View via:

- "Sculpt | Tunnel..." when the 3D Graphics View is active and is in Input Mode;
- the button on the Graphical Input Toolbar when the 3D Graphics View is active and is in Input Mode.

A tunnel or a series of connected tunnels may be input by left-clicking at different points in the view to specify the ends of the consecutive tunnels. The end point of a tunnel or the end point of the last tunnel of the connected tunnels is marked through a double left-click. At this double left-click , the "Tunnel Data" dialog will pop up through which the other properties of the tunnel (or connected tunnels) can be edited. The dialog will initially have default values.

While adding a tunnel, the last input point (left-clicked point) can be erased by pressing the <ESC> key.

While adding a tunnel, a point which is already input can be deleted by:
- moving the mouse over the point so the cursor changes to a square;
- left-click by holding the <SHIFT> key.



Input of a tunnel (or series of tunnels) may be cancelled by clicking the "Cancel" button or by closing the dialog.

3.15.2.3 Embedded Wall Excavations

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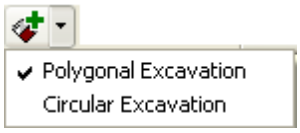
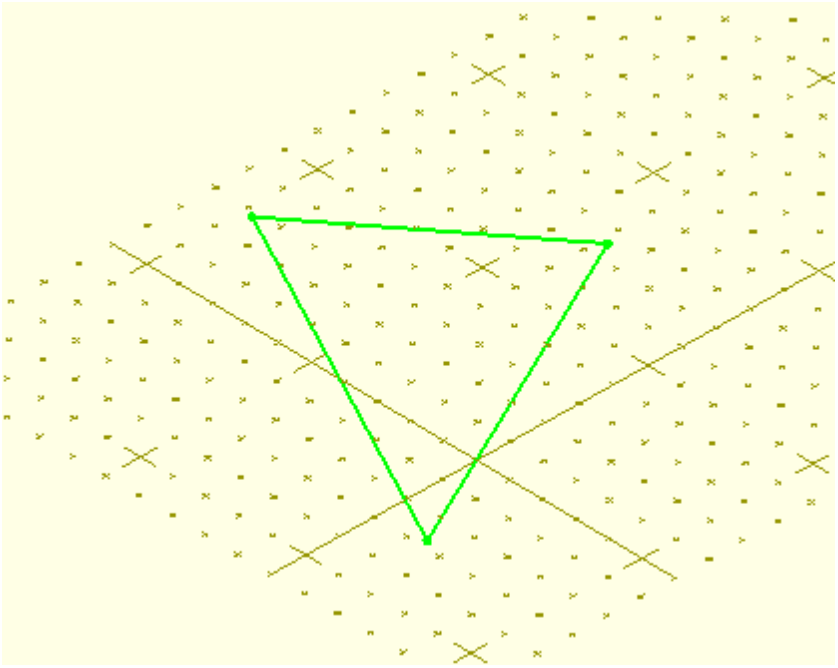
3.15.2.3.1 Polygonal Excavations

Polygonal excavations may be input graphically in the 3D Graphics View via:

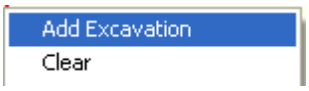
- "Sculpt | Excavation | Polygonal Excavation..." when the 3D Graphics View is active and is in Input Mode;
- the 

button on the Graphical Input Toolbar when the 3D Graphics View is active and is in Input Mode.

To input a polygonal excavation then click at each corner of the excavation's surface polygon in a particular (clockwise or counter-clockwise) order.



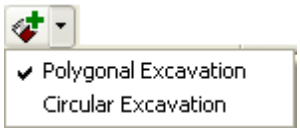
When the required surface polygon is established, to complete the addition of the excavation, double left-click at the final point, or right-click in the view and select "Add Excavation" from the subsequent context menu. The input may be cleared by selecting "Clear" from that menu.



The "Polygonal Excavation" dialog will pop up after an excavation is added. The properties of the excavation can be edited in this wizard. Initially the dialog will have default values. The input of the excavation may be cancelled by clicking the "Cancel" button or by closing the dialog.

3.15.2.3.2 Circular Excavations

Circular excavations may be input graphically in the 3D Graphics View via:

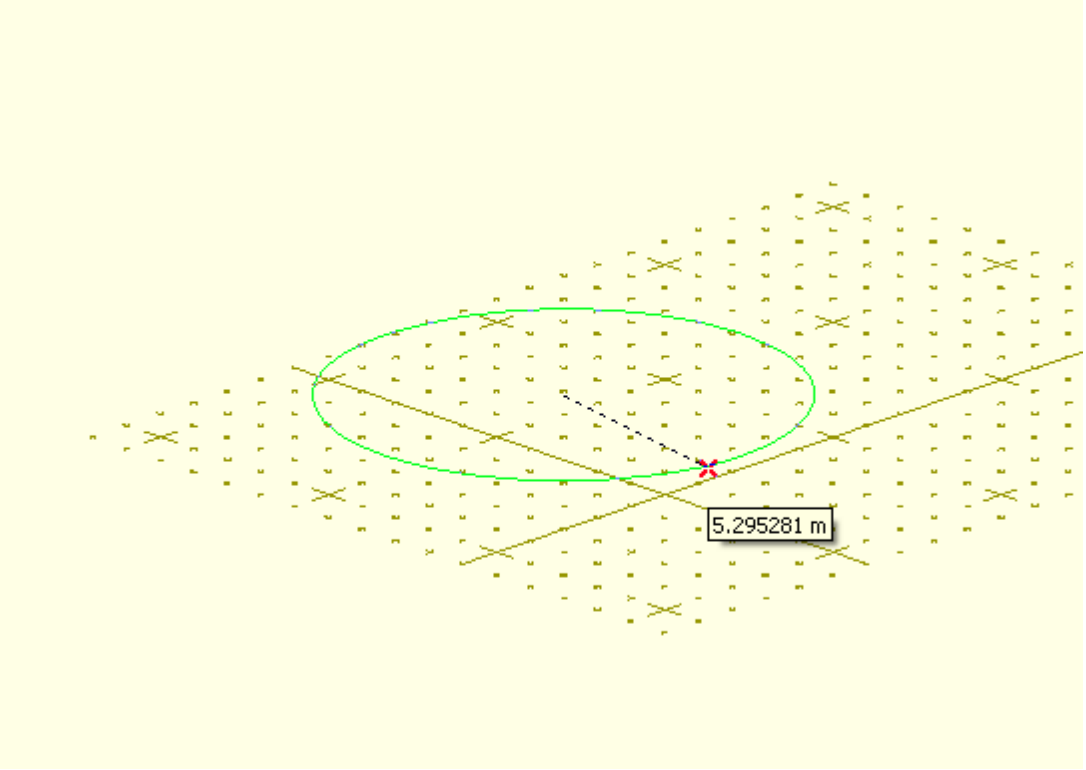
- "Sculpt | Excavation | Circular excavation..." when the 3D Graphics View is active and is in Input Mode;
- the 

button on the Graphical Input Toolbar when the 3D Graphics View is active and is in Input Mode.

To input a circular excavation then left-click on the centre of the surface circle, move the mouse, and left-click again on the circumference of the circle to complete the input.

The user can edit the properties of the excavation via the dialog which pops up at the end of the second click.

To cancel the input after the first click press <ESC>.



3.15.2.4 Displacement Entities

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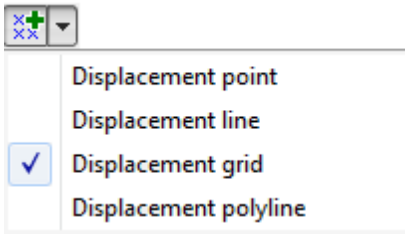
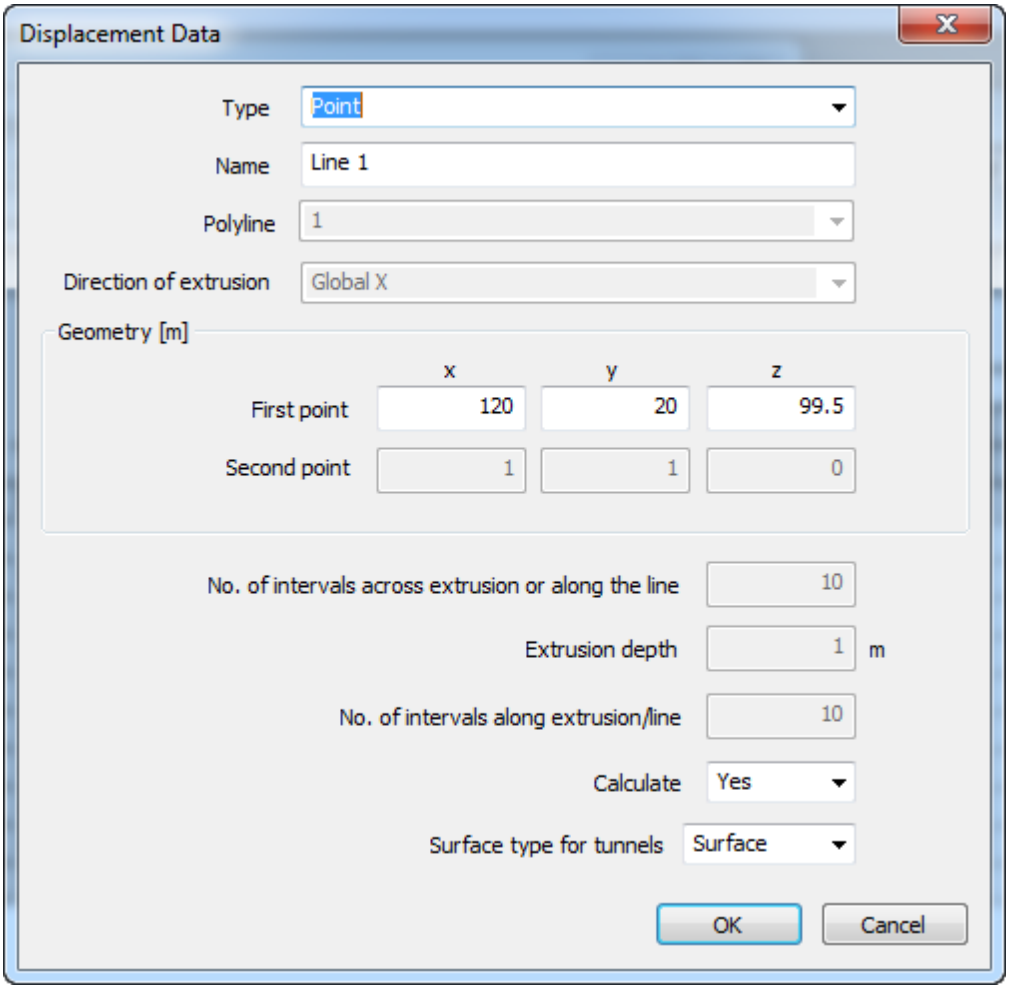
3.15.2.4.1 Displacement Point

Displacement Points maybe input graphically in the 3D Graphics View via:

- "Sculpt | Displacement | Displacement Point..." when the 3D Graphics View is active and is in Input Mode;
- the "Displacement point" menu item 

on the Graphical Input Toolbar when the 3D Graphics View is active and is in Input Mode.

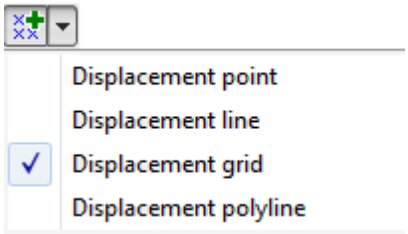
Left-click at any desired point in the 3D Graphics View to complete the input. A dialog will then pop up in which the properties of the point may be edited.



The input of the displacement point may be cancelled by clicking the "Cancel" button or by closing the dialog.

3.15.2.4.2 Displacement Line

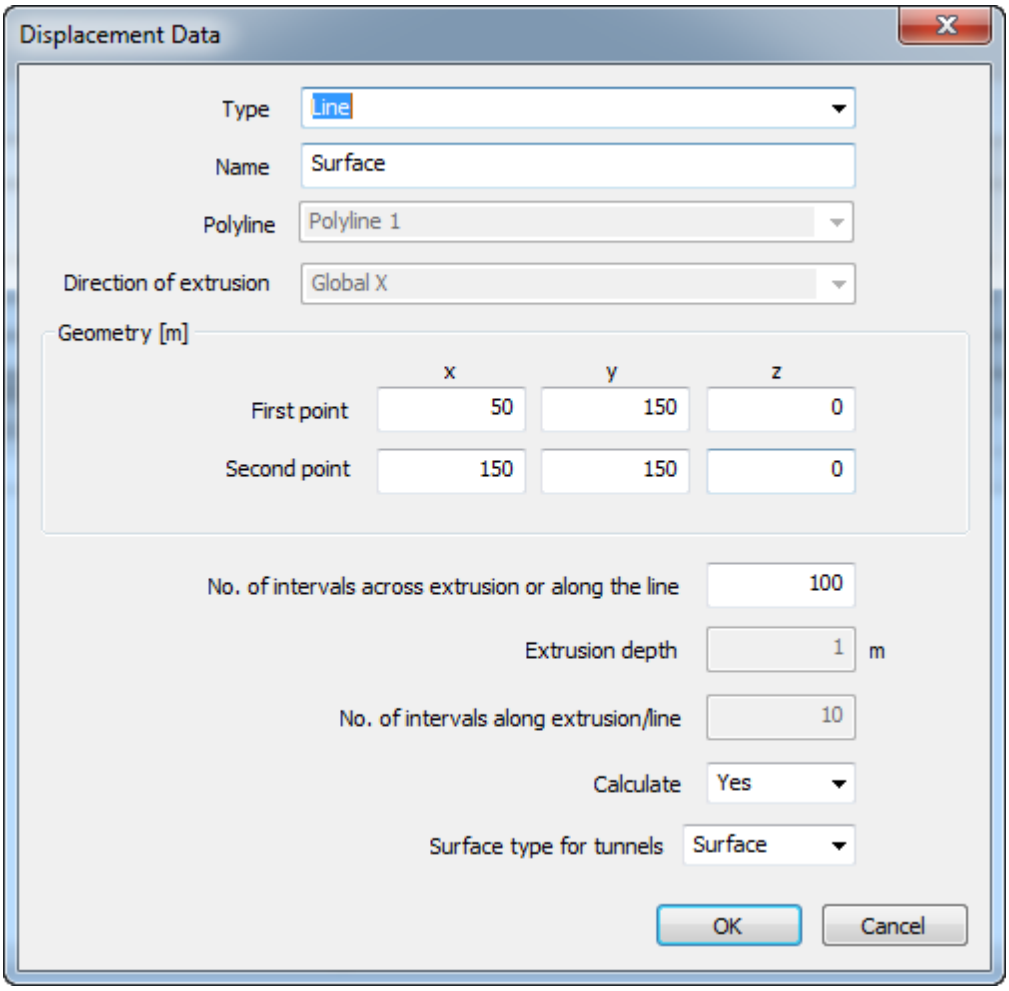
Displacement lines may be input graphically in the 3D Graphics View via:

- "Sculpt | Displacement | Displacement Line..." when the 3D Graphics View is active and is in Input Mode;
- the "Displacement line" menu item 

on the Graphical Input Toolbar when the 3D Graphics View is active and is in Input Mode.

Left-click at the ends of the displacement line to complete the input. A dialog will then pop up in which the properties of the line may be edited.

To cancel the input of the displacement line after the first click, press <ESC>.



The input of the displacement line may be cancelled by clicking the "Cancel" button or by closing the dialog.

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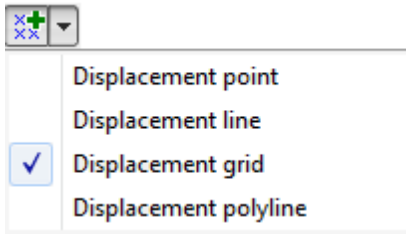
3.15.2.4.3 Displacement Grid

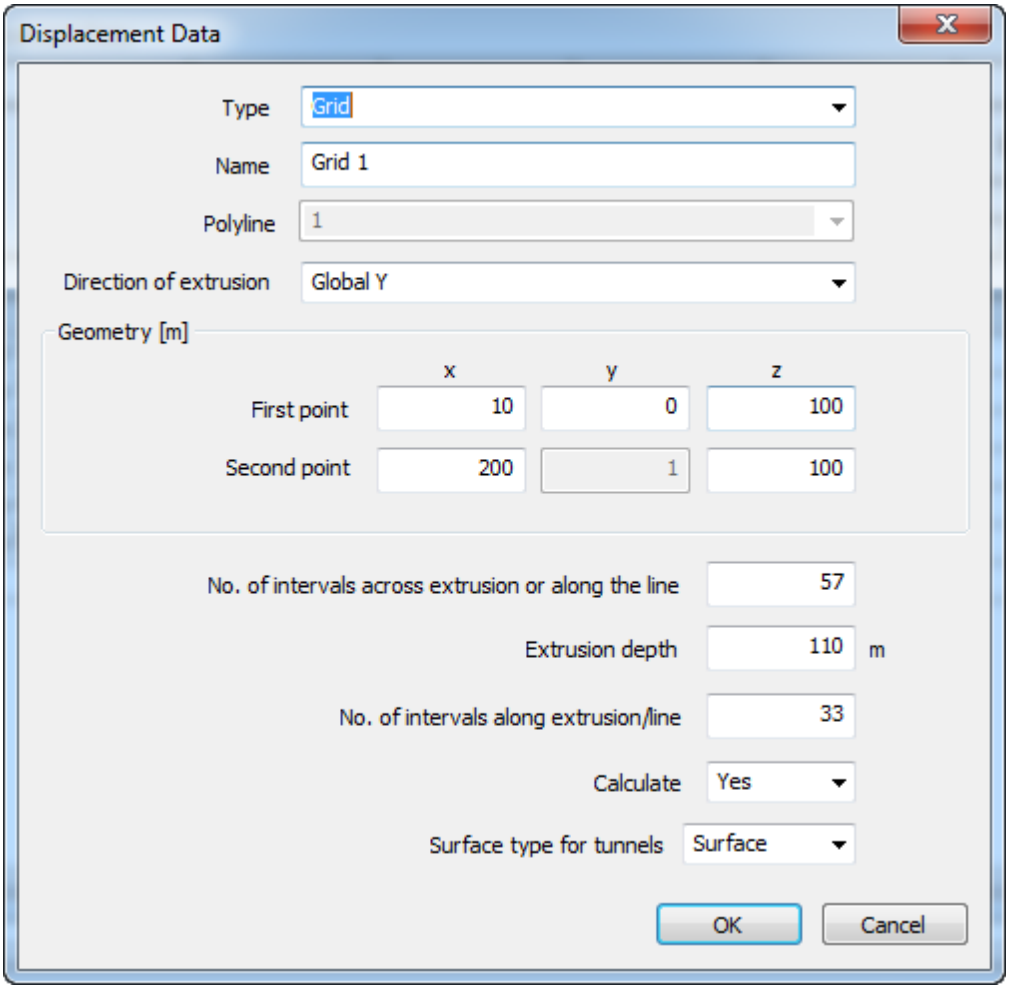
Displacement grids may be input graphically in the 3D Graphics View via:

- "Sculpt | Displacement | Displacement Grid..." when the 3D Graphics View is active and is in Input Mode;
- the "Displacement grid" menu item 

on the Graphical Input Toolbar when the 3D Graphics View is active and is in Input Mode.

A displacement grid can be input only on the plane of the grid. Left-clicking at two opposing corners of the grid will complete the input. The displacement data dialog will pop up after the input in which the properties of the displacement grid may be edited.

To cancel the input of the displacement grid after the first click, press <ESC>.

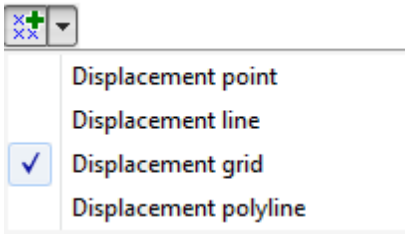


The input of the displacement grid may be cancelled by clicking the "Cancel" button or by closing the dialog.

3.15.2.4.4 Displacement Polyline

Displacement polylines may be input graphically in the 3D Graphics View providing there are polylines available via:

- "Sculpt | Displacement | Displacement Polyline..." from the program menu when the 3D Graphics View is active and is in Input Mode;
- the "Displacement polyline" menu item shown below on the Graphical Input Toolbar when the 3D Graphics View is active and is in Input Mode.



To input a displacement polyline left-click on a polyine. A displacement polyline with default properties will be added. The properties of the displacement polyline may be edited via the dialog that subsequently pops up.

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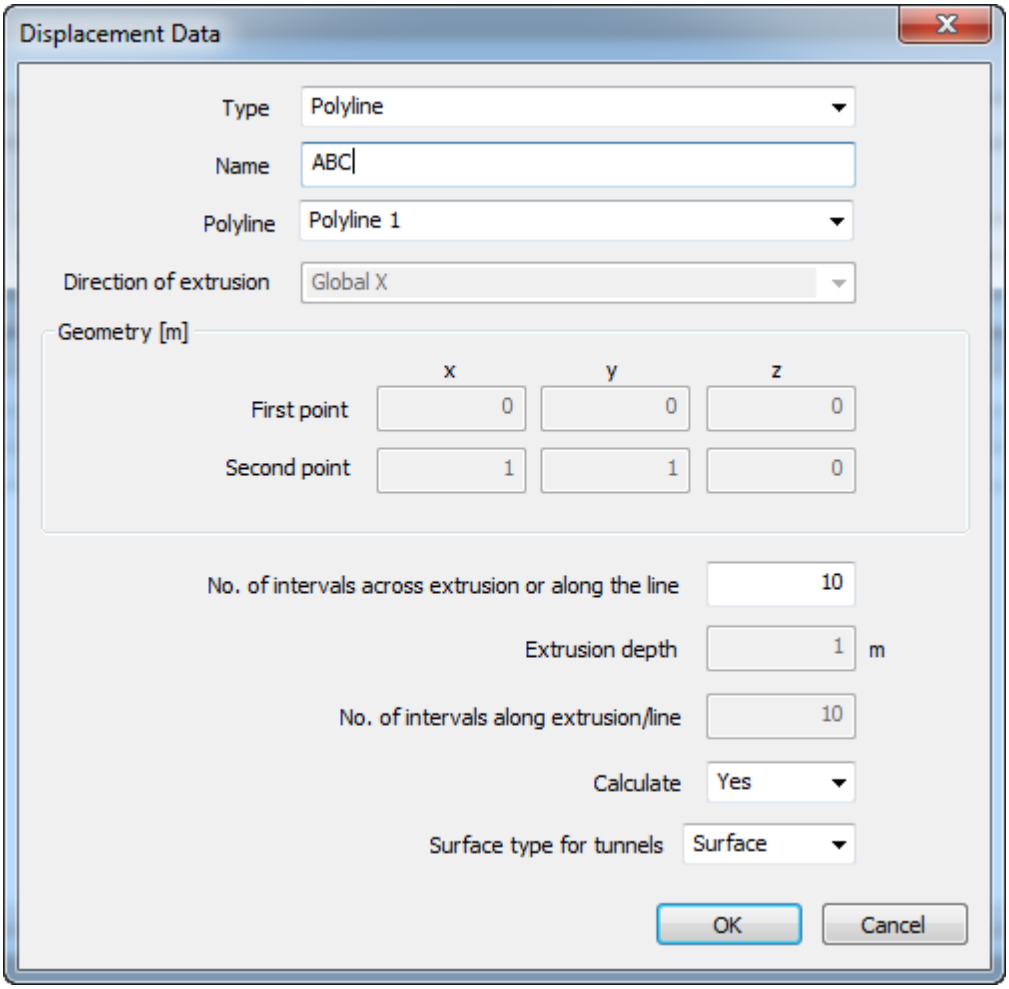


The input of the displacement polyline may be cancelled by clicking the "Cancel" button or by closing the dialog.

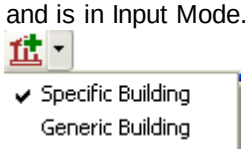
3.15.2.5 Buildings

3.15.2.5.1 Specific Buildings

Specific Buildings may be input graphically only when there are displacement lines available.

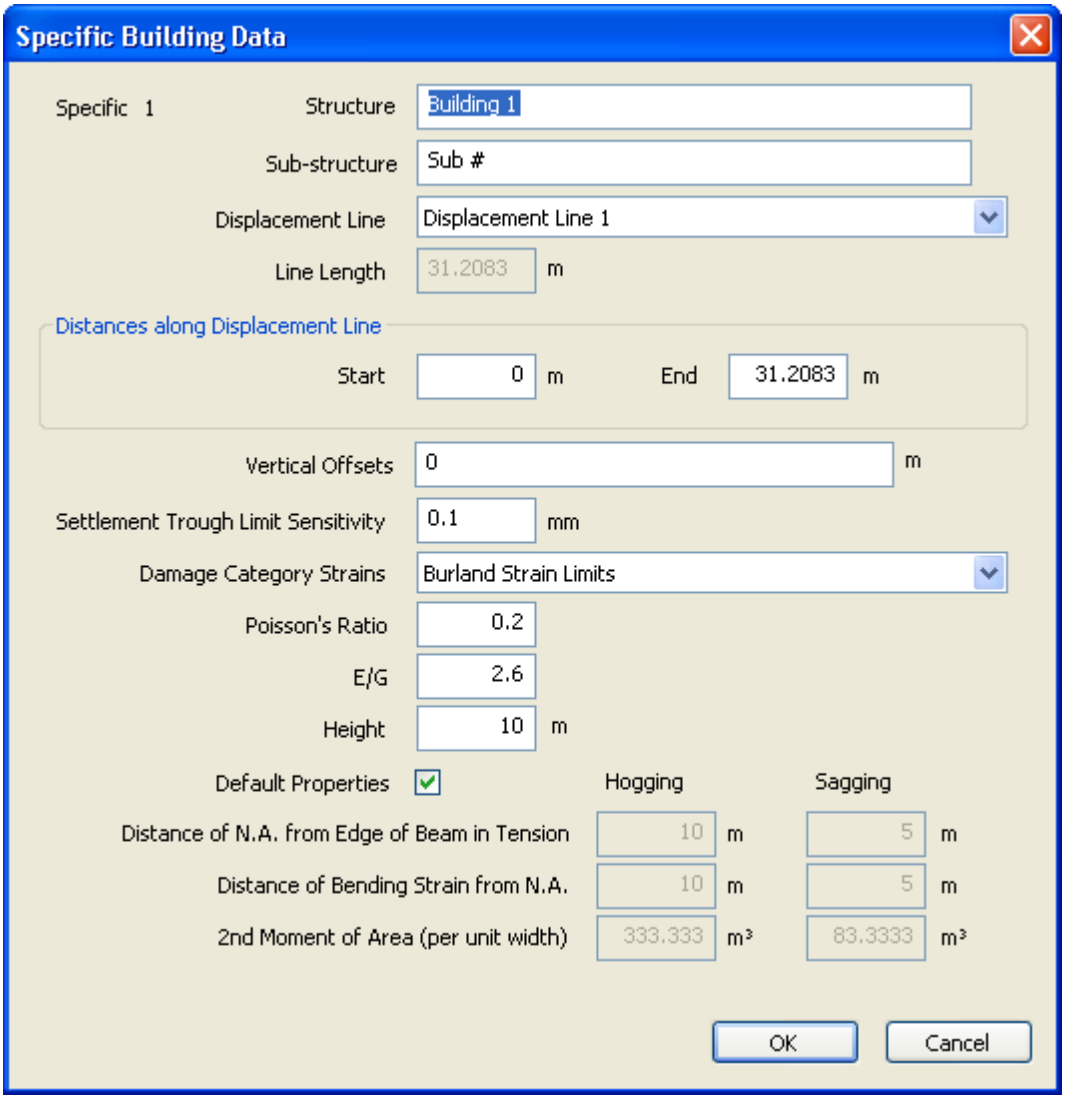
Specific Buildings may be input graphically in the 3D Graphics View via:

- "Sculpt | Building | Specific Building..." from the program menu when the 3D Graphics View is active and is in Input Mode;
- the buildings button (shown below) on the Graphical Input Toolbar when the 3D Graphics View is active and is in Input Mode.



To input a building left-click on a displacement line. A building with default properties will be added.

The properties of the building may be edited via the dialog which subsequently pops up.



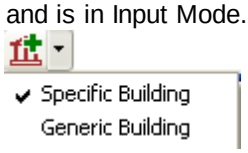
The input of specific building may be cancelled by clicking the "Cancel" button or by closing the dialog.

3.15.2.5.2 Generic Buildings

Generic Buildings may be input graphically only when there are polylines available.

Generic Buildings may be input graphically in the 3D Graphics View via:

- "Sculpt | Building | Generic Building..." when the 3D Graphics View is active and is in Input Mode;
- the buildings button (shown below) on the Graphical Input Toolbar when the 3D Graphics View is active and is in Input Mode.



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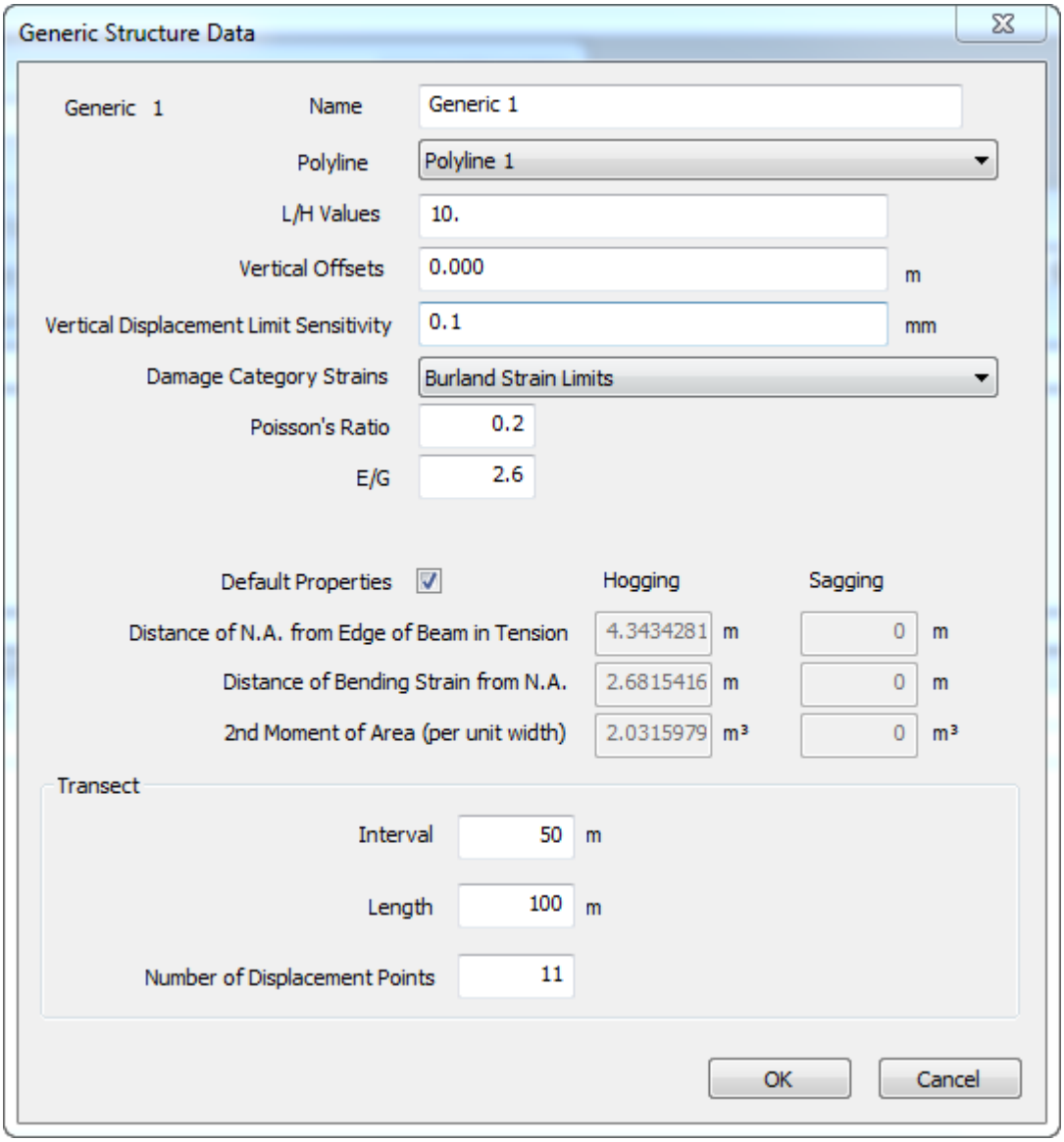
Then left-click on a polyline. A building with default properties will be added. The properties of the building may be edited via the dialog which subsequently pops up.



The input of generic building may be cancelled by clicking the "Cancel" button or by closing the dialog.

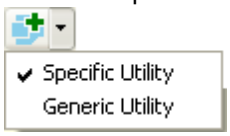
3.15.2.6 Utilities

3.15.2.6.1 Specific Utilities

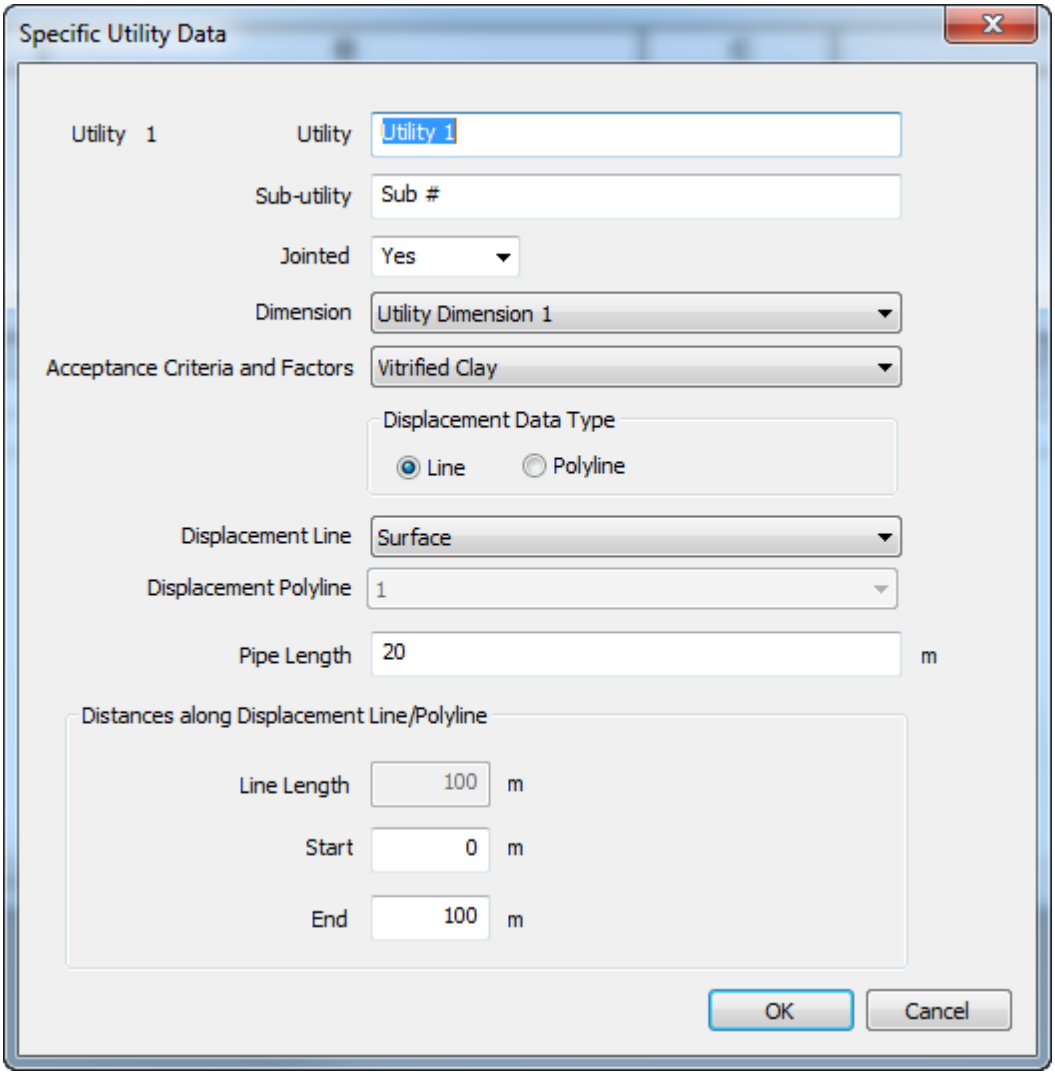
Providing there are displacement lines or displacement polylines available, Specific Utilities may be input graphically in the 3D Graphics View via:

- "Sculpt | Utility | Specific Utility..." from the program menu when the 3D Graphics View is active and is in Input Mode;

- the utilities button (shown below) on the Graphical Input Toolbar when the 3D Graphics View is active and is in Input Mode.



Then left-click on a displacement line or a displacement polyline. A specific utility with default properties will be added. The properties of the utility may be edited via the dialog that subsequently pops up.



The input of specific utility may be cancelled by clicking the "Cancel" button or by closing the dialog.

3.15.2.6.2 Generic Utilities

Generic Utilities may be input graphically only when there are polylines available.

Generic Utilities may be input graphically in the 3D Graphics View via:

- "Sculpt | Utility | Generic Utility..." when the 3D Graphics View is active and is in Input Mode;

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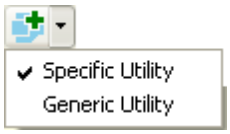
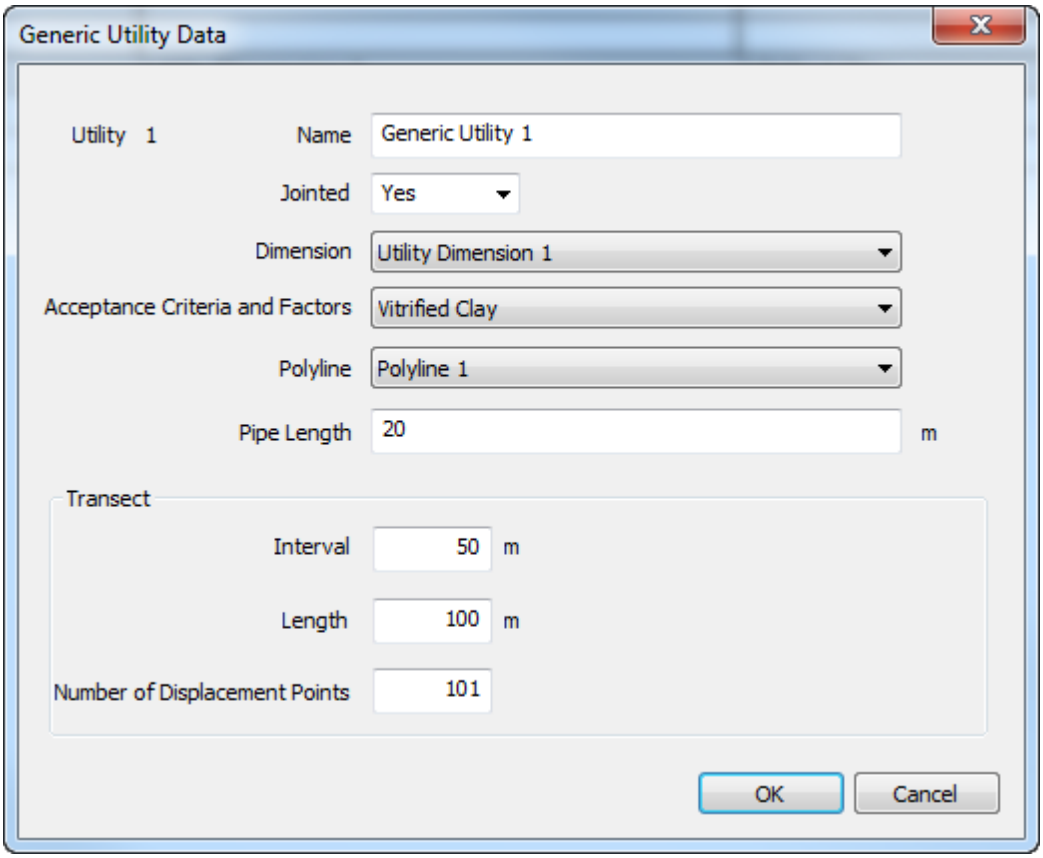
- the 

button on the Graphical Input Toolbar when the 3D Graphics View is active and is in Input Mode.

To input a building left-click on a polyline. A generic utility with default properties will be added. The properties of the utility may be edited via the dialog which subsequently pops up.



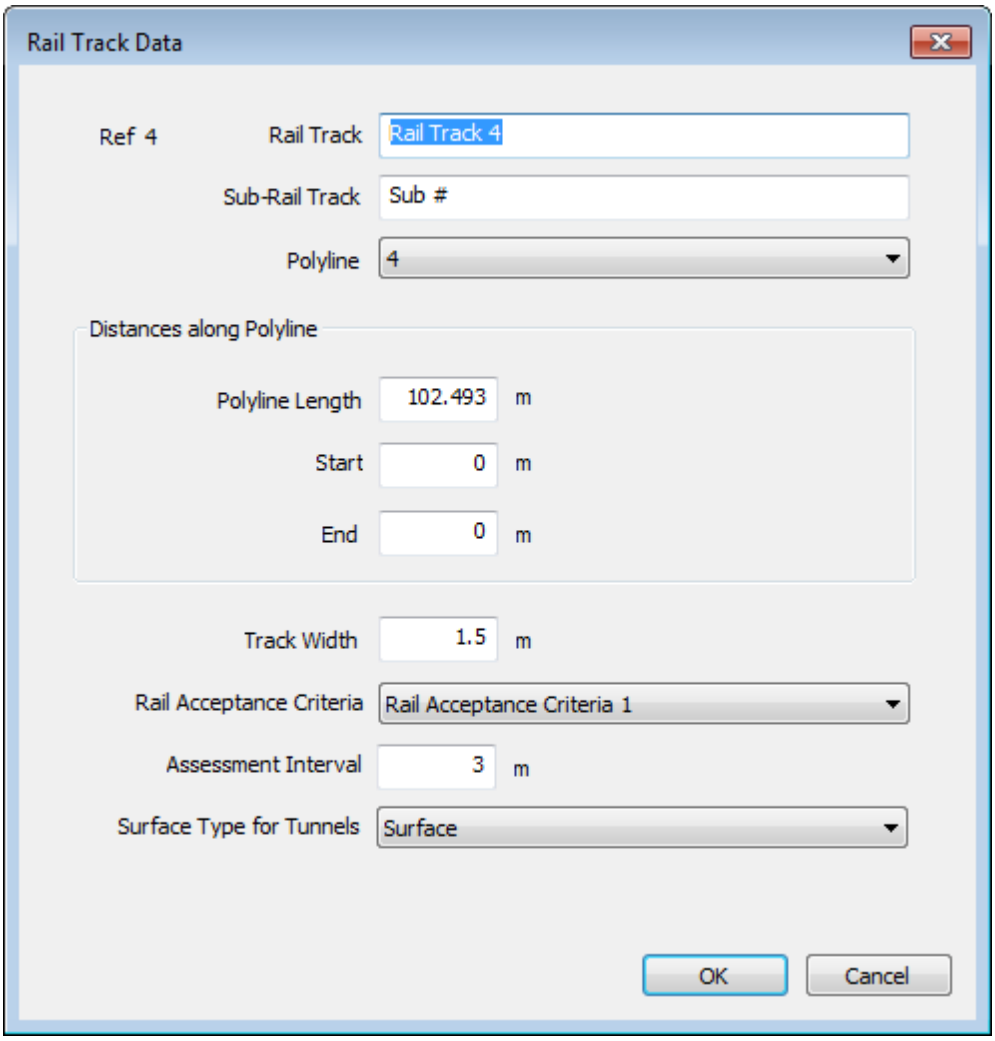
The input of generic utility may be cancelled by clicking the "Cancel" button or by closing the dialog.

3.15.2.7 Rail Tracks

Providing there are polylines available, Rail Tracks may be input graphically in the 3D Graphics View via:

- "Sculpt | Utility | Specific Utility..." from the program menu when the 3D Graphics View is active and is in Input Mode;
- the Rail Tracks button ( ) on the Graphical Input Toolbar when the 3D Graphics View is active and is in Input Mode.

Then left-click on a polyline. A rail track with default properties will be added. The properties of the rail track may be edited via the dialog that subsequently pops up.



The input of rail track may be cancelled by clicking the "Cancel" button or by closing the dialog.

3.15.3 Selection

Selection of elements in the 3D Graphics View for editing or deletion is enabled only in the input mode and only when there are elements available.

The Selection Mode may be activated via:

- "Sculpt | Select..." when the 3D Graphics View is active and is in Input Mode;
- the "Select" button on the Graphical Input Toolbar when the 3D Graphics View is active and is in Input Mode.

The selection can be made in two ways:

- selection of an individual element;
- selection by dragging the mouse to surround or intersect a group of elements.

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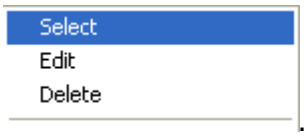
Selection of an Individual Element:

Moving the cursor over an element will highlight a part or whole of the boundary of the element which is in the close vicinity of the cursor. This is an indication that the element is available for selection.

Right-clicking on the highlighted element will pop-up the selection menu 

.

The highlighted element can either be modified, deleted or selected

Clicking on "Edit" will pop-up the corresponding data dialog. Clicking on "Delete" will delete the element.

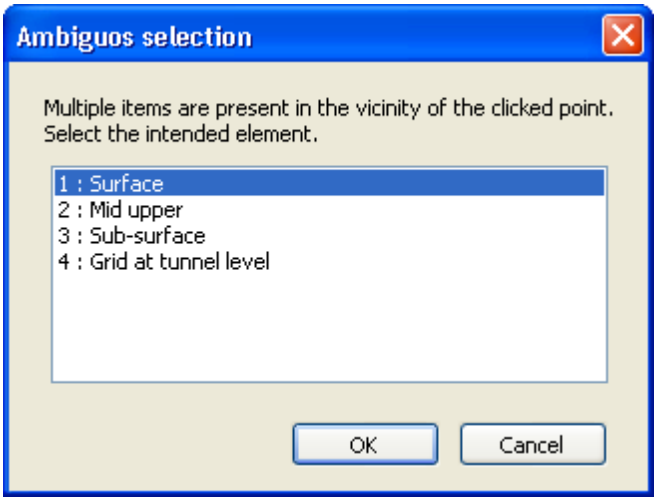
The element can also be selected so that editing and deletion operations can be performed later by right-clicking in any part of the view. The selection can be done via "Select" in right-click menu on the highlighted element or by left-clicking on the highlighted element.

Once elements are selected their boundaries are shown highlighted.

Selected elements can be modified via the "Edit" item in the menu which is presented by right-clicking in any part of the view. It can also be deleted through this menu or by pressing the <DELETE> key.

Multiple elements can be selected by holding the <CTRL> key while selections are made. Multiple selections can only be deleted, not edited.

If there are multiple elements available for selection at the cursor position, then the Ambiguous Deletion Dialog will pop-up if the user tries to perform any selection operation. This dialog lists all the elements in the vicinity. The required element in the list can then be selected.



Elements can be de-selected by re-selecting them individually.

Multiple elements can be selected by holding the left button down and dragging the mouse in the 3D

Graphics View. On releasing the button all the elements falling completely within the area are selected. If the right button is pressed while dragging the mouse then those elements that are partially within the area are selected too.

Shortcuts

- Pressing <DELETE> button will delete all the selected elements.
- Pressing <ESC> will de-select all the selected elements.

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Part IV

4 Programming Interface (API)

An Application Programming Interface (API) is provided by COM Automation.

COM Automation allows commands to be issued from a separate process via a set of Python, VBA or C++ instructions. The separate process could be a Python script, a VBA script called from a spreadsheet or a separate program.

4.1 COM Automation

COM Automation allows other programs to access XDisp operations by creating an instance of XDisp class "XDispAuto_XX_X.ComAuto", where "XX_X" is the major and minor version of XDisp, e.g."XDispAuto_20_0.ComAuto", then calling the exported functions of that class.

The available COM functions are listed in COM Functions. Some use enums.

VB and Python examples are provided with the program. These are summarised in COM Examples.

When installing XDisp the installer should be run with Administrator rights to ensure the XDisp.tlb file is registered in the host computer's registry, thus enabling its functions to be recognised e.g. by the Microsoft VBA editor. If the functions are not recognised, then it may be necessary to set the reference to the XDisp.tlb file manually in the editor. The XDisp.tlb file can be found in the program installation folder whose default location is specified in Sample Files.

Prerequisite Python Libraries

The Python library "pywin32" must be installed on the host computer in order for Python to call the functions XDisp's API.

The Python library "comtypes" must be installed on the host computer in order for Python scripts to refer to enums by name rather than by value.

More:

COM Functions

COM Enums

COM Examples

4.2 COM Functions

COM function names are case sensitive. The return code (short data type) for all functions is zero on successful execution and -1 on failure. Where parameters represent indices in e.g. accessor and mutator ("Get..." and "Set...") functions, these are 1-based with the exception of Stages whose indexes are 0-based (the value 0 indicating the base model).

Enums are used as parameters in some functions. Client scripts written in VB should, once the XDispLib is registered, provide lists of valid enums via context-dependent intellisense droplists. Python scripts may not benefit from such intellisense listings. See COM Enums for more information on valid enum values, and COM Automation for information on the Python library needed to refer to enums by name rather than by value.

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All input data are in SI units. Units of results tables written to disc via e.g. `WriteResultsTables(...)` may be specified by first calling `SetUnits(...)`. Functions offering direct access to results will provide results in SI units.

File Management

`short Open(string sFilename)`

Opens an XDisp *.xdd binary file or *.json text file (see File Types) with a filename which includes the path

`short Save()`

Saves the data to the default file (i.e. overwriting the file that was opened or last saved)

`short SaveAs(string sFilename)`

Saves the data to an XDisp *.xdd binary file or *.json text file (see File Types) to a filename which includes the path and extension.

`short Close()`

Closes the current file.

`short Show()`

Shows the running instance of XDisp created by the Automation client.

Analysis

`short CheckData()`

Checks the data of the current file. (Recommended before analysis.)

`short Analyse()`

Analyses the current file.

Results

`short DeleteResults()`

Deletes the results in the current file.

```
short SetUnits(enum EUnitDisplacement eDisplacement,
               enum EUnitLength eLength,
               enum EUnitStrain eStrain)
```

Sets the units in which results tables are to be output to disc by `WriteResultsTables(...)` and `WriteResultsTable(...)`.

```
short WriteResultsTables(string sFilePath,
                         enum EResultsTablesFileFormat eFileFormat,
```

```
                                short iStage)
```

Writes all results tables to disc for one or all stages.

sFilePath	-	file path of output file excluding extension
eFileFormat	-	whether CSV, HTML, RTF or TXT
iStage	-	stage index (-1 for all)

```
short WriteResultsTable(string sFilePath,
                        enum EResultsTablesFileFormat eFileFormat,
                        enum EResult eResult,
                        short iStage,
                        short iEntity)
```

Writes one results table to disc for one or all stages.

sFilePath	-	file path of output file excluding extension
eFileFormat	-	whether CSV, HTML, RTF or TXT
eResult	-	type of results table (e.g. Displacement Points) (ALL for all results' tables)
iStage	-	stage index (-1 for all)
iEntity	-	entity index (-1 for all)

Charts

```
short WriteResultsCharts(string sOutputFolder,
                         enum EResultsChartsFolderStructure
                         eFolderStructure,
                         enum EResultsChartsFileFormat eFileFormat,
                         enum EBuildingChartsExclusions
                         eBuildingExclusion,
                         enum EUtilityRailChartsExclusions
                         eUtilityRailExclusion,
                         enum EChart eChart,
                         SHORT iStage,
                         SHORT iEntity)
```

Writes one or more results' charts to disc.

sOutputFolder	-	the folder to which charts are to be written
eFolderStructure	-	whether a deep folder structure is to be created to contain the charts is to be flat or deep
eFileFormat	-	whether JPG, WMF or BMP
eBuildingChartsExclusions	-	building charts will be excluded from output based on the level of damage category specified here (BUILDING_CHARTS_EXCLUSIONS_NONE to output all)
eUtilityRailChartsExclusions	-	utility and rail track charts will be excluded from output based on the level of damage category specified here (UTILITY_RAIL_CHARTS_EXCLUSIONS_NONE to output all)
eChart	-	chart type (e.g. displacement line or building damage interaction) (RESULTS_CHART_ALL to output all results' charts)
iStage	-	stage index (-1 for all)

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`iEntity` - entity index (-1 for all)

Data - Tunnels

```
short NumTunnels (short* iNumTunnels)
```

Gets the number of tunnels in the current file.

```
short SetTunnel_GroundVolumeLoss(short iTunnel, double dVolumeLoss)
```

Sets the ground volume loss of a tunnel.

Data - Polygonal Excavations

```
short NumPolygonalExcavations (short* iNumPolygonalExcavations)
```

Gets the number of polygonal excavations in the current file.

```
short GetPolygonalExcavation_NumSides(short iPolygonalExcavation,
                                      short* iNumSides)
```

Gets the numbers of sides of a polygonal excavation.

```
short SetPolygonalExcavation_GMCurveVert(short iPolygonalExcavation,
                                         short iSide,
                                         short iGMCurveVert)
```

Sets the index of the vertical ground movement curve of one side of a polygonal excavation.

```
short SetPolygonalExcavation_GMCurveHorz(short iPolygonalExcavation,
                                         short iSide,
                                         short iGMCurveHorz)
```

Sets the index of the horizontal ground movement curve of one side of a polygonal excavation.

Data - Circular Excavations

```
short NumCircularExcavations (short* iNumCircularExcavations)
```

Gets the number of circular excavations in the current file.

```
short SetCircularExcavation_GMCurveVert(short iCircularExcavation,
                                        short iGMCurveVert)
```

Set the index of the vertical ground movement curve of a circular excavation.

```
short SetCircularExcavation_GMCurveHorz(short iCircularExcavation,
                                        short iGMCurveHorz)
```

Set the index of the horizontal ground movement curve of a circular excavation.

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Data - Ground Movement Curves

```
short NumGMCurvesVert (short* iNumGMCurvesVert)
```

Get the number of vertical ground movement curves in the current file.

```
short NumGMCurvesHorz(short* iNumGMCurvesHorz)
```

Gets the number of horizontal ground movement curves in the current file.

Data - Specific Buildings

```
short NumSpecificBuildings(short* iNumSpecificBuildings)
```

Gets the number of specific buildings in the current file.

```
short SetSpecificBuidling_EOverG(short iSpecificBuilding,
                                 double dEOverG)
```

Sets the E/G value of a tunnel.

Data - Specific Utilities

```
short NumSpecificUtilities(short* iNumSpecificUtilities)
```

Gets the number of specific utilities in the current file.

```
short SetSpecifcUtility_UtilityAcceptanceCriteria(short
iSpecificUtility,
                                                  short
                                                  iUtilityAcceptanceCrit
                                                  eria)
```

Set the index of the acceptance criteria of a specific utility.

Data - Utility Acceptance Criteria

```
short NumUtilityAcceptanceCriteria(short* iNumUtilityAcceptanceCriteria)
```

Gets the number of utility acceptance criteria in the current file.

More:

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4.3 COM Enums

Enums are named sufficiently descriptively to be self-documenting to a user who is familiar with the XDisp, so no more than their names are provided here.

It is intended that enums are specified as function parameters by these names, rather than by their numeric values, to allow the possibility of their numeric values changing in subsequent versions of the program, while names are intended to remain unchanged. This approach also makes scripts more readable. Numeric values are therefore not supplied here.

See COM Functions for more information on the use of enums in VB and Python scripts.

It should not be assumed that enums are 0-based.

```
enum EResultsTable

      RESULTS_TABLE_DISPLACEMENT_POINTS
      RESULTS_TABLE_DISPLACEMENT_LINES
      RESULTS_TABLE_DISPLACEMENT_POLYLINES
      RESULTS_TABLE_DISPLACEMENT_GRIDS
      RESULTS_TABLE_BUILDINGS_SPECIFIC_HORIZONTAL_DISPLACEMENTS
      RESULTS_TABLE_BUILDINGS_SPECIFIC_VERTICAL_DISPLACEMENTS
      RESULTS_TABLE_BUILDINGS_SPECIFIC_UNCOMBINED_DETAIL
      RESULTS_TABLE_BUILDINGS_SPECIFIC_UNCOMBINED_SUMMARY_BY_SUB_BUILDIN
      G
      RESULTS_TABLE_BUILDINGS_SPECIFIC_UNCOMBINED_SUMMARY_BY_BUILDING
      RESULTS_TABLE_BUILDINGS_SPECIFIC_COMBINED
      RESULTS_TABLE_BUILDINGS_GENERIC_TRANSECTS
      RESULTS_TABLE_BUILDINGS_GENERIC_HORIZONTAL_DISPLACEMENTS
      RESULTS_TABLE_BUILDINGS_GENERIC_VERTICAL_DISPLACEMENTS
      RESULTS_TABLE_BUILDINGS_GENERIC_UNCOMBINED_DETAIL
      RESULTS_TABLE_BUILDINGS_GENERIC_UNCOMBINED_MAX_TENS_STRAIN_BY_TRAN
      SECT_AND_LOVERH
      RESULTS_TABLE_BUILDINGS_GENERIC_UNCOMBINED_MAX_TENS_STRAIN_BY_TRAN
      SECT
      RESULTS_TABLE_BUILDINGS_GENERIC_COMBINED
      RESULTS_TABLE_UTILITIES_SPECIFIC_COORDINATES_AND_DISPLACEMENTS
      RESULTS_TABLE_UTILITIES_SPECIFIC_PULLOUTS_AND_ROTATIONS
      RESULTS_TABLE_UTILITIES_SPECIFIC_STRAINS
      RESULTS_TABLE_UTILITIES_SPECIFIC_MAX_VALUES
      RESULTS_TABLE_UTILITIES_GENERIC_TRANSECTS
      RESULTS_TABLE_UTILITIES_GENERIC_COORDINATES_AND_DISPLACEMENTS
      RESULTS_TABLE_UTILITIES_GENERIC_PULLOUTS_AND_ROTATIONS
      RESULTS_TABLE_UTILITIES_GENERIC_STRAINS
      RESULTS_TABLE_UTILITIES_GENERIC_MAX_VALUES
      RESULTS_TABLE_RAIL_TRACKS_CANT_DISPLACEMENTS
      RESULTS_TABLE_RAIL_TRACKS_CANT
      RESULTS_TABLE_RAIL_TRACKS_TWIST_SHORT_BASE_DISPLACEMENTS
      RESULTS_TABLE_RAIL_TRACKS_TWIST_SHORT_BASE
      RESULTS_TABLE_RAIL_TRACKS_TWIST_LONG_BASE_DISPLACEMENTS
      RESULTS_TABLE_RAIL_TRACKS_TWIST_LONG_BASE
      RESULTS_TABLE_ALL
```

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```
enum EResultsChart

      RESULTS_CHART_DISLACEMENT_LINE
      RESULTS_CHART_DISPLACEMENT_POLYLINE
      RESULTS_CHART_SPECIFIC_BUILDING_DISPLACEMENT
      RESULTS_CHART_SPECIFIC_BUILDING_DAMAGE_INTERACTION
      RESULTS_CHART_GENERIC_BUILDING_BY_TRANSECT_DISPLACEMENT
      RESULTS_CHART_GENERIC_BUILDING_BY_TRANSECT_DAMAGE_INTERACTION
      RESULTS_CHART_GENERIC_BUILDING_BY_BUILDING_DISPLACEMENT
      RESULTS_CHART_GENERIC_BUILDING_BY_BUILDING_MAX_TENSILE_STRAIN
      RESULTS_CHART_SPECIFIC_UTILITY_DISPLACEMENT
      RESULTS_CHART_SPECIFIC_UTILITY_ROTATION
      RESULTS_CHART_SPECIFIC_UTILITY_PULLOUT
      RESULTS_CHART_SPECIFIC_UTILITY_STRAIN_AXIAL
      RESULTS_CHART_SPECIFIC_UTILITY_STRAIN_FLEXURAL
      RESULTS_CHART_SPECIFIC_UTILITY_STRAIN_COMBINED
      RESULTS_CHART_SPECIFIC_UTILITY_STRAIN_ALL
      RESULTS_CHART_SPECIFIC_UTILITY_RADIUS_OF_CURVATURE
      RESULTS_CHART_GENERIC_UTILITY_BY_TRANSECT_DISPLACEMENT
      RESULTS_CHART_GENERIC_UTILITY_BY_TRANSECT_ROTATION
      RESULTS_CHART_GENERIC_UTILITY_BY_TRANSECT_PULLOUT
      RESULTS_CHART_GENERIC_UTILITY_BY_TRANSECT_STRAIN_AXIAL
      RESULTS_CHART_GENERIC_UTILITY_BY_TRANSECT_STRAIN_FLEXURAL
      RESULTS_CHART_GENERIC_UTILITY_BY_TRANSECT_STRAIN_COMBINED
      RESULTS_CHART_GENERIC_UTILITY_BY_TRANSECT_STRAIN_ALL
      RESULTS_CHART_GENERIC_UTILITY_BY_TRANSECT_RADIUS_OF_CURVATURE
      RESULTS_CHART_GENERIC_UTILITY_BY_UTILITY_DISPLACEMENT
      RESULTS_CHART_GENERIC_UTILITY_BY_UTILITY_ROTATION
      RESULTS_CHART_GENERIC_UTILITY_BY_UTILITY_PULLOUT
      RESULTS_CHART_GENERIC_UTILITY_BY_UTILITY_STRAIN_AXIAL
      RESULTS_CHART_GENERIC_UTILITY_BY_UTILITY_STRAIN_FLEXURAL
      RESULTS_CHART_GENERIC_UTILITY_BY_UTILITY_STRAIN_COMBINED
      RESULTS_CHART_GENERIC_UTILITY_BY_UTILITY_STRAIN_ALL
      RESULTS_CHART_GENERIC_UTILITY_BY_UTILITY_RADIUS_OF_CURVATURE
      RESULTS_CHART_RAIL_TRACK_CANT
      RESULTS_CHART_RAIL_TRACK_TWIST_SHORT_BASE
      RESULTS_CHART_RAIL_TRACK_TWIST_LONG_BASE
      RESULTS_CHART_ALL


enum EResultsTablesFileFormat

      CSV
      HTML
      RTF
      TXT


enum EResultsChartsFileFormat

      JPG
      BMP
      WMF
```


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```
enum EResultsChartsFolderStructure

      FLAT
      DEEP


enum EUnitDisplacement

      UNIT_DISPLACEMENT_M
      UNIT_DISPLACEMENT_CM
      UNIT_DISPLACEMENT_MM
      UNIT_DISPLACEMENT_FT
      UNIT_DISPLACEMENT_IN


enum EUnitLength

      UNIT_LENGTH_M
      UNIT_LENGTH_CM
      UNIT_LENGTH_MM
      UNIT_LENGTH_FT
      UNIT_LENGTH_IN


enum EUnitStrain

      UNIT_STRAIN_E
      UNIT_STRAIN_PERCENT_E
      UNIT_STRAIN_MILLI_E
      UNIT_STRAIN_MICRO_E


enum EBuildingChartsExclusions

      BUILDING_CHARTS_EXCLUSIONS_LT_CAT_1
      BUILDING_CHARTS_EXCLUSIONS_LT_CAT_2
      BUILDING_CHARTS_EXCLUSIONS_LT_CAT_3
      BUILDING_CHARTS_EXCLUSIONS_LT_CAT_4
      BUILDING_CHARTS_EXCLUSIONS_NONE


enum EUtilityRailChartsExclusions

      UTILITY_RAIL_CHARTS_EXCLUSIONS_LT_THRESHOLD
      UTILITY_RAIL_CHARTS_EXCLUSIONS_LT_LIMIT
      UTILITY_RAIL_CHARTS_EXCLUSIONS_NONE
```

More:

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4.4 COM Examples

A series of VB and Python example files to demonstrate the use of the COM API is provided with the program. They are installed in the folder 'C:\Program Files\Oasys\XDisp *n*\Samples\API', where *n* indicates the version of the program. VB examples are accessible via the Excel spreadsheet "ExcelVBA Examples.xlsm". Python scripts of identical examples are provided in files named "Python_Example_*n*.py" where *n* is the index of the example.

The behaviour of each example is summarised in the Excel spreadsheet.

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4.5 COM Troubleshooting

	Symptom	Cause	Solution
(1)	Unable to create XDisp COM object. e.g. VB error: *'Run-time error '429'* *ActiveX component can't create object'*	The program variant does not permit use of the COM API.	Purchase and activate the appropriate XDisp licence.
(2)	Unable to create XDisp COM object	A rogue instance of XDisp.exe has been left running, perhaps from a previous failed operation.	Open the Windows Task Manager, select its Details tab, and end any XDisp.exe instances listed there
(3)	Python script fails, producing error e.g. Python error: *ModuleNotFoundError: No module named 'win32com'*	The Python library 'pywin32' has not been installed.	Download and install the Python library 'pywin32' from the internet.
(4)	Python script fails or produces error e.g. Python error: *ModuleNotFoundError: No module named 'comtypes'*	The Python library 'comtypes' has not been installed.	Download and install the Python library 'comtypes' from the internet.
(5)	A COM function call fails referring to IXDispAutomation. e.g. VB error:	The COM function cannot be executed, e.g. due a a rogue argument.	Check all function arguments, e.g. file paths, are valid.

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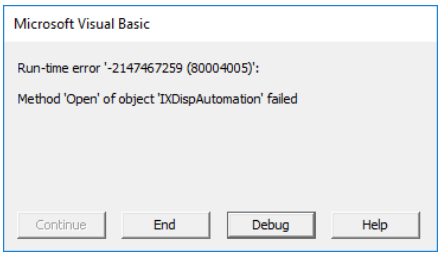
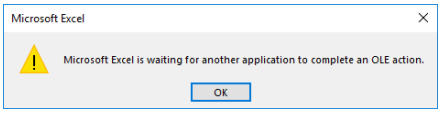
			

(6)	A VB function called from Excel causes a warning that Excel is waiting for another application to complete an OLE action e.g. Excel error:
	 
		Excel warnings are interfering with the COM process, requiring manual intervention.	Surround the problematic VB function code with:
			`Application.DisplayAlerts = False`
			`...`
			`Application.DisplayAlerts = True`

More:

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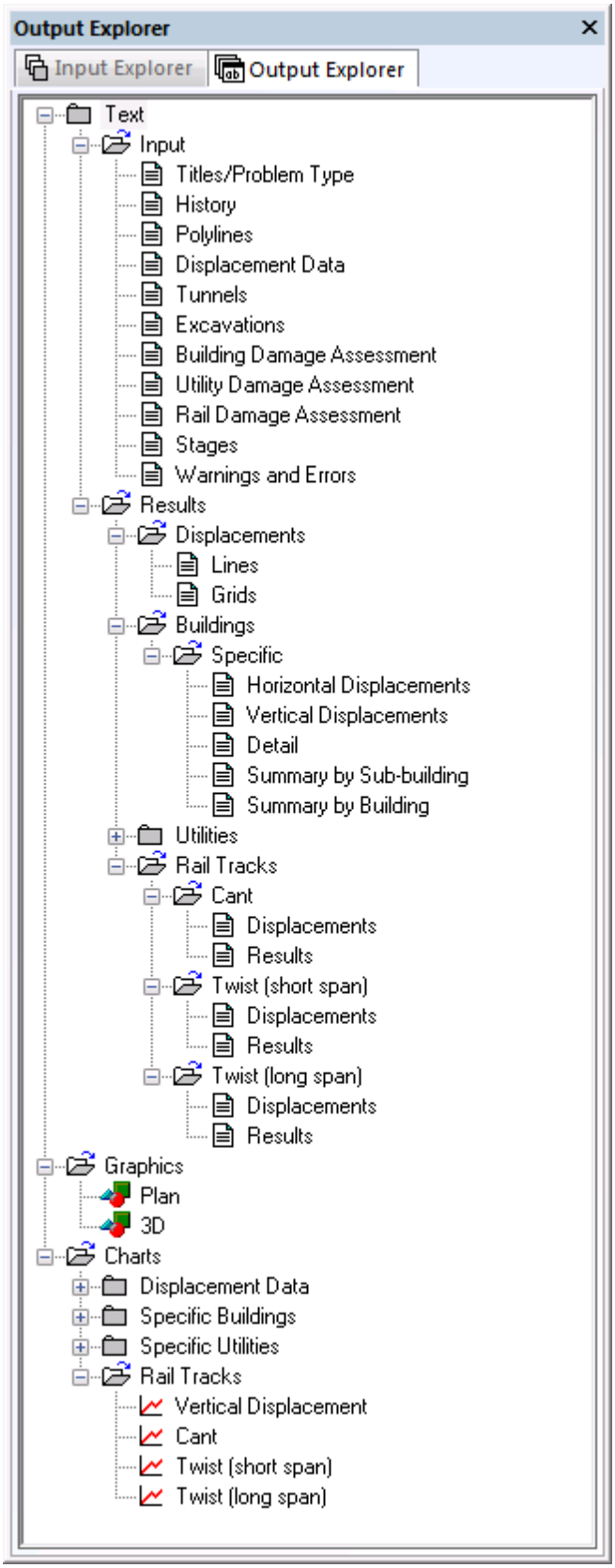
Part V

5 Output

5.1 Output Explorer

The Output Explorer is accessible from the 'View' menu, or via the 'Explorers' button on the XDisp Toolbar. It allows access to all output: the input data and tables of results for inclusion in reports; the Plan View or 3D Graphics View; or Results Charts.



A context menu, to expand or collapse individual or all items, is available by right-clicking in the window.

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5.2 Text Output

Text Output is available in the Text View. Input data or results may be viewed in text by selecting its category from the Output Explorer.

If a results category is selected, such as Displacement Lines, then further options, such as which Stages and Displacement Lines are displayed, can be specified via the droplists embedded at the head of the window's frame

Right-clicking on the Test View opens a context menu with the following options:

- **Stripey Output** - toggles shading of alternate rows in the text output, to improve readability of tables
- **Fully populate fields** - toggles whether blank fields are to be shown where data is repeated from one row to the next, or whether that data is to be repeated, to allow more effective data sorting if exported to a spreadsheet
- **Grid View** - opens the Grid View or rows and columns, for easy copying to a spreadsheet
- **Export...** - opens a dialog to allow the text output to be exported to a CSV, HTML, RTF or TXT file

The **Stripey Output, Fully populate fields** and **Grid View** options are also available via "Output" from the program menu when the Text View is active.

The **Export...** option is also available via "File | Export" from the program menu when the Text View is active.

The font size of the Text Output can be controlled for printing, and so to size tables to fit better to page widths, via the font size control on the XDisp toolbar.

Typical Text View of Input Data:

Staged construction.xdd : Text Output - Input Data

Displacement Lines

Ref.	Name	x1 [m]	y1 [m]	z1 [m]	x2 [m]	y2 [m]	z2 [m]	Intervals [No.]	Calculate	Surface type for tunnels
1	Northern Buildings #1, South Face	60.00000	120.00000	100.00000	90.00000	120.00000	100.00000	10	Surface	Yes
2	Northern Buildings #1, East Face	90.00000	120.00000	100.00000	90.00000	150.00000	100.00000	10	Surface	Yes
3	Northern Buildings #1, North Face	90.00000	150.00000	100.00000	60.00000	150.00000	100.00000	10	Surface	Yes
4	Northern Buildings #1, West Face	60.00000	150.00000	100.00000	60.00000	120.00000	100.00000	10	Surface	Yes
5	Northern Buildings #2, South Face	100.00000	120.00000	100.00000	140.00000	120.00000	100.00000	10	Surface	Yes
6	Northern Buildings #2, East Face	140.00000	120.00000	100.00000	140.00000	150.00000	100.00000	10	Surface	Yes
7	Northern Buildings #2, North Face	140.00000	150.00000	100.00000	100.00000	150.00000	100.00000	10	Surface	Yes
8	Northern Buildings #2, West Face	100.00000	150.00000	100.00000	100.00000	120.00000	100.00000	10	Surface	Yes
9	Northern Buildings #3, South Face	150.00000	120.00000	100.00000	170.00000	120.00000	100.00000	10	Surface	Yes
10	Northern Buildings #3, East Face	170.00000	120.00000	100.00000	170.00000	150.00000	100.00000	10	Surface	Yes
11	Northern Buildings #3, North Face	170.00000	150.00000	100.00000	150.00000	150.00000	100.00000	10	Surface	Yes
12	Northern Buildings #3, West Face	150.00000	150.00000	100.00000	150.00000	120.00000	100.00000	10	Surface	Yes
13	Northern Buildings #4, South Face	180.00000	120.00000	100.00000	210.00000	120.00000	100.00000	10	Surface	Yes
14	Northern Buildings #4, East Face	210.00000	120.00000	100.00000	210.00000	150.00000	100.00000	10	Surface	Yes
15	Northern Buildings #4, North Face	210.00000	150.00000	100.00000	180.00000	150.00000	100.00000	10	Surface	Yes
16	Northern Buildings #4, West Face	180.00000	150.00000	100.00000	180.00000	120.00000	100.00000	10	Surface	Yes
17	Northern Buildings #5, South Face	240.00000	120.00000	100.00000	260.00000	120.00000	100.00000	10	Surface	Yes
18	Northern Buildings #5, East Face	260.00000	120.00000	100.00000	260.00000	150.00000	100.00000	10	Surface	Yes
19	Northern Buildings #5, North Face	260.00000	150.00000	100.00000	240.00000	150.00000	100.00000	10	Surface	Yes
20	Northern Buildings #5, West Face	240.00000	150.00000	100.00000	240.00000	120.00000	100.00000	10	Surface	Yes
21	Northern Buildings #6, South Face	270.00000	120.00000	100.00000	310.00000	120.00000	100.00000	10	Surface	Yes
22	Northern Buildings #6, East Face	310.00000	120.00000	100.00000	310.00000	150.00000	100.00000	10	Surface	Yes
23	Northern Buildings #6, North Face	310.00000	150.00000	100.00000	270.00000	150.00000	100.00000	10	Surface	Yes

Typical Text View of Results:

Staged construction.xdd : Text Output - Results

Stage Base model Displacement Line 1: Northern Buildings #1, South Face

Displacement Results - Stage: Base model - Displacement Lines

Ref.	Name	Chainage [m]	x [m]	y [m]	z [m]	δx [m]	δy [m]	δz [m]	δH// [m]	δHperp. [m]	Angle [°]
1	Northern Buildings #1, South Face	0.0	60.00000	120.00000	100.00000	0.050123	-0.0092615	0.039304	0.050123	-0.0092615	0.0
		3.0000	63.00000	120.00000	100.00000	0.050938	-0.011342	0.042686	0.050938	-0.011342	0.0
		6.0000	66.00000	120.00000	100.00000	0.050910	-0.014224	0.046247	0.050910	-0.014224	0.0
		9.0000	69.00000	120.00000	100.00000	0.049471	-0.018446	0.049949	0.049471	-0.018446	0.0
		12.000	72.00000	120.00000	100.00000	0.045472	-0.025094	0.053694	0.045472	-0.025094	0.0
		15.000	75.00000	120.00000	100.00000	0.036465	-0.036464	0.057225	0.036465	-0.036464	0.0
		18.000	78.00000	120.00000	100.00000	0.018075	-0.056540	0.059858	0.018075	-0.056540	0.0
		21.000	81.00000	120.00000	100.00000	3.4596E-6	-0.075002	0.060475	3.4596E-6	-0.075002	0.0
		24.000	84.00000	120.00000	100.00000	20.938E-6	-0.075012	0.060485	20.938E-6	-0.075012	0.0
		27.000	87.00000	120.00000	100.00000	93.067E-6	-0.075063	0.060536	93.067E-6	-0.075063	0.0
		30.000	90.00000	120.00000	100.00000	303.82E-6	-0.075251	0.060724	303.82E-6	-0.075251	0.0

Headers to text output tables are deliberately brief to allow effective export to and sorting in a spreadsheet, and so avoid headers spanning columns. A few explanatory notes for text output of results are given below.

Displacement and Strain Results

δz	-	vertical displacement in the z direction (positive being downwards)
δH//	-	horizontal displacement parallel to a Displacement Line
δHperp.	-	horizontal displacement perpendicular to a Displacement Line
Angle	-	the angle of a Displacement Line to the x axis
ε_1, ε_2 and θ	-	major and minor principal tensile strains and angle for the x-y plane

An asterisk "*" at the right of a row indicates that a result includes an imported displacement.

Major and minor principal tensile strains and angle are available only if the model contains no excavations and no tunnels which refer to the Harris and Alvarado or Mair et al methods, and if there are no imported displacements.

Specific Building Damage Results

Horizontal Displacements - lists horizontal ground movements at all points along the displacement line that is associated with each Sub-Building.

Vertical Displacements - lists vertical ground movements at all points along the displacement line that is associated with each Sub-Building, once that line has been offset by each of the vertical offset distances.

Building damage results are thus calculated using each sub-building's horizontal displacements, combined with each vertical displacements set, to give n sets of results per Sub-Building, where n is the number of vertical offsets. See Points of Inflexion, Gradient and Radius of Curvature for further information.

Each Sub-Building is divided into hogging and sagging segments and building damage results are calculated for each segment. The following summaries are presented:

Detail (All Segments) - lists results for each segment, of each Sub-Building, of each Building

Summary by Sub-building (Critical Values for All Segments within Each Sub-Building) - lists the critical values of all segments within each Sub-Building. These values may therefore be drawn from more than one segment and vertical offset in the Sub-Building.

Summary by Building (Critical Segments within Each Sub-Building) - lists each Sub-

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Building's critical segment, based on damage category and horizontal strain

Combined Segments - lists results for each combined segment, of each Sub-Building, of each Building

The segment lengths that are listed are those before accounting for imposed horizontal strains. However, points of inflexion, and therefore the segment lengths that are used in calculating deflection ratios and building damage categories, take account of imposed horizontal strains.

Generic Building Damage Results

Horizontal Displacements - lists horizontal ground movements at all displacement locations along every transect.

Vertical Displacements - lists vertical ground movements at all displacement locations along every transect, once those transects have been offset by each of the vertical offset distances.

Generic building damage results are thus calculated using each transect's horizontal displacements, combined with each vertical displacements' set, to give n sets of results per transect, where n is the number of vertical offsets. See Points of Inflexion, Gradient and Radius of Curvature for further information.

Each Sub-Building on a transect is divided into hogging and sagging segments and building damage results are calculated for each segment. The following summaries are presented:

Detail (All Segments) - lists results for each segment, along each transect, of each Building

Summary by Sub-building (Maximum Tensile Strain - **By Transect and L/H) -** lists the maximum tensile strain along each transect for each offset and for each L/H.

Summary by Building (Maximum Tensile Strain - **By Transect) -** lists the maximum tensile strain along each transect for each offset.

Combined Segments - lists results for each combined segment, along each transect, of each Building

The segment lengths that are listed are those before accounting for imposed horizontal strains. However, points of inflexion, and therefore the segment lengths that are used in calculating deflection ratios and building damage categories, take account of imposed horizontal strains.

Utility Damage Results

Coordinates and Displacements - for each iteration lists the coordinates and displacements of a) all the joint locations where pullouts and rotations are calculated and b) locations at, one pipe length upstream and one pipe length downstream of a joint.

Pullouts and Rotations - for each iteration, it lists the pullouts and rotations calculated at joint locations in that iteration. At those locations, it checks whether the factored values are within their respective threshold and limit values and prints "OK" if passed and "FAIL" if failed.

With regard to reported rotations, the figures in the Text Output are such that:

- “Pullout: Left Seg.: Ax.” is equivalent to the “$PO_{axial\text{-}upstream}$” shown in pullout calculations

- “Pullout: Right Seg: Ax.” is equivalent to -1 x the “$PO_{axial\text{-}downstream}$” shown in pullout calculations

i.e.

- the help file assumes positive values for upstream and downstream are away from the joint (i.e. in opposing directions so pulling the joint open)

whereas

- the Text Output assumes positive values for left and right are both in the direction of the utility’s travel i.e. if the upstream pipe is considered to move 2mm downstream, and the downstream pipe is considered to move 3mm downstream, then the total pullout is 3 – 2 = 1mm across the joint.

Strains - At every displacement point on the sub-utility's length, it lists the peak flexural tensile strain orientation angle (with respect to global z-axis), radius of curvature, axial strain and flexural strain values. It checks whether the factored total strain values are within their respective threshold and limit values and prints "OK" if passed and "FAIL" if not.

Maximum Values - lists the maximum displacements, maximum rotations, maximum displacements and minimum radii of curvature in each sub-utility along with the coordinates of the respective locations at which they occur.

Note: If a utility is associated with a displacement polyline, then there will be gaps in results at bends, because each straight length of a polyline is treated as a displacement line for calculation purposes. There must be a pipe length both upstream and downstream of any displacement point in order for calculation of pullout and rotation to be performed at that point, and the distance of a displacement interval for strains.

Generic Utility Damage Results

Utility damage results are calculated for all utilities on all transects. The Utility damage results' tables are output for all utilities on all transects.

Rail Damage Results

Cant | Displacements - lists the chainages, coordinates and displacements of the left and right rail at each assessment location.

Cant | Results - lists the chainages, displacements of the left and right rail, and the resulting cant, at each assessment location.

Twist | Displacements - lists the chainages, coordinates and displacements of the left and right rail required for twist results at each assessment location.

Twist | Results - lists the chainages, displacements of the left and right rail and twist, at each assessment location.

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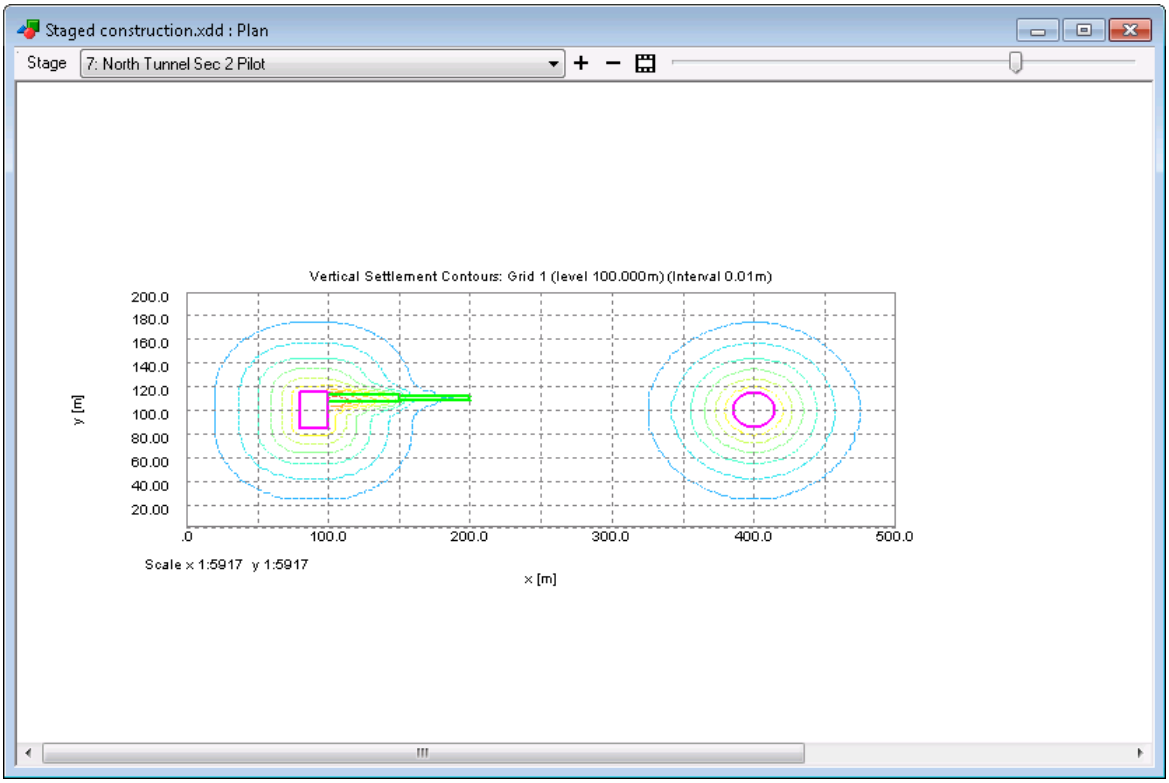
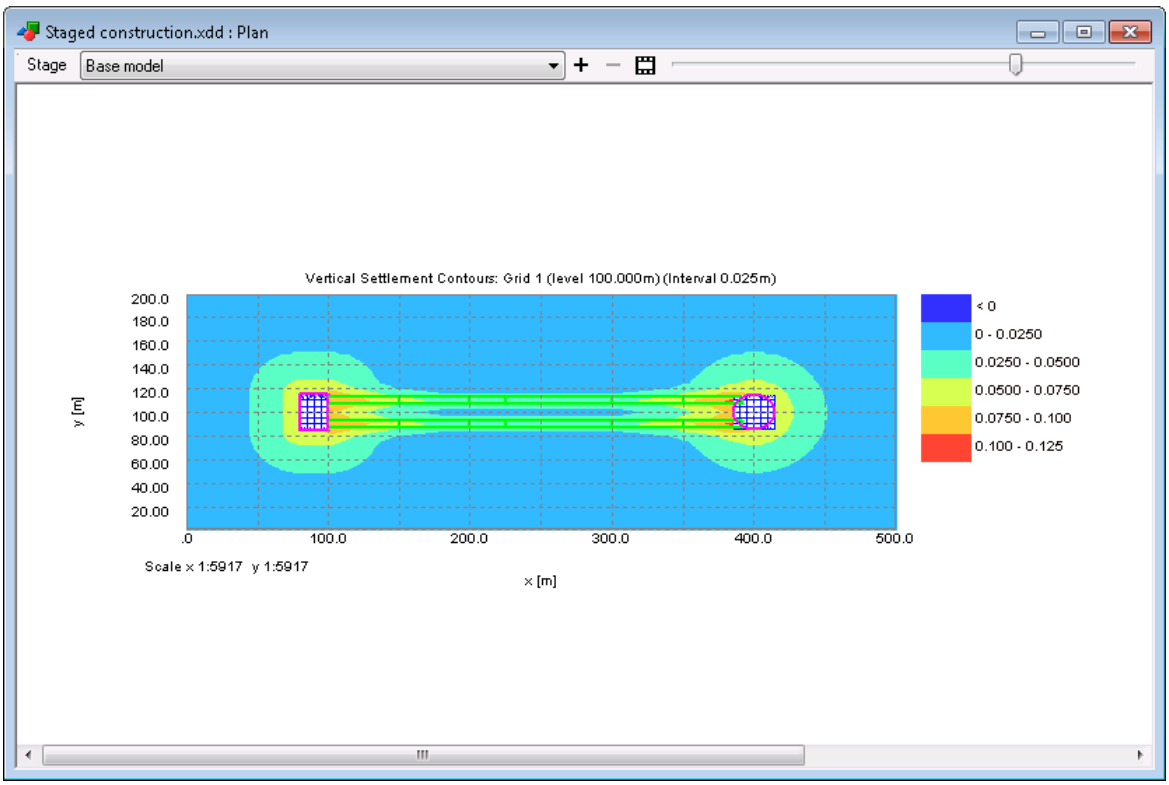
5.3 Plan View

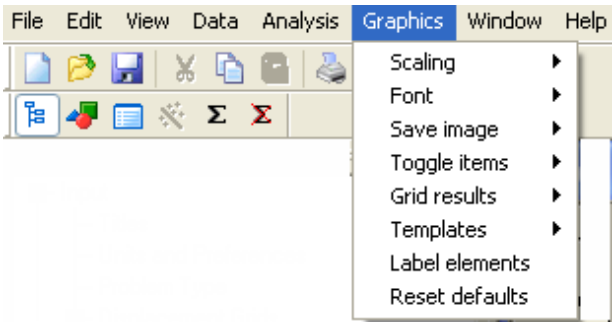
The Plan View is available via View -> Plan from the program menu or from the appropriate leaf on the Output Explorer. It displays a plan view of the model and its available results.





The embedded toolbar at the top of the window allows the model data and results to be viewed stage-by-stage. Animation of the model data and results from one stage to the next is available via the 'animate' button . The speed of animation is controlled via its neighbouring slider control. Alternatively stages may be stepped-through manually via the +/- buttons.

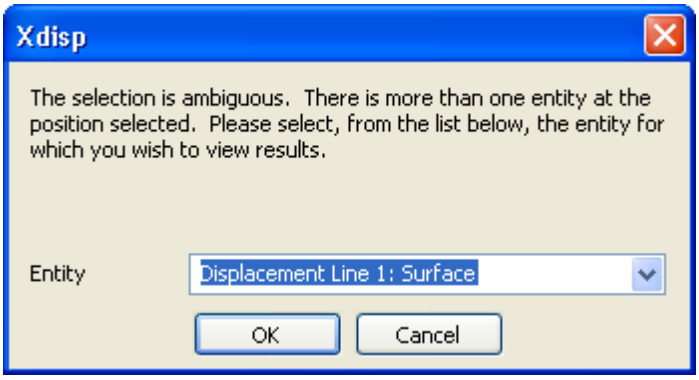
The Plan Toolbar presents commands for controlling the display on the Plan View.



The Graphics menu is available if the Plan View is active. This menu allows the use of templates to save the graphical display set-up, display of displacement data, and annotation and scaling of the data displayed.

5.3.1 Ambiguous Selection

When selecting an element from the Plan View in order to view a results' chart, if there is more than one element present at the cursor location then left-clicking will pop up the Ambiguous Selection Dialog. This dialog lists all the elements present at that location. The element of interest may be selected from that list.



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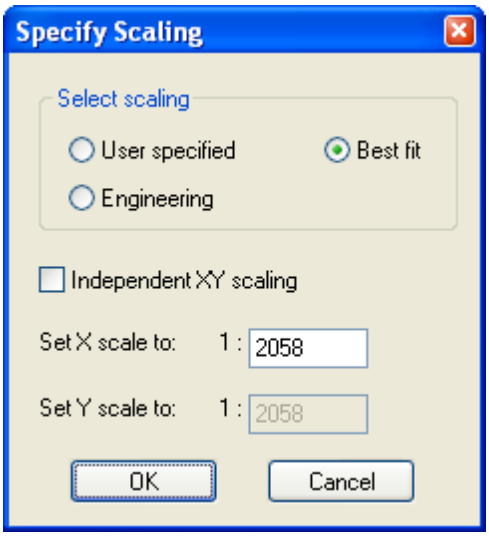
5.3.2 Set Exact Scale

Selection of Set Exact Scale allows you to set any required scale for the Plan View. This is done using the Specify Scaling dialog.



5.3.3 Templates

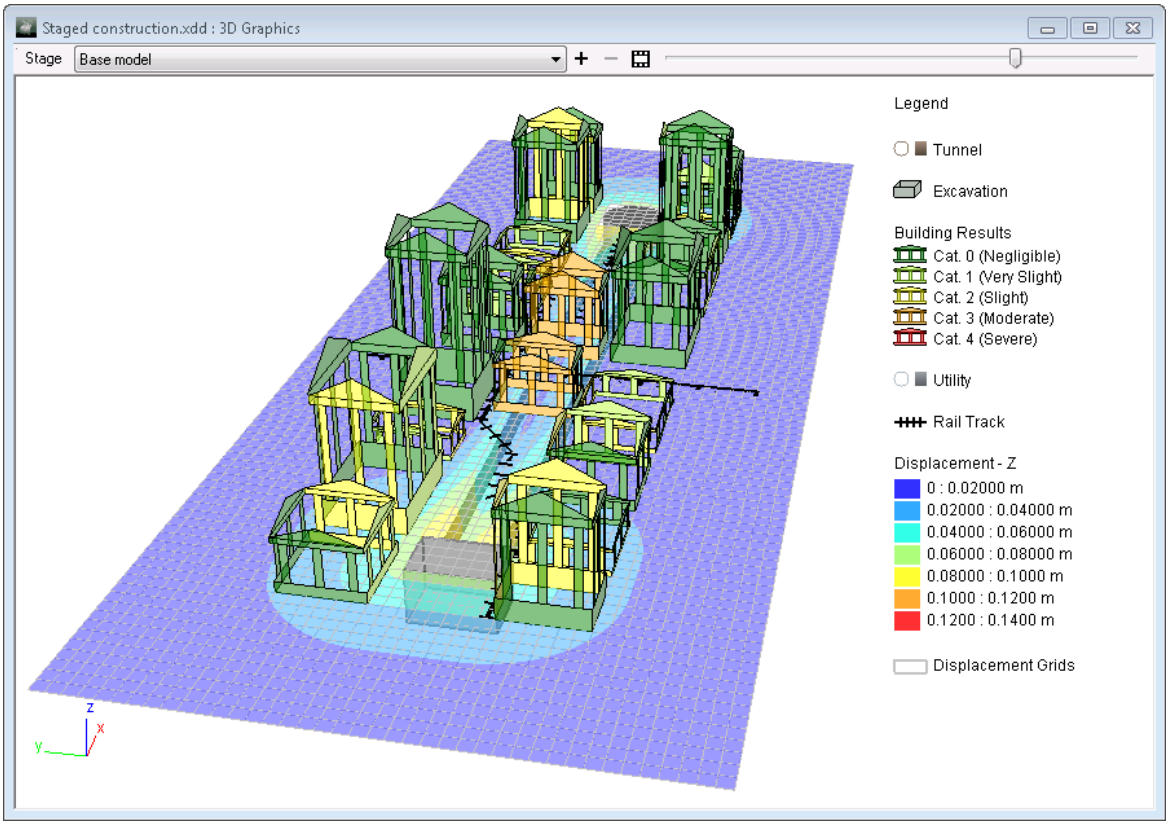
The Templates function works by following the procedure below.

1. Set up the Plan View which you would like to repeat for other files in the future.
2. Select the 'Save as template' option and save the view with a specific file name.
3. To reload the template select the 'Load template' option.
4. To return to the original view when the Plan View is open select 'Reset defaults'.

5.4 3D Graphics View

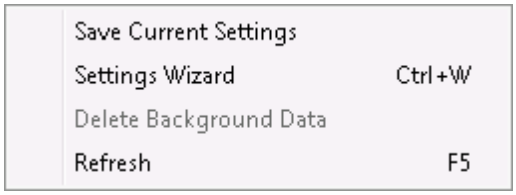
The 3D Graphics View is available via View -> 3D Graphics from the program menu, from the appropriate leaf on the Output Explorer, or via the XDisp toolbar. It displays a three dimensional plot of the model and its available results.

The 3D Graphics View may be converted to input mode, so as to enter data graphically, by clicking the "Input/Output" button . Clicking the button again returns the view to output mode. See Graphical Input of Data for more information on inputting data graphically.



The embedded toolbar at the top of the window allows the model data and results to be viewed stage-by-stage. Animation of the model data and results from one stage to the next is available via the 'animate' button . The speed of animation is controlled via its neighbouring slider control. Alternatively stages may be stepped-through manually via the +/- buttons.

The 3D Graphics View is dependent on parameters defined in the Graphic Settings Wizard which may be accessed, when the view is active, by Ctrl + W, by clicking the Wizard button on the XDisp Toolbar, or by right-clicking in the view and selecting 'Settings Wizard' from the view's context menu.



The view may be refreshed via the F5 key.

Rotate

The model can be rotated by holding left-click and dragging the mouse. Horizontal drag rotates the model with respect to its z axis. Vertical drag rotates the model with respect to the axis parallel to a horizontal line through the centre of the view.

Zoom

The model can be zoomed in or out by scrolling the mouse wheel or by <ctrl> + drag up or down.

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The model can be zoomed to its original scale by pressing 'z' from keyboard.

Pan

The model can be panned by dragging the mouse with the mouse wheel (or middle button) held down.

Saving the view

The view point and zoom factor can be saved by selecting "Save default view settings" from the context menu of the view. The context menu is accessible by right-clicking in the view or by using the context menu key on the keyboard).

Printing

The view can be printed.

The 3D Graphics menu and toolbar presents other commands that are specific to the 3D Graphics View.

5.4.1 3D Graphic Settings

The Graphic Settings property sheet allows the parameters that govern the format and content of the 3D Graphics View to be specified. It allows a more detailed, granular specification of what should be displayed on the 3D Graphics View than the 3D Graphics Toolbar. For instance, individual buildings may be selected to be viewed or hidden, whereas the toolbar allows only the display or all or none.

These graphic settings are stored in the data file. The 'Apply' button applies the settings to the 3D Graphics View without closing the dialog. The 'OK' button applies the settings to the 3D Graphics View and closes the dialog.

This property sheet may be accessed via:

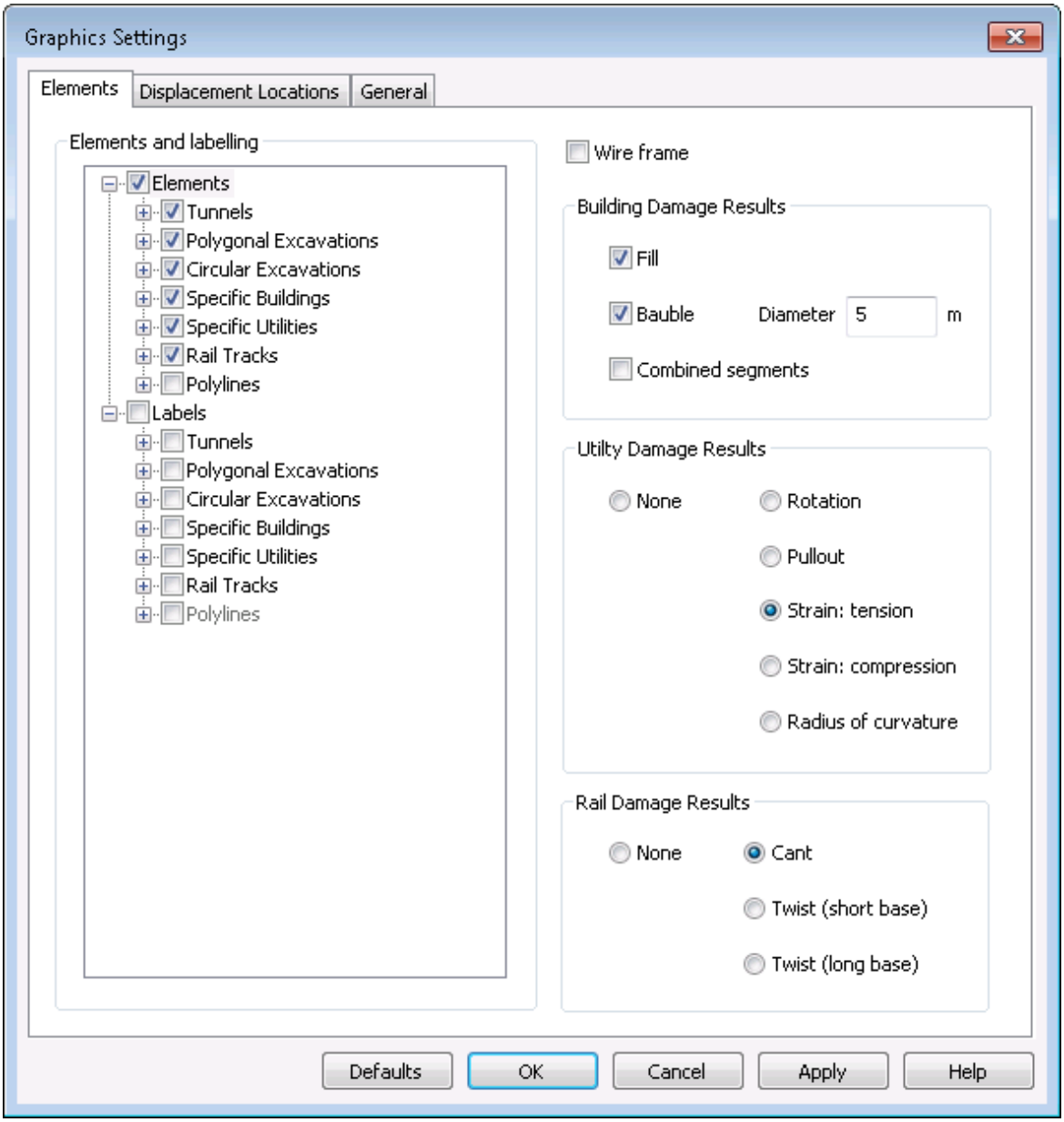
- "Edit | Wizard..." when the 3D Graphics View is active;
- the Wizard button on the XDisp Toolbar when the 3D Graphics View is active; or
- selecting "Graphic settings" from the context menu of the 3D Graphics View (the context menu is accessible by right-clicking in the view or typing the context menu key from keyboard)

The controls are separated into three different pages:

- Elements
- Displacements
- Preferences

Each of these is described in detail below.

Elements



Elements - elements to be viewed may be selected via the check boxes.

Labels - labels of the elements selected for viewing will be displayed if the appropriate check boxes in the labels branch are selected.

Wire frame - if this is checked then elements will be displayed as a wire frame.

Building Damage Results, **Utility Damage Results** and **Rail Damage Results** allow customisation of the view to display the required results.

The **Fill** setting for building damage results fills each building's outline with colour to indicate the highest damage category found for any of the building's segments. The **Bauble** setting adorns the apex of each building's pediment with a similarly coloured bauble of specified **Diameter**. The **Bauble** setting ensures the visibility of building damage results for every building in any orientation of the view.

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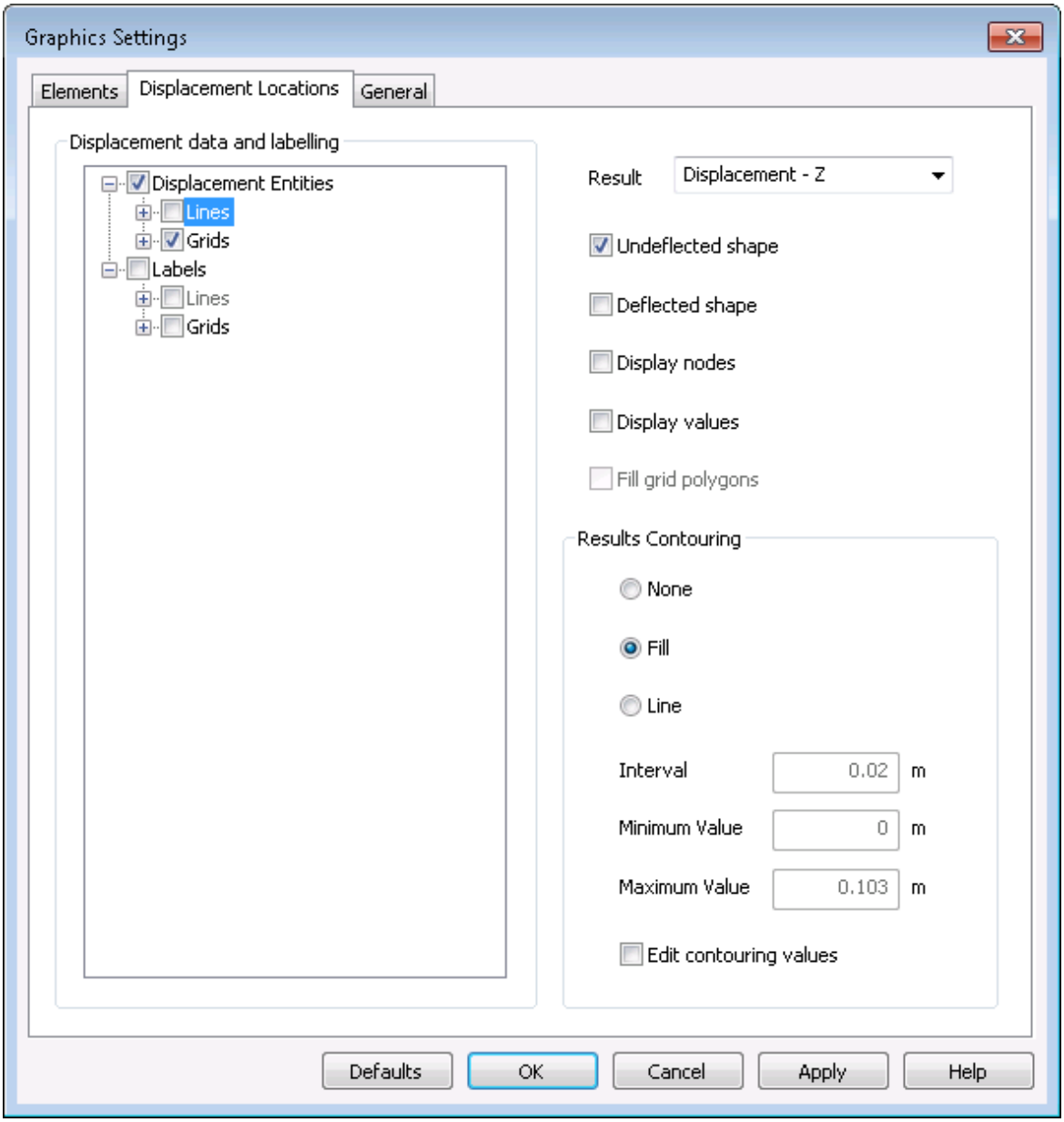
Displacements

The Displacements' page specifies how the displacement results are to be displayed.



After performing an analysis, results are available for the Points, Lines and Grids specified in the Displacement Data table. The 3D Graphics View can illustrate these results. If no results are available then the locations of the proposed displacement data are shown.

Displacement Entities

Points, Lines and Grids to be viewed may be selected via the check boxes.

Labels

Labels of the entities selected for viewing will be displayed if the appropriate check boxes in

the labels branch are selected.

Direction

Allows selection of the displacement result that is to be displayed, e.g. displacement in the x, y and z directions, horizontal resultant or the resultant. The contour display or deflected shape will be based on this selection.

Undeflected shape

When this is checked the undeflected positions of Points, Lines and Grids are displayed. This is required to view the locations of Displacement Data when there are no results.

Deflected shape

When this is checked the deflected shape of Points, Lines and Grids are displayed. Deflections are not to scale but are indicative of relative movements.

Display nodes

When this is checked the nodes on the grids and/or lines will be highlighted with a small cube.

Display values

When this is checked the nodes will be annotated with displacement values. This button is enabled only if results exist.

Fill grid polygons

When this is checked the deflected nodes on a grid form a surface with filled polygons. When unchecked it displays polygons by outlines (i.e. as a mesh). This button is enabled only if results exist and when the 'Contour surface' button is unchecked.

Results Contouring

This allows the specification of filled or lined contours and either default or user-defined contour limits and intervals. Contour intervals may not be chose to exceed 50 contours. The maximum value is the results' range.

General

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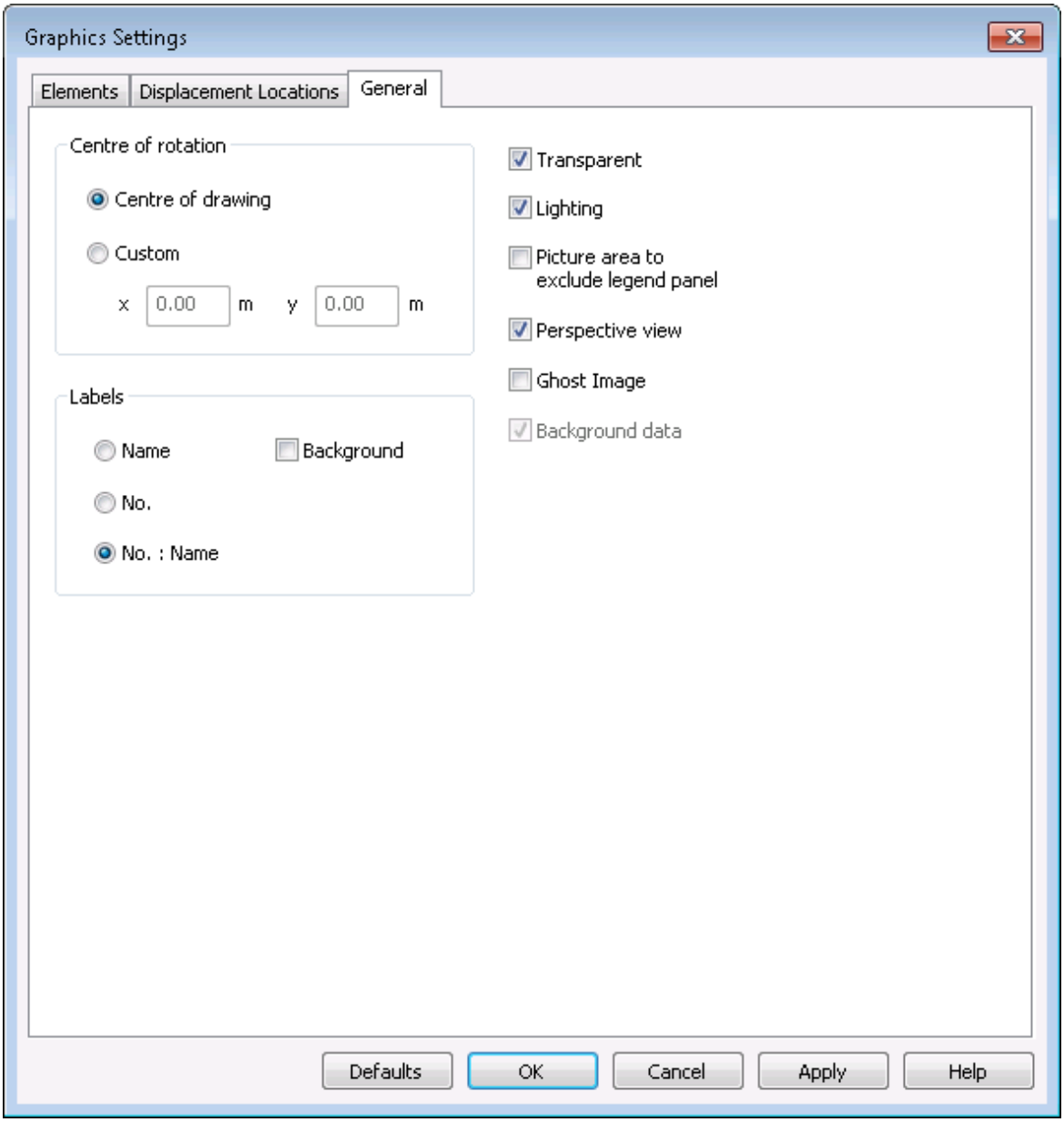

Centre of rotation

This specifies the co-ordinate of the centre for rotating and zooming.

Centre of drawing

When this is selected the centre of rotation is set to the centre of the model, the resulting x and y co-ordinates are displayed in the edit boxes. These cannot be edited directly.

Custom

When this is selected the edit boxes x and y are enabled so that the centre of rotation may be entered directly.

Labels

These controls specify how labels should appear.

Name

Labels will display only the name of the entity.

No.

Labels will display only the index number of the entity.

No. Name

The entity's index number and name are concatenated.

Background

When this is checked a white background is provided behind the text for all the labels in the view.

Transparent

When this is checked the surfaces become semi-transparent. The transparency depends on the sequence of the drawing order.

Lighting

When this is checked light falls on the model from a pre-defined position set by the program. This button is enabled only when lighting is appropriate.

Picture area to exclude legend panel

When this is checked the picture area that is used for the model excludes that of the legend. Otherwise the legend is superimposed on the model's image.

Perspective view

This toggles the view between orthogonal and perspective.

Ghost Image

When this is checked a ghost image will be drawn when the elements are rotated. This avoids time lag especially when there are many elements in the view.

Background Data

Selects whether to view the background data that has been imported via DXF import.

Defaults

This resets all the settings to the program's defaults and applies them to the 3D Graphics View.

OK

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This applies the current settings from all the pages to the 3D Graphics View, and closes the property sheet.

Undo

This undoes the changes to all those pages that have been modified since the 'Apply' button was last pressed.

Apply

This applies the current settings from all the pages to the 3D Graphics View without exiting the property sheet.

More:

3D Graphics View

3D Graphics Toolbar

5.5 Charts

Results charts are most easily accessible from the Output Explorer. However, they may also be selected by the following procedure while the Plan View is open.

1) Perform an analysis
2) Open the Plan View
3) Ensure the element for which a chart of results is required is visible via by choosing 'Graphics | Toggle Items' or by activating the appropriate button on the Plan Toolbar e.g. Displacements , Buildings , Utilities , or Rail Tracks
4) Activate the Charts button on the Plan Toolbar
5) Left-click on the Plan View over the element for which the chart is required
6) Navigate the subsequent dialog options to select the required chart

Once a chart is shown further options for specifying the required output may be available via the droplists embedded at the head of the chart's frame. Right-clicking on the chart offers options to control the display of e.g. tooltips, symbols, chart style etc.

Bulk Chart Export allows many charts to be exported to image files without the need to open each.

The following charts are viewable in the program providing the appropriate data and results are available.

Displacement Data

- Displacement Lines
- Any Location - All Stages

Specific Buildings

- Displacement[1]
- Building Damage Interaction[1][2]

Generic Buildings (by Transect)[3]

- Displacement[1]
- Building Damage Interaction[1][2]

Generic Buildings (by Building)[4]

- Displacement
- Maximum Tensile Strain

Specific Utilities

- Displacement
- Rotation - if the utility is jointed
- Pullout - if the utility is jointed
- Axial Strain
- Flexural Strain
- Combined Strain
- All Strains
- Radius of Curvature

Generic Utilities (by Transect)[3]

- Displacement
- Rotation - if the utility is jointed
- Pullout - if the utility is jointed
- Axial Strain
- Flexural Strain
- Combined Strain
- All Strains
- Radius of Curvature[5]

Generic Utilities (by Utility)[4]

- Displacement
- Rotation - if the utility is jointed
- Pullout - if the utility is jointed
- Axial Strain
- Flexural Strain
- Combined Strain
- All Strains
- Radius of Curvature[5]

Rail Tracks

- Cant
- Twist (short base)
- Twist (long base)

Notes

[1] The appropriate Segment Combinations dialog may be accessed by clicking the 3 dots "**...**" beside the Segment selection drop-list that is embedded at the top of either the Building

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Damage Interaction chart's window or the Building's Displacement chart's window.

[2] "No data to display" indicates that settlements are less than the Vertical Displacement Limit Sensitivity for the chose building segment.

[3] Generic results by Transect allow each Transect's results to be inspected for each Stage by specifying the Stage and Transect from the selection drop-list that is embedded at the top of a chart's window. Charts are plotted against chainage along the polyline, with the origin being the start of the building or utility, if that is offset from the start of the polyline on which its alignment depends.

[4] Generic results by Building or by Utility allow the critical result for each Transect to be plotted along the chainage of the Generic Building or Generic Utility. Charts are plotted against distance along the Transect.

[5] Where displaced utilities are straight, so radius of curvature is infinity, the charts will show a nominal value of 10^{12}m.

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Part VI

6 Import/Export

6.1 Import

6.1.1 AutoCAD (DXF)

Geometric data may be imported from DXF files via 'File | Import | AutoCAD (DXF)...' from the program menu.

The purpose of DXF import is twofold: firstly to allow tunnels, buildings, utilities or excavations to be created quickly from existing AutoCAD or GIS data; and secondly to allow background lines and circles to be imported for display on the 3D Graphics View.

Alignments of tunnels, buildings, utilities or excavations may be traced in AutoCAD and, provided they are saved in the appropriate entity types and named layers, read into **XDisp** to create complex geometries with minimal input by the user in **XDisp** itself.

DXF files may be used only to specify the alignments, and, where appropriate, the levels of tunnels, buildings, utilities and excavations. Other, non-geometrical data are set to default values by **XDisp**. After the DXF file has been imported this data should be checked by the user, and, where relevant, reset to appropriate values.

Sample DXF files are supplied with the program. See Sample Files for more information.

XDisp Element	Required Name of DXF Layer	DXF Entity	Interpretation	
Tunnels	"Tunnels"	POLYLINE	Series of tunnels	The DXF entity's vertices specify the end coordinates and levels of each tunnel.
		LWPOLYLINE	Series of tunnels	As POLYLINE, but tunnel levels are all set to 0m.
		LINE	Single tunnel	End points of a LINE specify the end coordinates and levels of one tunnel.
Buildings(1)	"Buildings"	POLYLINE(2)	Series of sub-buildings	The vertices of the POLYLINE specify the end coordinates and levels of each sub-building.
		LWPOLYLINE(2)	Series of sub-buildings	As POLYLINE, but sub-building levels are all set to 0m.
		LINE	Single sub-building	The end points of a LINE specify the end coordinates and levels of one sub-building.
Utilities(3)	"Utilities"	POLYLINE	Series of sub-utilities	The vertices of the POLYLINE specify the end coordinates and levels of each sub-utility.
		LWPOLYLINE	Series of sub-utilities	As POLYLINE, but sub-utility levels are all set to 0m.
		LINE	Single sub-utility	The end points of a LINE specify the end coordinates and levels of one sub-utility.
Excavations(4)(5)	"Excavations"	POLYLINE	Base perimeter of a single excavation	The vertices of the POLYLINE specify the end coordinates and levels of each point on the base of the excavation's perimeter.

		LWPOLYLINE	Perimeter of a single excavation	As POLYLINE, but the levels of the excavation's base points are set to 0m.
		CIRCLE	Perimeter of circular excavation	The centre of the circular excavation and its diameter. The base of the excavation is set to 0m.
Rail Tracks[6]	"Rail_Tracks"	POLYLINE	Single rail track	The vertices of the POLYLINE specify changes in direction of the single rail track.
		LWPOLYLINE	Single rail track	The vertices of the LWPOLYLINE specific changes in direction and height of the single rail track.
		LINE	Single rail track	the end points of the LINE specify the end coordinates and levels of the single rail track.

[1] For each building a corresponding displacement line will also be created.
[2] POLYLINEs and LWPOLYLINEs may therefore be used to define all the façades of a real building. In **XDisp**, each façade will be represented as a sub-building.
[3] For each utility a corresponding displacement line will also be created.
[4] POLYLINEs and LWPOLYLINEs can describe either a closed, or an incomplete, loop. If **XDisp** encounters the latter, then it will close the loop by assuming a final side is intended between the first and last points of the (LW)POLYLINE.
[5] The top level of the excavation is set to be 10 m above the highest base point.
[6] For each rail track a corresponding polyline will also be created.

On importing data from DXF, if XDisp finds any DXF LINES, POLYLINES, LWPOLYLINES and CIRCLES that are not in a recognisably named DXF layer (as specified in the table above). Such entities will be imported as background data for display on the 3D Graphics View and in the Background Data input table.

Once imported, tunnels, buildings, utilities and excavations may be edited as for others input directly into the program. However, background data is edited, after importing, via the Background Data input table.

The Background Data input table, can be accessed via 'Data | Background Data' from the program menu or via the Gateway. Once imported this data cannot be edited, but individual or all records can be deleted by right-clicking in the Background Data input table and, from the subsequent context menu, selecting 'Delete' to delete selected data or 'Delete All' to delete all data.

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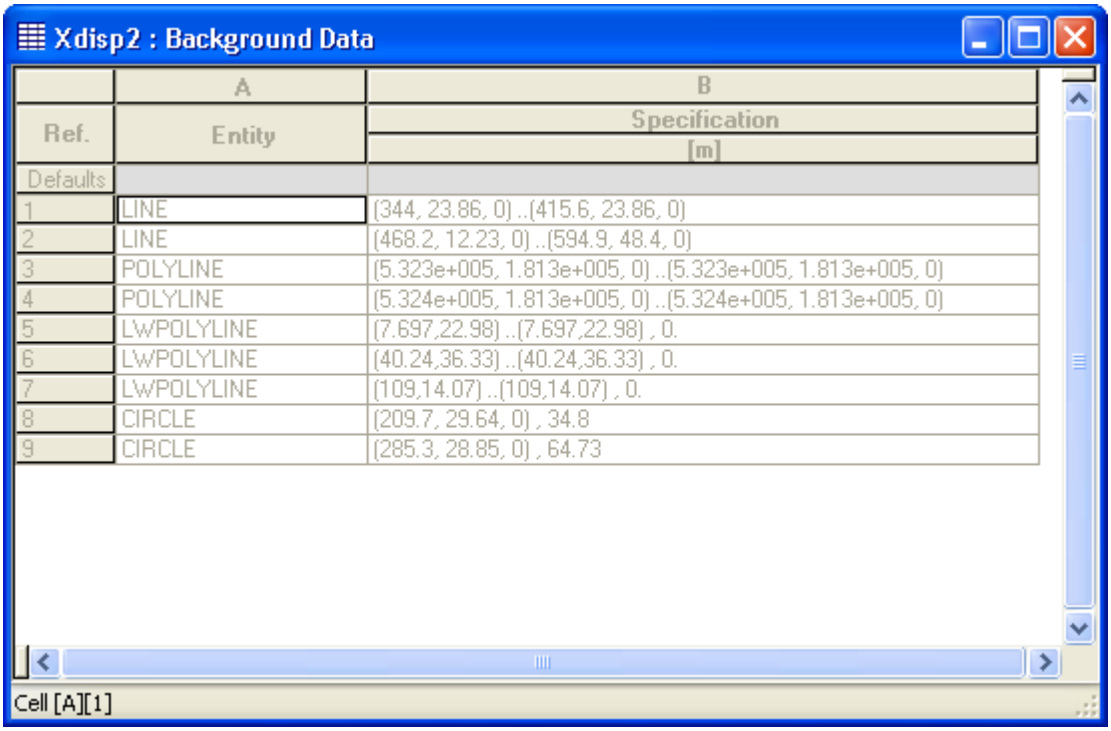
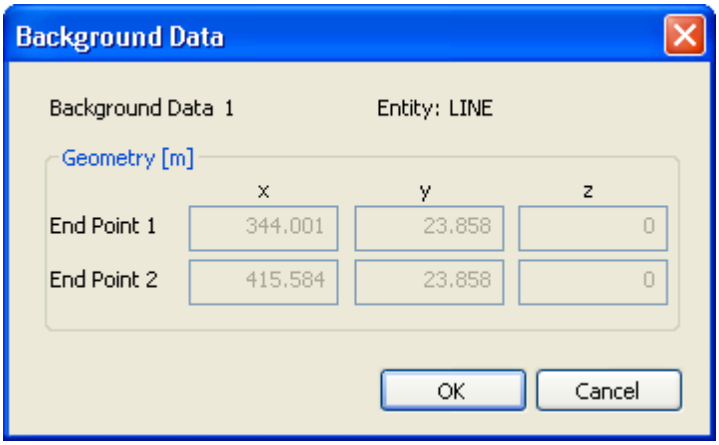
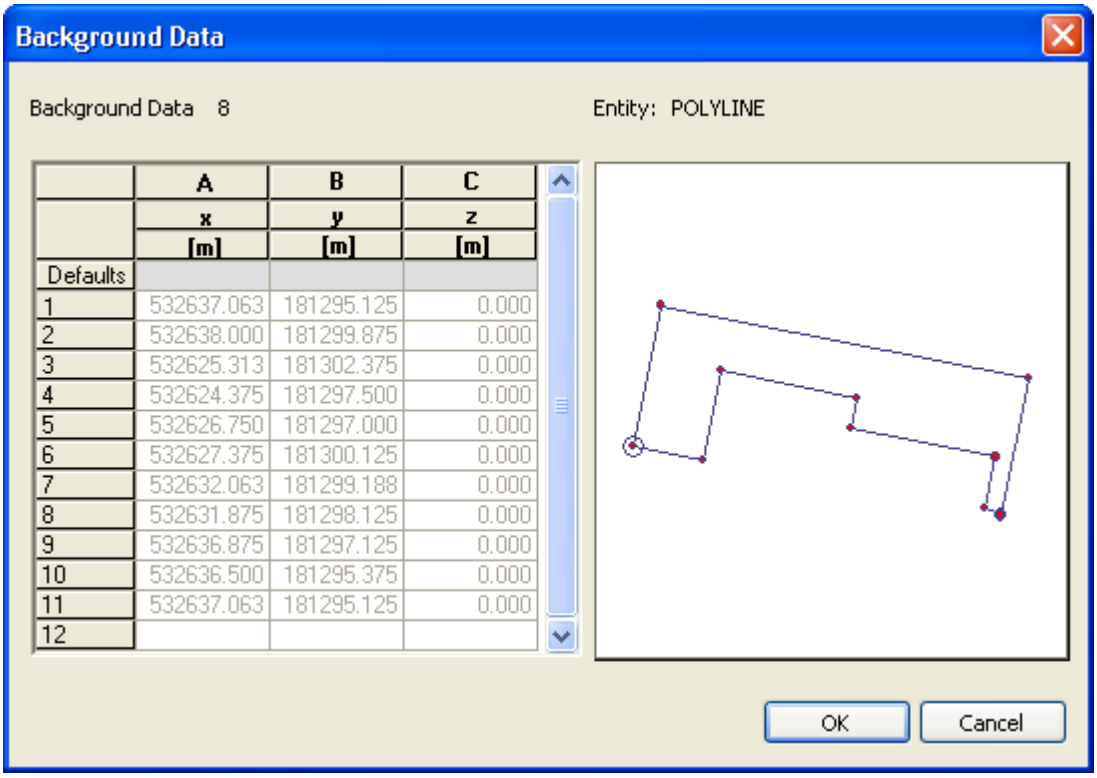
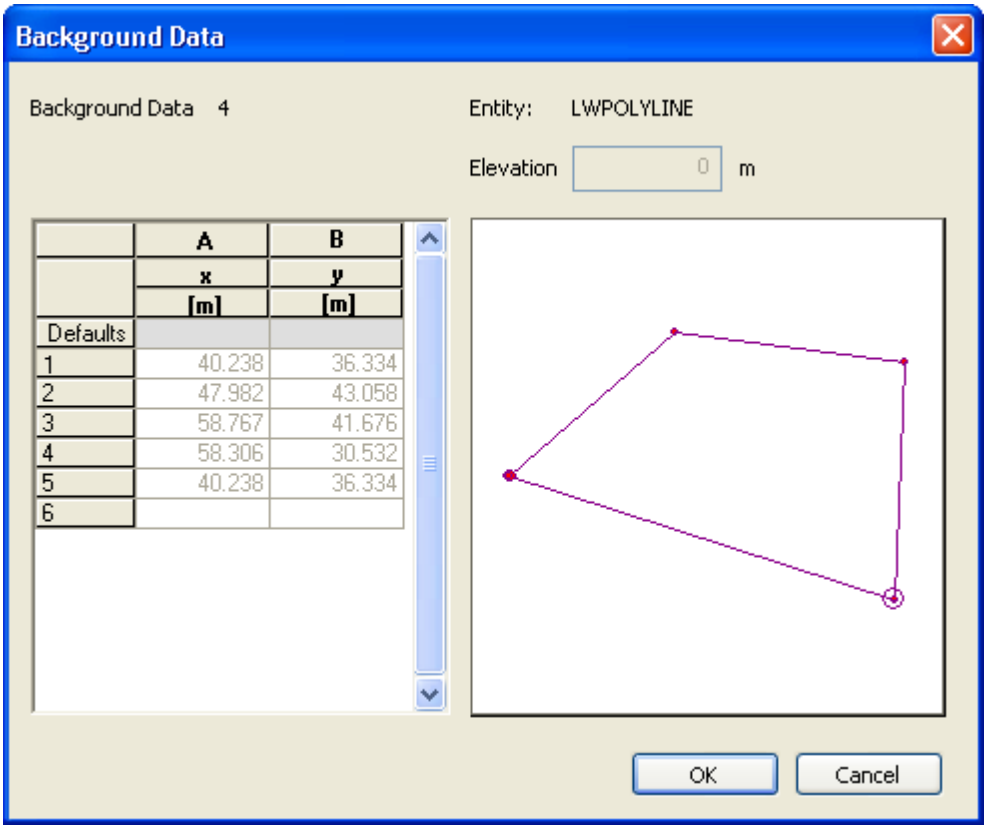


The "Specification" field corresponding to an entity in the Background Data input table gives its condensed information. Detailed information can be viewed via the wizard which is accessed by double clicking the wizard button on the XDisp Toolbar. A context sensitive dialog, depending on the type of DXF data item concerned, will then appear.





	A	B	C
	x	y	z
	[m]	[m]	[m]
Defaults			
1	532637.063	181295.125	0.000
2	532638.000	181299.875	0.000
3	532625.313	181302.375	0.000
4	532624.375	181297.500	0.000
5	532626.750	181297.000	0.000
6	532627.375	181300.125	0.000
7	532632.063	181299.188	0.000
8	532631.875	181298.125	0.000
9	532636.875	181297.125	0.000
10	532636.500	181295.375	0.000
11	532637.063	181295.125	0.000
12			



	A	B
	x	y
	[m]	[m]
Defaults		
1	40.238	36.334
2	47.982	43.058
3	58.767	41.676
4	58.306	30.532
5	40.238	36.334
6		

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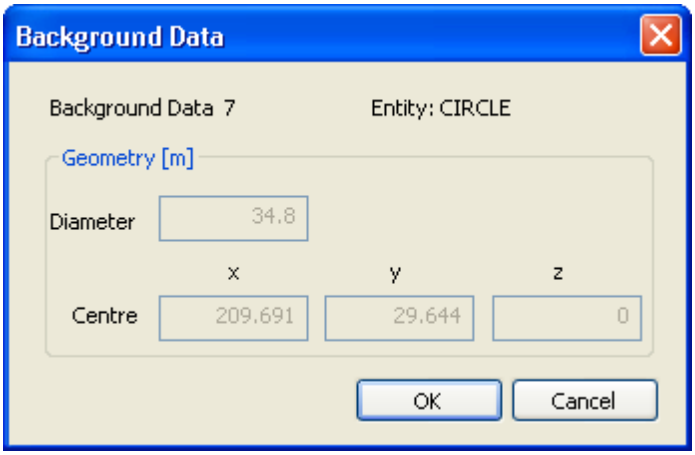


All background data can also be deleted via the 3D Graphics' View's context menu (i.e. by right-clicking on the 3D Graphics View and selecting "Delete Background Data" from the subsequent pop-up menu). Imported DXF background data in the 3D Graphics View can be displayed or hidden via the Graphic Settings property sheet.

6.1.2 Pdisp (PDD)

The following data from Oasys PDisp may be imported from PDisp data files via 'File | Import | PDisp (PDD)...' from the program menu.

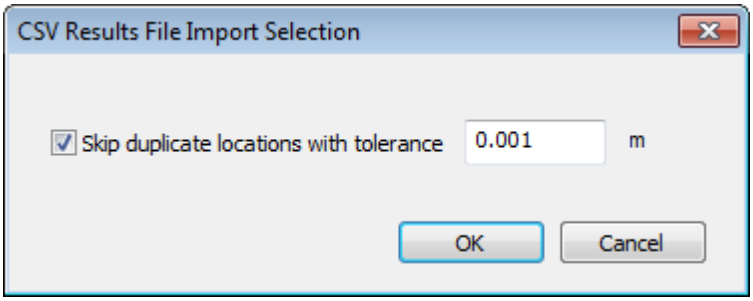
- Displacement data
- Background data
- Imported displacements
- Displacement results

The data for each may be appended to the existing data that has already been entered into the XDisp model, or may replace it.

This allows, for instance, building damage assessment and utility damage assessment to be performed, in XDisp, on ground movements that have been calculated from soil loads in PDisp.

6.1.3 Displacement Results (CSV)

Displacements from other programs may be imported from CSV files via 'File | Import | Displacement Results (CSV)...' from the program menu. On the selection of that option and the csv file subsequently, the 'CSV Results File Import Selection' dialog will appear..



'Skip duplicate locations with tolerance' option allows the user to ignore duplicate points. All the points that are at a distance within the tolerance limit specified from an existing point are ignored.

The purpose of Imported Displacements is to combine the displacements from other programs together with those from XDisp. The combined displacements may then be shown on the Text Output, the Plan View or the 3D Graphics View.

The import file should include rows of data beginning with one of the following keywords. Each row of data contains displacement results for a single coordinate.

- LOAD_RESULT
- POINT_RESULT
- LPOINT_RESULT
- PLPOINT_RESULT
- GPOINT_RESULT
- INTERMEDIATE_LOAD_RESULT
- INTERMEDIATE_POINT_RESULT
- INTERMEDIATE_LPOINT_RESULT
- INTERMEDIATE_PLPOINT_RESULT
- INTERMEDIATE_GPOINT_RESULT

Whichever of these keywords is used, the data will be imported and treated in the same way. The range of keywords is to allow the import of CSV files that have been exported from XDisp or Oasys PDisp, which may contain any of these keywords.

Displacements follow the sequence: Keyword,x Coordinate,y Coordinate,z Coordinate,x Displacement,y Displacement,z Displacement.

Units for data in the file are specified by the keywords UNIT_DISP and UNIT_LENGTH (displacement and length units respectively) followed by the index of the unit. Length and displacement units' indices are: 0 - metres; 1 - centimetres; 2 - millimetres; 3 - feet; 4 - inches.

Units information should appear in the file before the displacement results.

e.g.

```
UNIT_DISP, 2
UNIT_LENGTH, 0
LOAD_RESULT, 0.5, 43.5, 0, -0.4967472, -93.72664, 47.38838
INTERMEDIATE_LOAD_RESULT, 0.5, 43.5, -2.587683439, 0, 0, 38.77201
INTERMEDIATE_LOAD_RESULT, 0.5, 43.5, -4, 0, 0, 34.85815
GPOINT_RESULT, -80, -90, 0, 32.98127, 27.33411, -0.5642965
INTERMEDIATE_GPOINT_RESULT, -80, -90, -4, 0, 0, -0.5535589
INTERMEDIATE_GPOINT_RESULT, -80, -90, -6, 0, 0, -0.5062072
LPOINT_RESULT, -70, -80, 0, 41.05777, 32.48021, -6.13E-03
INTERMEDIATE_LPOINT_RESULT, -70, -80, -4, 0, 0, 3.54E-02
INTERMEDIATE_LPOINT_RESULT, -70, -80, -6, 0, 0, 0.1545731
```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```
POI NT_RESULT, 0, 0, 0, 0. 7738549, - 31. 88898, 30. 52104
I NTERMEDI ATE_POI NT_RESULT, 0, 0, - 4, 0, 0, 26. 76711
I NTERMEDI ATE_POI NT_RESULT, 0, 0, - 6, 0, 0, 23. 55008
```

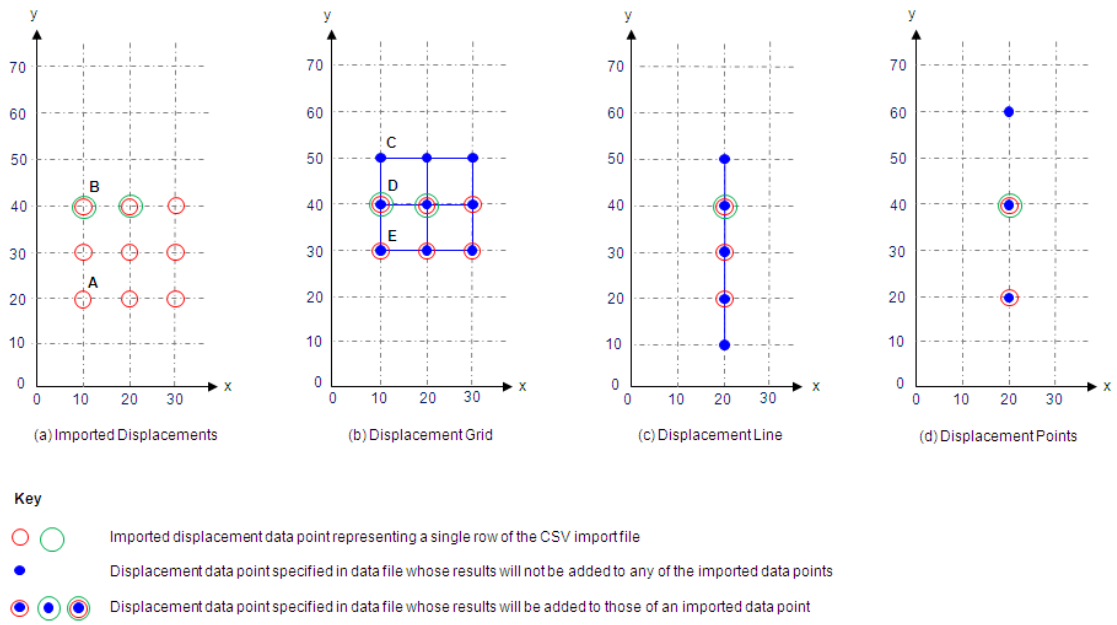
If units are not specified in the file then a dialog will be shown at the beginning of the import process for the user to specify the units of the data in the file.

These imported displacements may be viewed via 'Data | Imported Displacements...' from the program menu or via the Gateway. Once imported they are non-editable. Imported displacements can be deleted by right-clicking in the Imported Displacements input table and selecting 'Delete All' from the subsequent context menu.

In order that imported displacements may be combined sensibly with displacements that are generated by **XDisp**, the following rules apply.

1) All coordinates of data in the import file are imported whether a match is found for them or not in the displacement grids, lines and points of the current XDisp file.
2) The checking of whether coordinates match those of the displacement grids, lines and points in the XDisp file is performed at the time of analysis. The tolerance for coincidence is 1 mm in all of the x, y and z directions. Those coordinates which match any in the XDisp file will have their results added to those of that XDisp file after analysis.
3) If there are multiple entries of displacements for the same point in the import file, all those displacements will be added to those calculated by XDisp for the displacement position, whether that position is modelled by XDisp as a displacement point, or as a point within a displacement line or grid.
4) Similarly, if one point in the import file is matched with more than one in the data file, e.g. if displacement points, lines or grids contain coincident positions, then the imported displacements will be added to each of the matching positions in the data file.

The diagram below illustrates a series of displacement coordinates in a CSV import file, a Displacement Grid, a Displacement Line, and three Displacement Points in an XDisp data file. It shows how the results would be combined.



Coordinates such as 'A' are present in the CSV import file in one row of data only with one set of x, y and z displacements. Coordinates such as 'B' are present in the CSV file in two rows of data and so

have two sets of x,y and z displacements. Coordinates such as 'C' are present only in the XDisp data file and not in the CSV import file. Their results will therefore only reflect the results from XDisp's calculation of displacements. Coordinates such as 'D' are present in the XDisp data file, but also in two rows of the CSV import file. Their results will therefore be the sum of those from XDisp's calculation of displacements and the two rows of results in the CSV import file. Coordinates such as 'E' are present in the XDisp data file and in one row of the CSV import file. Their results will therefore be the sum of those from XDisp's calculation of displacements and that one row of results in the CSV import file.

If an imported result is intended to be added to results at each displacement point in the XDisp data file, then care should be taken to ensure that the imported file contains one result for every data point. When importing results from Oasys PDisp this is most easily achieved by creating the same set of Displacement Grids, Lines and Points in the two programs for export from one and import to the other. Having created the Displacement Grids, Lines and Points in one of the programs they can be input to the other by copying and pasting between the programs' Displacement Data input tables by highlighting the required cells and via the right-click context menu options of 'Copy' and 'Paste'. Note that the last columns in the Displacement Data for the two programs may display different data, so only the first, common columns should be copied.

Caution should be employed if results are inspected for which not all points of Displacement Grids, Lines and Points have matching imported displacements.

The Text Output may be inspected for a summary of the displacements that have been imported and, after analysis, those which have been found to match displacement points in the XDisp file.

6.2 Export

6.2.1 CSV Results File

A comma-separated value (CSV) file of results may be output by selecting 'File | Export | CSV Results File ..." on the program menu. This option is disabled if there are no results, so an analysis must have first been performed. On selection of that menu option the CSV export selection dialog will appear.

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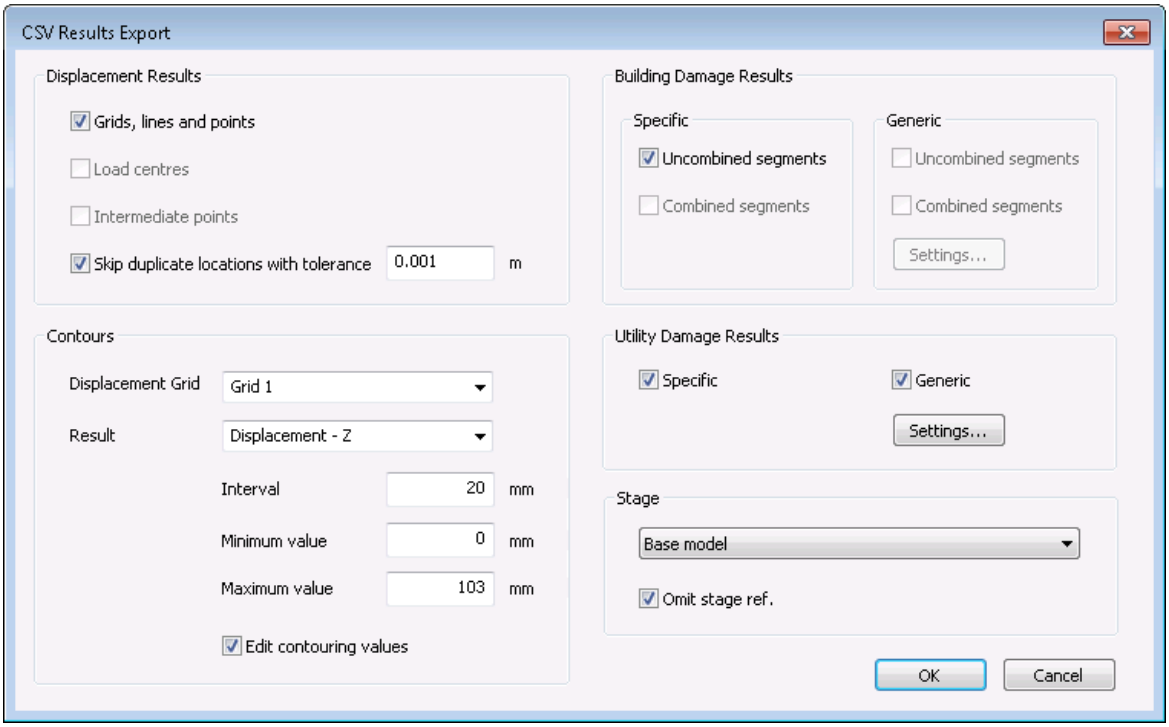

The CSV output file may contain any of the following:

- grid, line and point displacements;
- alignments of displacement contours in any of the x, y, z or resultant directions;
- specific building damage results for uncombined and/or combined segments of sub-buildings;
- generic building damage results for uncombined and/or combined segments of sub-buildings;
- specific utility damage results.

If a grid is selected for a direction that contains results that are all zero, then that direction will be disabled.

'Skip duplicate locations with tolerance' option allows the user to ignore duplicate points. Only one instance of the result at each location is output. All subsequent results at that location are ignored. For instance, if one displacement line's end point is coincident with another's start point, then only one results will be output for that point.

The option to 'Omit stage ref.' controls whether entries will be included in the CSV file to identify the stage that is associated with the result. The option is enabled and pre-selected if 'All' stages are selected, since the Stage reference is necessary to distinguish one stage's results from another. However, if CSV results for a single stage are to be exported for subsequent import into Oasys PDisp, then this option should be unselected since Oasys PDisp does not recognise stage information.

One purpose of this output is to allow building damage segments/categories and displacement contours to be plotted on drawings in other design programs e.g. AutoCAD.

The output file includes keywords to identify the content of each row of data.

Samples of output are given below to show the format.

Displacements for displacement data are identified by the keyword: POINT_RESULT (for a Displacement Point); LPOINT_RESULTS (for a single location on a Displacement Line);

PLPOINT_RESULT (for a single location on a Displacement Polyline); or GPOINT_RESULT (for a single location on a Displacement Grid). They follow the sequence:

Keyword,
(Stage No.),
x Coordinate,
y Coordinate,
z Coordinate,
x Displacement,
y Displacement,
z Displacement.

Contour data lines are identified by the keyword: CONTOUR_RESULTANT; CONTOUR_X; CONTOUR_Y; or CONTOUR_Z. They follow the sequence:

Keyword,
(Stage No.),
Grid No.,
Contour value,
x Coordinate 1,
y Coordinate 1,
x Coordinate 2,
y Coordinate 2.

They describe discrete segments of a contour line.

Specific building damage results' data lines are identified by the keyword BDA_SPECIFIC_RESULT_UNCOMBINED_SEGMENTS or BDA_SPECIFIC_RESULT_COMBINED_SEGMENTS. They follow the sequence:

Keyword,
(Stage No.),
Building No.,
Building Name,
Sub-Building Name,
Offset No.,
Segment No.,
Segment Start x,
Segment Start y,
Segment Start z,
Segment End x,
Segment End y,
Segment End z,
Damage Category.

Specific building damage results' data lines for critical values for all segments in a sub-building are identified by the keyword BDA_SPECIFIC_RESULT_UNCOMBINED_SEGMENTS_CRITICAL_VALUES. They follow the sequence:

Keyword,
(Stage No.),
Building No.,
Building Name,
Sub-Building Name,

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Offset No.,
Max. Deflection Ratio,
Max. Average Horizontal Strain
Max. Slope
Max. Settlement
Max. Tensile Strain
Max. Gradient of Horizontal Displacement Curve
Max. Gradient of Vertical Displacement Curve
Minimum Radius of Curvature (Hogging)
Minimum Radius of Curvature (Sagging)
Damage Category

Generic building damage results' data lines are identified by the keyword BDA_GENERIC_RESULT_UNCOMBINED_SEGMENTS or BDA_GENERIC_RESULT_COMBINED_SEGMENTS follow the sequence:

Keyword,
(Stage No.),
Building No : Name.,
Polyline No : Name.,
L/H,
Transect No.,
Transect Start x,
Transect Start y,
Transect Start z,
Transect End x,
Transect End y,
Transect End z,
Vertical Offset,
Segment No.,
Segment Start,
Segment Length,
Curvature,
Deflection Ratio,
Average Horizontal Strain,
Maximum Tensile Strain,
Maximum Gradient of Horizontal Displacement Curve,
Maximum Gradient of Vertical Displacement Curve,
Minimum Radius of Curvature
Damage Category.

However, for generic buildings the user can choose the columns that they want to export via its Export Columns dialog that is accessed by clicking the Settings button present in the Generic Building Damage Results group box.

Note: Maximum Gradient of Horizontal Displacement Curve, Maximum Gradient of Vertical Displacement Curve and Minimum Radius of Curvature won't be exported for the combined segments.

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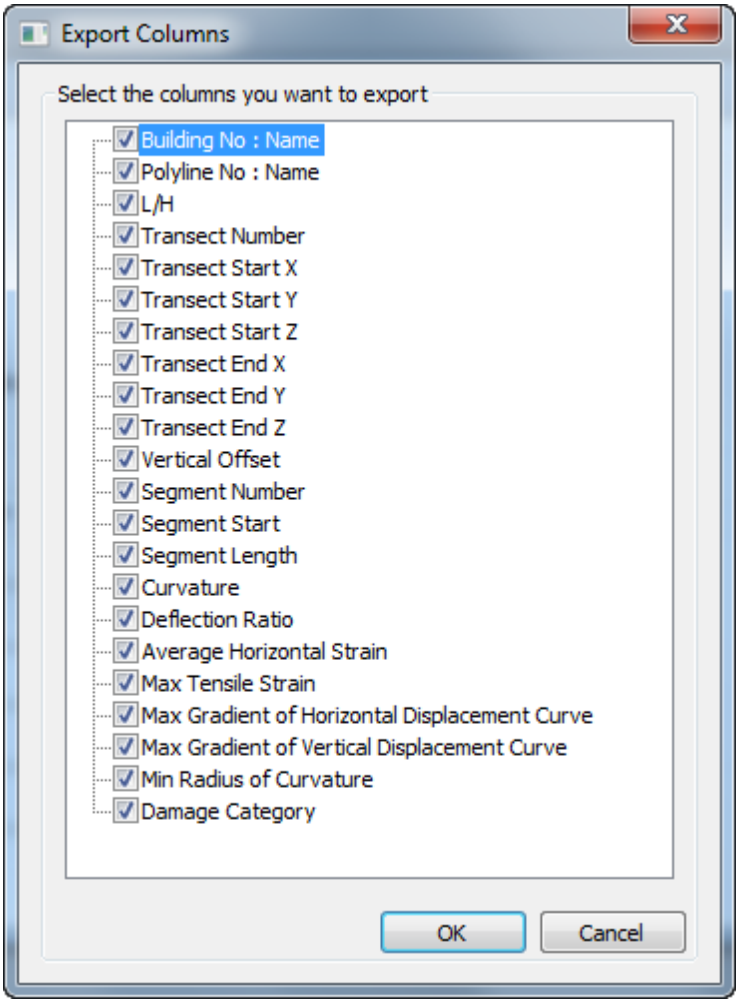

Specific utility damage results' data lines are identified by the keyword UDA_SPECIFIC_RESULT_COODS_DISPS for coordinates and displacements. They follow the sequence:

Keyword,
(Stage No.),
Utility Name,
Sub-Utility Name,
Iteration No.,
Distance (from the utility's start point),
x Coordinate,
y Coordinate,
z Coordinate,
x Displacement,
y Displacement,
z Displacement,
Horizontal Displacement along the utlility,
Horizontal Displacement perpendicular to the utility,
x Displacement at (n-L_p),
y Displacement at (n-L_p),
z Displacement at (n-L_p),
Horizontal Displacement along the utlility at (n-L_p),

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Horizontal Displacement perpendicular to the utility at (n-L_p),
x Displacement at (n+L_p),
y Displacement at (n+L_p),
z Displacement at (n+L_p),
Horizontal Displacement along the utlility at (n+L_p),
Horizontal Displacement perpendicular to the utility at (n+L_p),

Specific utility damage results' data lines for pullouts and rotations are identified by the keyword UDA_SPECIFIC_RESULT_PULLOUTS_ROTATIONS. They follow the sequence:

Keyword,
(Stage No.),
Utility Name,
Sub-Utility Name,
Iteration No.,
Distance (from the utility's start point),
x Coordinate,
y Coordinate,
z Coordinate,
Axial Pullout (left segment) - Unfactored,
Axial Pullout (left segment) - Factored,
Flexural Pullout (left segment) - Unfactored,
Flexural Pullout (left segment) - Factored,
Axial Pullout (right segment) - Unfactored,
Axial Pullout (right segment) - Factored,
Flexural Pullout (right segment) - Unfactored,
Flexural Pullout (right segment) - Factored,
Total Axial Pullout - Unfactored,
Total Axial Pullout - Factored,
Total Flexural Pullout - Unfactored,
Total Flexural Pullout - Factored,
Total Pullout - Unfactored,
Total Pullout - Factored,
Threshold Check,
Limit Check,
Rotation - Unfactored,
Rotation - Factored,
Threshold Check,
Limit Check,
Sagging vs Hogging.

Specific utility damage results' data lines for strains are identified by the keyword UDA_SPECIFIC_RESULT_STRAINS. They follow the sequence:

Keyword,
(Stage No.),
Utility Name,
Sub-Utility Name,
Distance (from the utility's start point),
x Coordinate,
y Coordinate,
z Coordinate,
Axial Strain - Unfactored,

Axial Strain - Factored,
Flexural Strain - Tension - Unfactored,
Flexural Strain - Tension - Factored,
Flexural Strain - Compression - Unfactored,
Flexural Strain - Compression - Factored,
Total Tension - Unfactored,
Total Tension - Factored,
Tension Check,
Total Compression- Unfactored,
Total Compression- Factored,
Compression Check,
Radius of Curvature,
Threshold Check,
Limit Check,
Peak Flexural Tensile Strain Orientation Angle (with respect to global z axis).

Generic utility damage results' data lines for coordinates and displacements are identified by the keyword UDA_GENERIC_RESULT_COODS_DISPS. They follow the sequence:

Keyword,
(Stage No.),
Generic Utility No : Name,
Polyline No : Name,
Transect No.,
Transect Start x,
Transect Start y,
Transect Start z,
Transect End x,
Transect End y,
Transect End z,
Iteration No.,
Distance (from the utility's start point),
x Coordinate,
y Coordinate,
z Coordinate,
x Displacement,
y Displacement,
z Displacement,
Horizontal Displacement along the utlility,
Horizontal Displacement perpendicular to the utility,
x Displacement at (n-L_p),
y Displacement at (n-L_p),
z Displacement at (n-L_p),
Horizontal Displacement along the utlility at (n-L_p),
Horizontal Displacement perpendicular to the utility at (n-L_p),
x Displacement at (n+L_p),
y Displacement at (n+L_p),
z Displacement at (n+L_p),
Horizontal Displacement along the utlility at (n+L_p),
Horizontal Displacement perpendicular to the utility at (n+L_p),

Generic utility damage results' data lines for pullouts and rotations are identified by the keyword

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UDA_GENERIC_RESULT_PULLOUTS_ROTATIONS. They follow the sequence:

Keyword,
(Stage No.),
Generic Utility No : Name,
Polyline No : Name,
Transect No.,
Transect Start x,
Transect Start y,
Transect Start z,
Transect End x,
Transect End y,
Transect End z,
Iteration No.,
Distance (from the utility's start point),
x Coordinate,
y Coordinate,
z Coordinate,
Axial Pullout (left segment) - Unfactored,
Axial Pullout (left segment) - Factored,
Flexural Pullout (left segment) - Unfactored,
Flexural Pullout (left segment) - Factored,
Axial Pullout (right segment) - Unfactored,
Axial Pullout (right segment) - Factored,
Flexural Pullout (right segment) - Unfactored,
Flexural Pullout (right segment) - Factored,
Total Axial Pullout - Unfactored,
Total Axial Pullout - Factored,
Total Flexural Pullout - Unfactored,
Total Flexural Pullout - Factored,
Total Pullout - Unfactored,
Total Pullout - Factored,
Threshold Check,
Limit Check,
Rotation - Unfactored,
Rotation - Factored,
Threshold Check,
Limit Check,
Sagging vs Hogging.

Generic utility damage results' data lines for strains are identified by the keyword UDA_GENERIC_RESULT_STRAINS. They follow the sequence:

Keyword,
(Stage No.),
Generic Utility No : Name,
Polyline No : Name,
Transect No.,
Transect Start x,
Transect Start y,
Transect Start z,
Transect End x,
Transect End y,
Transect End z,
Iteration No.,

Distance (from the utility's start point),
x Coordinate,
y Coordinate,
z Coordinate,
Axial Strain - Unfactored,
Axial Strain - Factored,
Flexural Strain - Tension - Unfactored,
Flexural Strain - Tension - Factored,
Flexural Strain - Compression - Unfactored,
Flexural Strain - Compression - Factored,
Total Tension - Unfactored,
Total Tension - Factored,
Tension Check,
Total Compression- Unfactored,
Total Compression- Factored,
Compression Check,
Radius of Curvature,
Threshold Check,
Limit Check,
Peak Flexural Tensile Strain Orientation Angle (with respect to global z axis).

However, for generic utilities the user can choose the columns that they want to export via its Export Columns dialog that is accessed by clicking the Settings button present in the Generic Utility Damage Results group box.

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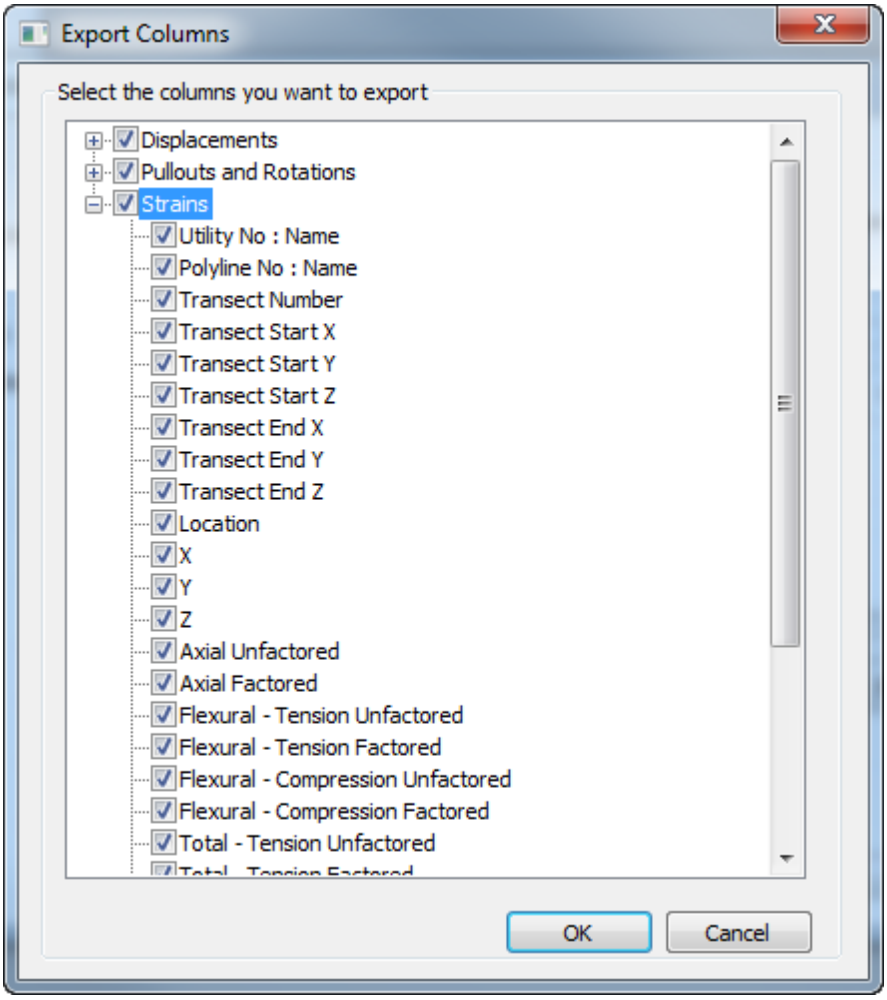

Dimensions for output data are chosen by the user in the "Save As" dialog that follows the "CSV Results File Output Selection" dialog. Length and displacement units' indices are: 0 - metres; 1 - centimetres; 2 - millimetres; 3 - feet; 4 - inches. Angle units' indices are 0 - radians; 1 - degrees.

Units information should appear before the results.

e.g. (an example with no Stage reference)

```
UNIT_DISP, 2
UNIT_LENGTH, 0
CONTOUR_RESULTANT, 1, 10. , 30. , 22. 94968, 27. 96293, 23. 98147
CONTOUR_RESULTANT, 1, 10. , 27. 96293, 23. 98147, 26. 13617, 25.
CONTOUR_RESULTANT, 1, 10. , 26. 13617, 25. , 23. 26587, 26. 63294
. . .
CONTOUR_X, 1, - 60. , 90. , 80. 55464, 89. 26049, 80. 36975
CONTOUR_X, 1, - 60. , 89. 26049, 80. 36975, 88. 89082, 80.
CONTOUR_X, 1, - 60. , 95. 56882, 75. , 91. 57434, 74. 21283
. . .
CONTOUR_Y, 1, - 60. , 48. 88889, 80. , 49. 25906, 79. 62953
CONTOUR_Y, 1, - 60. , 49. 25906, 79. 62953, 50. , 79. 4441
CONTOUR_Y, 1, - 60. , 49. 77666, 85. , 49. 81781, 84. 90891
. . .
CONTOUR_Z, 1, 0. , 50. , 0. 4412712, 48. 84946, 0. 5752676
CONTOUR_Z, 1, 0. , 48. 84946, 0. 5752676, 43. 20705, 0.
CONTOUR_Z, 1, 0. , 60. , 0. 3418683, 59. 22948, 0. 3852612
. . .
BDA_SPECIFIC_RESULT_UNCOMBINED_SEGMENTS, 1, Building 1, West
```

```
Facade,1,1,50.,150.,0.,66.96732,150.,0.,2
BDA_SPECIFIC_RESULT_UNCOMBINED_SEGMENTS,1,Building 1,West
Facade,1,2,66.96732,150.,0.,83.03243,150.,0.,1
BDA_SPECIFIC_RESULT_UNCOMBINED_SEGMENTS,1,Building 1,West
Facade,1,3,83.03243,150.,0.,116.9676,150.,0.,3
BDA_SPECIFIC_RESULT_UNCOMBINED_SEGMENTS,1,Building 1,West
Facade,1,4,116.9676,150.,0.,133.0326,150.,0.,1
BDA_SPECIFIC_RESULT_UNCOMBINED_SEGMENTS,1,Building 1,West
Facade,1,5,133.0326,150.,0.,150.,150.,0.,2
BDA_SPECIFIC_RESULT_UNCOMBINED_SEGMENTS,1,Building 1,West
Facade,2,1,50.,150.,0.,67.15132,150.,0.,3
BDA_SPECIFIC_RESULT_UNCOMBINED_SEGMENTS,1,Building 1,West
Facade,2,2,67.15132,150.,0.,80.84868,150.,0.,2
BDA_SPECIFIC_RESULT_UNCOMBINED_SEGMENTS,1,Building 1,West
Facade,2,3,80.84868,150.,0.,117.1513,150.,0.,3
BDA_SPECIFIC_RESULT_UNCOMBINED_SEGMENTS,1,Building 1,West
Facade,2,4,117.1513,150.,0.,130.8487,150.,0.,2
BDA_SPECIFIC_RESULT_UNCOMBINED_SEGMENTS,1,Building 1,West
Facade,2,5,130.8487,150.,0.,148.,150.,0.,3
BDA_SPECIFIC_RESULT_UNCOMBINED_SEGMENTS,1,Building 1,West
Facade,3,1,50.,150.,0.,64.3278,150.,0.,3
BDA_SPECIFIC_RESULT_UNCOMBINED_SEGMENTS,1,Building 1,West
Facade,3,2,64.3278,150.,0.,75.6722,150.,0.,2
BDA_SPECIFIC_RESULT_UNCOMBINED_SEGMENTS,1,Building 1,West
Facade,3,3,75.6722,150.,0.,114.3278,150.,0.,3
BDA_SPECIFIC_RESULT_UNCOMBINED_SEGMENTS,1,Building 1,West
Facade,3,4,114.3278,150.,0.,125.6722,150.,0.,2
BDA_SPECIFIC_RESULT_UNCOMBINED_SEGMENTS,1,Building 1,West
Facade,3,5,125.6722,150.,0.,140.,150.,0.,3
BDA_SPECIFIC_RESULT_COMBINED_SEGMENTS,1,Building 1,West
Facade,2,1,50.,150.,0.,67.13972,150.,0.,3
BDA_SPECIFIC_RESULT_COMBINED_SEGMENTS,1,Building 1,West
Facade,2,2,67.13972,150.,0.,117.1397,150.,0.,1
BDA_SPECIFIC_RESULT_COMBINED_SEGMENTS,1,Building 1,West
Facade,2,3,117.1397,150.,0.,130.8603,150.,0.,2
BDA_SPECIFIC_RESULT_COMBINED_SEGMENTS,1,Building 1,West
Facade,2,4,130.8603,150.,0.,148.,150.,0.,3
...
BDA_GENERIC_RESULT_UNCOMBINED_SEGMENTS,Building 1 : Generic 1,Polyline 1
: Polyline 1,10,1,50,200,0,150,200,0,0,1,0,13.54408393,Hogging,2.29E-
02,2.65E-02,5.03E-02,-2.93E-04,-1.59E-03,5312.377171,1 (Very Slight)
BDA_GENERIC_RESULT_UNCOMBINED_SEGMENTS,Building 1 : Generic 1,Polyline 1
: Polyline
1,10,1,50,200,0,150,200,0,0,2,13.54408393,23.37606931,Sagging,4.62E-02,-
3.24E-02,6.55E-03,1.01E-03,-1.59E-03,11144.33635,0 (Negligible)
BDA_GENERIC_RESULT_UNCOMBINED_SEGMENTS,Building 1 : Generic 1,Polyline 1
: Polyline
1,10,1,50,200,0,150,200,0,0,3,36.92015324,26.15969351,Hogging,3.33E-
02,2.86E-02,6.31E-02,-3.16E-04,1.59E-03,10204.52383,1 (Very Slight)
BDA_GENERIC_RESULT_UNCOMBINED_SEGMENTS,Building 1 : Generic 1,Polyline 1
: Polyline
1,10,1,50,200,0,150,200,0,0,4,63.07984676,23.37606931,Sagging,4.62E-02,-
3.24E-02,6.55E-03,1.01E-03,1.59E-03,11144.33635,0 (Negligible)
BDA_GENERIC_RESULT_UNCOMBINED_SEGMENTS,Building 1 : Generic 1,Polyline 1
: Polyline
1,10,1,50,200,0,150,200,0,0,5,86.45591607,13.54408393,Hogging,2.29E-
02,2.65E-02,5.03E-02,-2.93E-04,1.59E-03,5312.377171,1 (Very Slight)
BDA_GENERIC_RESULT_UNCOMBINED_SEGMENTS,Building 1 : Generic 1,Polyline 1
: Polyline 1,10,2,50,150,0,150,150,0,0,1,0,13.53985052,Hogging,4.58E-
02,5.31E-02,0.100628865,-5.86E-04,-3.18E-03,2656.829187,2 (Slight)
BDA_GENERIC_RESULT_UNCOMBINED_SEGMENTS,Building 1 : Generic 1,Polyline 1
: Polyline
1,10,2,50,150,0,150,150,0,0,2,13.53985052,23.38483934,Sagging,9.24E-02,-
6.47E-02,1.31E-02,2.02E-03,-3.18E-03,5567.203645,0 (Negligible)
BDA_GENERIC_RESULT_UNCOMBINED_SEGMENTS,Building 1 : Generic 1,Polyline 1
: Polyline
1,10,2,50,150,0,150,150,0,0,3,36.92468986,26.15062029,Hogging,6.65E-
02,5.72E-02,0.126163781,-6.32E-04,-3.18E-03,5104.761728,2 (Slight)
```


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```
BDA_GENERIC_RESULT_UNCOMBINED_SEGMENTS,Building 1 : Generic 1,Polyline 1
: Polyline
1,10,2,50,150,0,150,150,0,0,4,63.07531014,23.38483934,Sagging,9.24E-02,-
6.47E-02,1.31E-02,2.02E-03,3.18E-03,5567.203645,0 (Negligible)
BDA_GENERIC_RESULT_COMBINED_SEGMENTS,Building 1 : Generic 1,Polyline 1 :
Polyline 1,10,1,50,200,0,150,200,0,0,1,0,36.92389142,Sagging,4.08E-02,-
1.08E-02,1.28E-02,0 (Negligible),,,
BDA_GENERIC_RESULT_COMBINED_SEGMENTS,Building 1 : Generic 1,Polyline 1 :
Polyline
1,10,1,50,200,0,150,200,0,0,2,36.92389142,26.15221715,Hogging,3.32E-
02,2.86E-02,6.31E-02,1 (Very Slight)
BDA_GENERIC_RESULT_COMBINED_SEGMENTS,Building 1 : Generic 1,Polyline 1 :
Polyline
1,10,1,50,200,0,150,200,0,0,3,63.07610858,23.38363447,Sagging,4.62E-02,-
3.24E-02,6.55E-03,0 (Negligible)
BDA_GENERIC_RESULT_COMBINED_SEGMENTS,Building 1 : Generic 1,Polyline 1 :
Polyline
1,10,1,50,200,0,150,200,0,0,4,86.45974304,13.54025696,Hogging,2.29E-
02,2.66E-02,5.03E-02,1 (Very Slight)
...
UNIT_DISP,2

UNIT_LENGTH,0

UDA_SPECIFIC_RESULTS_COODS_DISPS,Utility 1,Sub
1,1,20,70,150,0,10.0678,0,40.27141,10.06785,0,0.46361,0,0.37089,0.46361,
0,-6.3250,0,8.44476,-6.3250,0
UDA_SPECIFIC_RESULTS_COODS_DISPS,Utility 1,Sub
1,2,21,70,150,0,8.64098,0,43.20492,8.64098,0,0.65264,0,0.54387,0.65264,0
,-5.290,0,6.6315,-5.290,0
UDA_SPECIFIC_RESULTS_COODS_DISPS,Utility 1,Sub
1,3,22,72,150,0,6.845,0,45.633,6.845,0,0.9029,0,0.7851,0.9029,0,-
4.3356,0,5.1298,-4.335,0
...
UNIT_DISP,2

UNIT_LENGTH,0

UNIT_ANGLE,1
UDA_SPECIFIC_RESULT_PULLOUTS_ROTATIONS,Utility 1,Sub
1,1,20,70,150,0,6.32531,6.32531,2.23968,2.23968,-4.75156,-
4.75156,2.23968,2.23968,-11.07688,-11.07688, 4.47935, 4.47935,
                                4.47935,4.47935,-,OK,0.20548,0.20548,-
,OK,Sagging
UDA_SPECIFIC_RESULT_PULLOUTS_ROTATIONS,Utility 1,Sub
1,2,21,71,150,0,6.714,6.714,2.474,2.474,-5.482,-5.482,2.474,2.474,-
12.197,-12.197,4.948,4.948,4.948,4.948,-,OK,0.2269,0.2269,-
                        ,OK,Sagging
UDA_SPECIFIC_RESULT_PULLOUTS_ROTATIONS,Utility 1,Sub
1,3,22,72,150,0,7.00959,7.00959,2.6651,-6.1008,-6.1008,2.6651,2.6651,-
13.1104,-13.1104,5.3302,5.3302,5.3302,-,OK,0.24452,-
           ,OK,Hogging
...
UNIT_DISP,2

UNIT_LENGTH,0

UNIT_ANGLE,1

UDA_SPECIFIC_RESULT_STRAINS,Utility 1,Sub
1,1,51,150,0,219.69,43.938,42.663,42.663,-42.663,-
42.663,262.351,86.600,OK,-,-,-,14638.051,Fails,Fails,0
UDA_SPECIFIC_RESULT_STRAINS,Utility 1,Sub
1,2,52,150,0,287.49,57.498,55.882,55.882,-55.882,-
55.882,343.372,113.38,Fails,-,-,-,11175.00,Fails,Fails,0
UDA_SPECIFIC_RESULT_STRAINS,Utility 1,Sub
1,3,53,150,0,368.39,73.667,71.67,71.67,-71.67,-
71.67,440.0571,145.347,Fails,-,-,-,8713.573,Fails,Fails,0
```

```
...
UNIT_DISP,2
UNIT_LENGTH,0
UDA_GENERIC_RESULT_COODS_DISPS,Utility 1 : Generic Utility 1,Polyline 1
:
Polyline1,2,50,150,0,150,150,0,1,20,70,150,0,10.06785,0,40.27141,10.0678
5,0,0.46361,0,0.37089,0.46361,0,-6.32503,0,8.44476,-6.32503,0
UDA_GENERIC_RESULT_COODS_DISPS,Utility 1 : Generic Utility 1,Polyline 1
: Polyline 1,2,50,150,0,150,150,0,1,40,90,150,0,-6.32503,0,8.44476,-
6.32503,0,10.06785,0,40.27141,10.06785,0,6.32503,0,8.44476,6.32503,0
UDA_GENERIC_RESULT_COODS_DISPS,Utility 1 : Generic Utility 1,Polyline 1
: Polyline
1,2,50,150,0,150,150,0,1,60,110,150,0,6.32503,0,8.44476,6.32503,0,-
6.32503,0,8.44476,-6.32503,0,-10.06785,0,40.27141,-10.06785,0
UDA_GENERIC_RESULT_COODS_DISPS,Utility 1 : Generic Utility 1,Polyline 1
: Polyline 1,2,50,150,0,150,150,0,1,80,130,150,0,-10.06785,0,40.27141,-
10.06785,0,6.32503,0,8.44476,6.32503,0,-0.46361,0,0.37089,-0.46361,0
UDA_GENERIC_RESULT_COODS_DISPS,Utility 1 : Generic Utility 1,Polyline 1
: Polyline
1,2,50,150,0,150,150,0,2,21,71,150,0,8.64098,0,43.20492,8.64098,0,0.6526
4,0,0.54387,0.65264,0,-5.2906,0,6.63154,-5.2906,0
UDA_GENERIC_RESULT_COODS_DISPS,Utility 1 : Generic Utility 1,Polyline 1
: Polyline 1,2,50,150,0,150,150,0,2,41,91,150,0,-5.2906,0,6.63154,-
5.2906,0,8.64098,0,43.20492,8.64098,0,7.40794,0,10.58978,7.40794,0
...
UNIT_DISP,2
UNIT_LENGTH,0
UNIT_ANGLE,1
UDA_GENERIC_RESULT_PULLOUTS_ROTATIONS,Utility 1 : Generic Utility
1,Polyline 1 : Polyline
1,1,50,200,0,150,200,0,1,20,70,200,0,3.16266,3.16266,1.17549,1.17549,-
2.37578,-2.37578,1.17549,1.17549,-5.53844,-
5.53844,2.35098,2.35098,2.35098,2.35098,-,OK,0.10785,0.10785,-
,OK,Sagging
UDA_GENERIC_RESULT_PULLOUTS_ROTATIONS,Utility 1 : Generic Utility
1,Polyline 1 : Polyline 1,1,50,200,0,150,200,0,1,40,90,200,0,-2.37578,-
2.37578,0.52159,0.52159,0,0,0.52159,0.52159,2.37578,2.37578,1.04317,1.04
317,3.41895,3.41895,-,OK,0.04785,0.04785,-,OK,Hogging
UDA_GENERIC_RESULT_PULLOUTS_ROTATIONS,Utility 1 : Generic Utility
1,Polyline 1 : Polyline
1,1,50,200,0,150,200,0,1,60,110,200,0,0,0,0.52159,0.52159,2.37578,2.3757
8,0.52159,0.52159,2.37578,2.37578,1.04317,1.04317,3.41895,3.41895,-
,OK,0.04785,0.04785,-,OK,Hogging
UDA_GENERIC_RESULT_PULLOUTS_ROTATIONS,Utility 1 : Generic Utility
1,Polyline 1 : Polyline
1,1,50,200,0,150,200,0,1,80,130,200,0,2.37578,2.37578,1.17549,1.17549,-
3.16266,-3.16266,1.17549,1.17549,-5.53844,-
5.53844,2.35098,2.35098,2.35098,2.35098,-,OK,0.10785,0.10785,-
,OK,Sagging
...
UNIT_DISP,2
UNIT_LENGTH,0
UNIT_ANGLE,1
UDA_GENERIC_RESULT_STRAINS,Utility 1 : Generic Utility 1,Polyline 1 :
Polyline 1,1,50,200,0,150,200,0,1,51,200,0,109.84,21.968,22.391,22.391,-
22.391,-22.391,132.23088,44.35934,OK,-,-0.42356,OK,2.79E
+04,OK,OK,17.70068
UDA_GENERIC_RESULT_STRAINS,Utility 1 : Generic Utility 1,Polyline 1 :
Polyline 1,1,50,200,0,150,200,0,2,52,200,0,143.74,28.747,29.329,29.329,-
29.329,-29.329,173.06558,58.0767,OK,-,-0.58226,OK,2.13E
+04,Fails,Fails,17.70068
UDA_GENERIC_RESULT_STRAINS,Utility 1 : Generic Utility 1,Polyline 1 :
Polyline 1,1,50,200,0,150,200,0,3,53,200,0,184.18,36.835,37.616,37.616,-
37.616,-37.616,221.79246,74.45105,OK,-,-0.78035,OK,1.66E
+04,Fails,Fails,17.70068
UDA_GENERIC_RESULT_STRAINS,Utility 1 : Generic Utility 1,Polyline 1 :
Polyline 1,1,50,200,0,150,200,0,4,54,200,0,230.91,46.183,47.202,47.202,-
47.202,-47.202,278.1145,93.38433,OK,-,-1.01924,OK,1.32E
```


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```
+04, Fails, Fails, 17.70068
UDA_GENERIC_RESULT_STRAINS, Utility 1 : Generic Utility 1, Polyline 1 :
Polyline 1, 1, 50, 200, 0, 150, 200, 0, 5, 55, 200, 0, 283.02, 56.604, 57.9, 57.9, -
57.9, -57.9, 340.91916, 114.50414, Fails, -, -1.29663, OK, 1.08E
+04, Fails, Fails, 17.70068
...
GPOINT_RESULT, 150., 240., -25., 0., 0., -1.e-003
GPOINT_RESULT, 150., 250., -25., 0., 0., -1.e-003
...
LPOINT_RESULT, 50., 150., 0., 0.4636086, 0., 0.3708869
LPOINT_RESULT, 51., 150., 0., 0.6526436, 0., 0.5438696
...
POINT_RESULT, 5., 150., 0., 0.9029427, 0., 0.7851676
POINT_RESULT, 55., 150., 0., 1.227543, 0., 1.115948
```

6.2.2 Bulk Chart Export

Once an analysis has been performed, so that results are available, bulk export of charts may be effected via 'File | Export | Charts...' from the program menu. Subsequent dialogs then allow the specification of the categories of charts to be exported, the format (JPG, BMP or WMF) and size (in pixels) of the exported image files, and the locations to which those files will be saved.

A context menu, to expand or collapse individual or all items, is available in the Chart Export Selections dialog by right-clicking in the dialog.

The Chart Export File Paths dialog presents options to specify a folder structure that can be created to contain the exported charts. To avoid long file paths, which may easily exceed operating system limits, codes are used instead of full descriptions for category titles in folder and file names.

"Charts" is an optional top level folder. Other folders adopt the abbreviations show below. If stage or entity category titles are required in file names too then these codes are used for that purpose too.

Stages:

ST - Stage

Entities:

DL - Displacement Line
DP - Displacement Polyline
SB - Specific Building
GB - Generic Building
SU - Specific Utility
GU - Generic Utility
RT - Rail Track

Generic building/utility chart options:

BT - By Transect
BB - By Building
BU - By Utility

Detailed chart options (included in file names where appropriate):

T - Transect
O - Offset

H - L/H ratio index
US - Uncombined Segment
CS - Combined Segment

e.g.

"<root>\Charts\ST0\SB\GB7\BT\GB7 - High Street - Building Damage Interaction T4 O2 H2 US4.jpg"

contains the "by Transect" Building Damage Interaction Chart for Transect 4, Offset 2, L/H ratio index 2, Uncombined Segment 4 of Generic Building 7 (named "High Street").

The Chart Export File Paths dialog allows the depth of the folder structure to be customised, along with the terms used in folder and file names. It also provides two default settings: "Deep" to create a folder structure as illustrated in the example above, and "Flat" to save all charts in the top level "Charts" folder.

As the various options are enabled or disabled in the Chart Export Paths dialog, so the status bar at the bottom of the program window shows a sample of the chosen folder structure and its folder and file names, in order to illustrate how the output will be arranged and named given the options that are currently selected in the dialog.

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Part VII

7 Toolbars and Keyboard Accelerators

7.1 Toolbars

Toolbars provide a short cut to the more commonly used commands. Toolbars except can be docked (attached to the application frame) or floating (free to be positioned by the user). The toolbars can be switched on and off as required from the “View | Toolbars” menu command.

7.1.1 Standard Toolbar

The Standard Toolbar provides access to the following common Windows functions along with some that are specific to the program.

New — create a new model
Open — open an existing file
Save — save the model to file

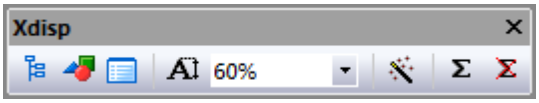
Cut — cut the data and place on clipboard
Copy — copy the data and place on the clipboard
Paste — paste the data from the clipboard into the model

Print — print the current view
Print Preview — preview the current view

About — opens the program's About Dialog e.g. to show version information
XDisp Home — opens the programs home page on the internet
Email — opens an email to the Oasys support team

7.1.2 Xdisp Toolbar

The XDisp Toolbar provides access to the following functions.



- open or close the Gateway
- open the 3D Graphics View
- open the Text Output View
- specify a custom font scale to size text in the Plan View, or when printing the Text Output (dependent on which of those views is active)
- select from a list of font scales to size text as above
- open the context sensitive wizard
- perform an analysis

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- delete the results

7.1.3 Plan Toolbar

The following graphical displays are available for the Plan View and can be displayed or hidden by toggling the individual icons on the Plan Toolbar or Graphics Menu.

Axis - Provides an axis and defined grid upon which the plan is drawn.

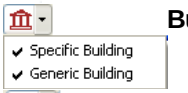
Engineering Scale - This allows the user to toggle between the default 'best fit' scale and the closest available engineering scale. e.g. 1:200, 1:250, 1:500, 1:1000, 1:1250, 1:2500.

Zoom Facility - The user can select an area to 'zoom in' to by using the mouse to click on a point on the drawing and then dragging the box outwards to select the area to be viewed. The program will automatically scale the new view. The original area can be restored by clicking on the 'restore zoom' icon as shown here.

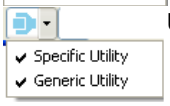
Edit Colours - The user can edit the colours of lines in the Plan View.

Tunnels and Mines - Toggles the display of tunnels and mines.

Excavations - Toggles the display of embedded wall excavation locations.



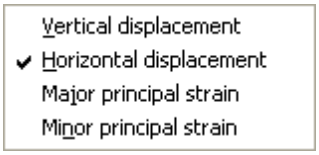
Buildings - Toggles the display of building alignments.



Utilities - Toggles the display of specific and generic utilities.

Grids, Lines, Points and Line Plots - All shown in blue as a grid or using crosses to define individual points and points along lines.

Contours - Right-click on the Plan View while either of these buttons is selected to choose the type of contour plot from the context menu. Contour lines or solid coloured contours are available depending on which button is selected.



.

Contours of major and minor principal strain are available providing the model contains no excavations, and no tunnels which use the Harris and Alvarado method or the Mair et al method.

Vectors - Toggles the display of horizontal displacement vectors. Right-click on the Plan View while this button is selected to select the type of vector plot from the context menu.

Strain crosses are available providing the model contains no excavations, and no tunnels which use the Harris and Alvarado method or the Mair et al method.

Line Graphs - Allows the user to plot the displacements along the selected displacement line, building damage results for the selected building, or utility damage results for the selected utility.

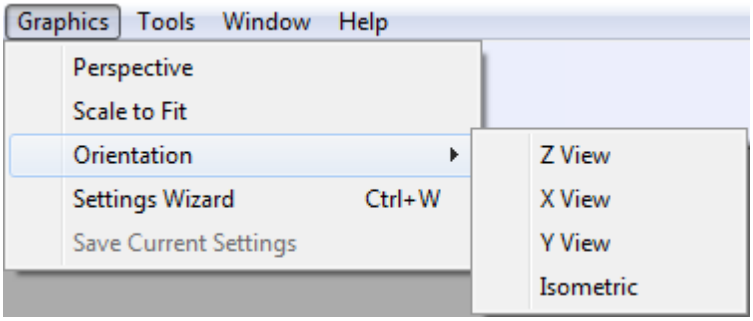
Change Displacement Grids - The user can move up or down to the results for different displacement grids.

Annotation - Allows the use of the cursor to annotate the contours. Place the cursor over the required location and left-click or press <return>. If a displacement line is in the vicinity of a contour you wish to annotate then de-select the displacement grids icon and proceed with the annotation.

Labels - Toggles the display of labels for tunnels, buildings and embedded wall excavations.

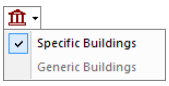
7.1.4 3D Graphics Toolbar

The 3D Graphics Menu and Toolbar provide rapid access to the functions to control the 3D Graphics View display. Greater control is possible via the 3D Graphics Settings wizard. For instance, the settings wizard allows individual buildings to be viewed or hidden, whereas the toolbar allows only the display of all or none.



- Toggles the display of all tunnels.

- Toggles the display of all excavations.



- Toggles the display of all buildings (clicking the drop arrow on the right of the button allows more specific selection).

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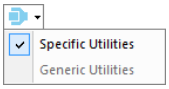
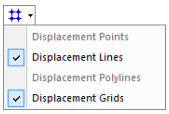


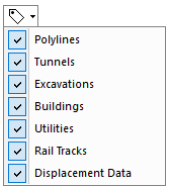
- Toggles the display of all utilities (clicking the drop arrow on the right of the button allows more specific selection).

- Toggles the display of all rail tracks.

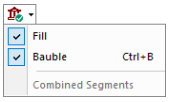


- Toggles the display of all displacement data (clicking the drop arrow on the right of the button allows more specific selection).

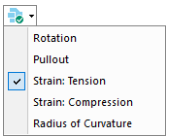
- Toggles the display of all polylines.



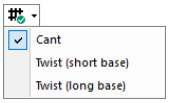
- Toggles the display of all labels (clicking the drop arrow on the right of the button allows more specific selection).



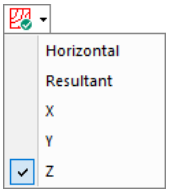
- Toggles the display of building results (clicking the button toggles 'Fill' results for uncombined segments, clicking the drop arrow on the right of the button allows more specific selection). Bauble results may also be toggled by <ctrl> + 'b' on the keyboard.



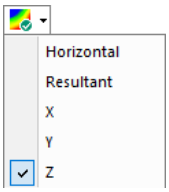
- Toggles the display of utility results (clicking the button toggles results for Strain: Tension, clicking the drop arrow on the right of the button allows more specific selection).



- Toggles the display of rail track results (clicking the button toggles results for Cant, clicking the drop arrow on the right of the button allows more specific selection).

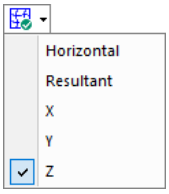


- Toggles the display of line contours for Displacement Grids (clicking the button toggles contours of Z displacement, clicking the drop arrow on the right of the button allows more specific selection).[1]



- Toggles the display of filled contours for Displacement Grids (clicking the button toggles contours of Z displacement, clicking the drop arrow on the right of the button allows more specific selection).[1]

- Toggles the display of the deflected shape of Displacement Data (clicking the



button toggles deflected shape based on Z displacement, clicking the drop arrow on the right of the button allows more specific selection).[1]

- Toggles the display of displacement values for Displacement Data locations (values are sensitive to which results are currently being displayed, or, if none, will show values for Z displacement).

- Orientates the view so as to be looking down the X axis.

- Orientates the view so as to be looking down the Y axis.

- Orientates the view so as to be looking down the Z axis (i.e. a plan view).

- Orientates the view so as to be viewing an isometric view.

- Toggles the display of the model in perspective mode.

- Re-sizes the view so as to be scaled to fit the available window size (when in graphical input mode it also resizes the grid if extents are not locked).

- Toggles the display of the model in wire frame mode.

- Toggles the display of nodes for Displacement Data.

- Toggles the display of the model in transparency mode.

- Toggles lighting on or off.

Notes

[1] Grids must first be visible, by selecting Displacement Data button to toggle Displacement Grids, before line contours, filled contours or the deflected shape of Displacement Grids can be shown.

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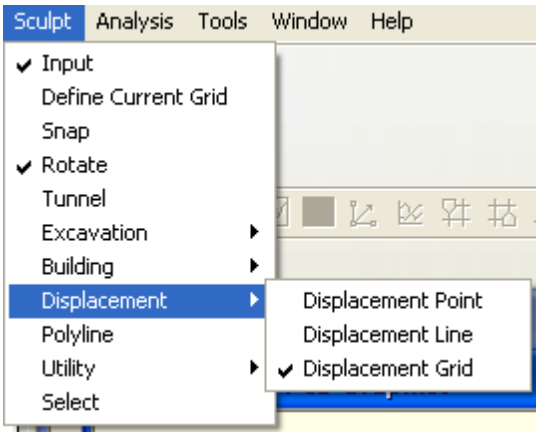
7.1.5 Graphical Input Toolbar

The Sculpt Menu and the Graphical Input Toolbar provide access to the following functions.



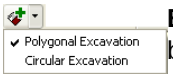
Input - toggles the mode of the 3DGraphics view between Input Mode and Output Mode.

Define Current Grid - to define grid planes and grid layouts and thereby set the current grid.

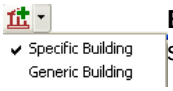
Snap - allows the cursor to snap to the nearest grid point.

Rotate - is the default cursor mode and allows models in the view to be rotated.

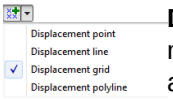
Tunnels - allows input of tunnels.



Excavations - by accessing the drop down menu of this button, the input mode can be set to polygonal or circular excavation to allow subsequent input of these elements.

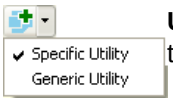


Buildings - by accessing the drop down menu of this button, the input mode can be set to specific or generic building to allow subsequent input of these elements.



Displacement Entities - by accessing the drop down menu of this button, the input mode can be set to displacement point or displacement line or displacement grid to allow subsequent input of these entities.

Polylines - allows input of polylines.



Utilities - by accessing the drop down menu of this button, the input mode can be set to specific or generic utility to allow subsequent input of these elements.

Select - allows selection of elements for modification

7.2 Keyboard Accelerators

Key	Action
Ctrl+Num 1	Window bottom-left
Ctrl+Num 2	Window bottom
Ctrl+Num 3	Window bottom-right
Ctrl+Num 4	Window left
Ctrl+Num 5	Window middle (full)
Ctrl+Num 6	Window right
Ctrl+Num 7	Window top-left
Ctrl+Num 8	Window top
Ctrl+Num 9	Window top-right
Ctrl+B	Manual Backup
Ctrl+C	Copy
Ctrl+F	Find
Ctrl+G	Go To
Ctrl+H	Replace
Ctrl+I	Converts an active 3D Graphics View to input mode
Ctrl+M	Modify
Ctrl+N	New
Ctrl+O	Open
Ctrl+P	Print
Ctrl+S	Save
Ctrl+Shft+S	Save As
Ctrl+V	Paste
Ctrl+W	Wizard
Ctrl+X	Cut
F1	Context Help
F5	Refresh (3D Graphics View)
Esc	Quit
Tab	Next Cell
Return	Next Cell
Insert	Insert
Delete	Delete
Home	Beginning of Cell
Ctrl+Home	Beginning of Table
End	End of Cell
Ctrl+End	End of Table
Page Up	Scroll up
Page Down	Scroll down

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↑Up	Row Up
←Lft	Column Left
→Rt	Column Right
↓Dn	Row Down

Part VIII

8 Miscellaneous

8.1 File Backups

A file backup results in a temporary copy of the model (input data and results if available) being saved in the user's temporary folder (i.e. C:\Users\<username>\AppData\Local\Temp).

Backups may be manual backups or timed backups.

Manual backups have "_M.xdd" appended to the file name. Timed backups have "_bak" appended to the file name.

A manual backup of the data file is created automatically on opening a file and on saving a file.

A timed backup of the data file is created periodically according to the user's preferences for timed backups and on beginning an analysis. If a model has results then no timed backup is made.

If the program shuts down prematurely (as a result of program malfunction or power failure etc) then the backup files remain on disk for subsequent use so that changes that were not saved by the user may be available. Such backup files may be deleted manually when they are no longer needed. Backup files will be overwritten if a data file with the same name is opened, so their previous contents will be lost.

If a data file is closed properly then its backup files are automatically deleted.

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Part IX

9 List of References

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