Geocentrix

ReActiv 2

Reference Manual

Set in Optimum using Corel WordPerfect X7. Printed in the UK.

Acknowledgments

ReActiv was designed and written by Dr Andrew Bond of Geocentrix, based on theory developed by Drs Jerry Love and George Milligan of the Geotechnical Consulting Group (GCG).

Version 1.0 of the program was tested by Rob Nyren (formerly at GCG) and Dr Ken Brady and Doug Boden of the Transport Research Laboratory. Version 1.5 was tested by Cedric Allenou (formerly at GCG). Professor David Hight of GCG helped design the database of critical state soil parameters.

The documentation was written by Andrew Bond and Jerry Love (of GCG).

Revision history

Last revised 27th October 2021 (for version 2.0.0).

Table of contents

Introduction

Welcome to ReActiv®, the reinforced slope design program. ReActiv is an interactive program that helps you to design reinforced slopes in a variety of different soil types, using reinforced soil or soil nails.

This chapter of the *ReActiv User Manual* outlines the contents of this book, explains the conventions that are used herein, and tells you what to do if you need help using the program.

About this book

This *User Manual* is divided into the following chapters:

- *Introduction*
- *Background theory and assumptions*
- *Proceeding to a final design*
- *Comparisons with published results*
- *Soil Classification System*

Conventions

To help you locate and interpret information easily, the *ReActiv User Manual* uses the following typographical conventions.

This	Represents
Bold	Items on a menu or in a list-box; the text on a button or next to an edit control; or the label of a group box.
Item1 > Item2	An item on a cascading menu. Item1 is the name of an option on the main menu bar (such as **File** or **Window**); and Item2 is the name of an option on the cascading menu that appears when you select Item1 (such as **New** or **Open**). Thus, **File > New** represents the New command from the File menu.
italic	Placeholders for information you must provide. For example, if you are asked to type *filename*, you should type the actual name for a file instead of the word shown in italics. Italic type also signals a new term. An explanation immediately follows the italicized term.
`monospaced`	Anything you must type on the keyboard.
CAPITALS	Directory names, filenames, and acronyms.
KEY1+KEY2	An instruction to press and hold down key 1 before pressing key 2. For example, "ALT+ESC" means press and hold down the ALT key before pressing the ESC key. Then release both keys.
KEY1, KEY2	An instruction to press and release key 1 before pressing key 2. For example, "ALT, F" means press and release the ALT key before pressing and releasing the F key.

Where to go for help

Your first source of help and information should be this manual and the ReActiv's extensive help system.

ReActiv's help system

ReActiv's help system contains detailed information about all aspects of the program. Help appears in a separate window with its own controls. Help topics that explain how to accomplish a task appear in windows that you can leave displayed while you follow the procedure.

To open the help system:

- Press `F1`
- Click the **Help** button in any dialog box
- Choose a command from the **Help** menu

If you need assistance with using the help system, choose the **How To Use Help** command from the **Help** menu.
Tooltips
If you pause while passing the mouse pointer over an object, such as a toolbar button, ReActiv displays the name of that object. This feature, called *tooltips*, makes it easier for you to identify what you see and to find what you need.

Software Re-Assurance™

Software Re-assurance for ReActiv (including updates, upgrades, and technical support) is available direct from Geocentrix. If you require Re-Assurance, please contact Geocentrix as follows:

ReActiv Technical Support Geocentrix Ltd Scenic House, 54 Wilmot Way Banstead, Surrey SM7 2PY, United Kingdom Please quote your licence number and on all correspondence	T: +44 (0)1737 373963 E: support@geocentrix.co.uk W: www.geocentrix.co.uk/support Please be at your computer and have your licence number ready when you call

Sales and marketing information

For sales and marketing information about ReActiv, please visit

http://www.geocentrix.co.uk/reactiv/index.html

or contact ReActiv Sales on the same numbers as above.

Documentation

The latest version of this *User Manual* (including any corrections and/or additions since the program's first release) are available in electronic (Adobe® Acrobat®) format from the Geocentrix website (www.geocentrix.co.uk/reactiv) and follow links to ReActiv's documentation.

Notes

The screenshots in this guide were produced on Windows 10. Your screen may differ, depending on the version of Windows on which you run ReActiv. Not all options are available in every edition of ReActiv.

In this guide, '[Documents]' refers to the folder where your ReActiv projects are saved. For Windows 10 and later this is:

C:\Users\Public\Documents\Geocentrix\ReActiv\2.0

Background theory and assumptions

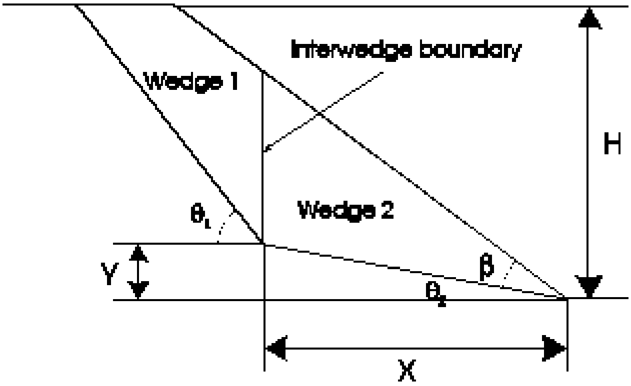
The UK Highways Agency's (HA's) Advice Note *Design methods for the reinforcement of highway slopes by reinforced soil and soil nailing techniques* (hereinafter called the Advice Note) describes a simple design method for the preliminary assessment of reinforcement requirements for highway slopes, using either reinforced soil or soil nailing techniques.

ReActiv follows this design method step-by-step, and is intended to fully compliment the Advice Note. However, the *User Manual* is also designed as a stand-alone document, so that it is not necessary to refer to the Advice Note to use the program. The theory behind ReActiv is, in some places, more advanced than that in the Advice Note.

This chapter gives a brief résumé of the basic theory and assumptions behind the design method used by ReActiv. The design is carried out in terms of effective stresses and applies to the long-term condition of permanent works. In some cases the notation adopted in this *User Manual* differs from that used in the Advice Note. A translation table of the terms that are different is given at the end of the chapter.

Two-part wedge mechanism with horizontal reinforcement

The design method used by ReActiv is based on limiting equilibrium of a two-part wedge mechanism (as shown below).



The mechanism considered has a vertical interwedge boundary. When there is no friction on the interwedge boundary, it provides inherently conservative solutions combined with reasonable simplicity, and is particularly suitable to reinforced soil geometries.

The inherent conservatism of the method can be reduced by taking interwedge friction into account. Guidance is given on this later in this chapter. Guidance is also given on the assumptions behind the method's simplified reinforcement distribution.

The design method assumes that a competent bearing material (which is significantly stronger than the slope fill) exists beneath the retained slope. The two-part wedge mechanism is constrained to pass through the toe of the slope.

ReActiv may be used as an automatic design tool or as a calculator. When used as a design tool, the program automatically and rapidly leads you to an optimized reinforcement layout for the given slope geometry, soil parameters, water regime, reinforcement type, etc. You do not have to guess a reinforcement layout or perform trial-and-error calculations (although you may do so, if you so wish).

Factors-of-safety

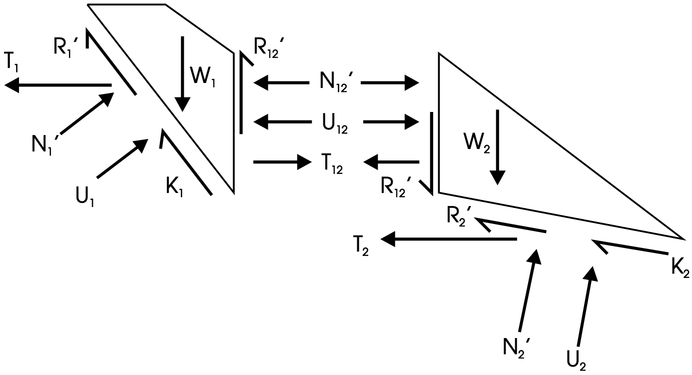
ReActiv employs partial factors-of-safety, along the lines given in the Advice Note.

The reinforcement strength that is entered into the program is assumed to be a *design* value (i.e. already factored).

You can enter soil strength parameters either as design values (i.e. critical state or large displacement values) or as peak values. When you specify strength parameters in terms of peak values, the program requires you to enter the partial factors-of-safety that should be applied to these peak values before using them for design.

Governing equations

The following diagram defines the forces acting on the two-part wedge mechanism when horizontal reinforcement is used.



The various symbols on this diagram have the following meanings:

- W_i is the weight of Wedge i
- N_i' is the force due to effective earth pressures acting on the base of Wedge i
- U_i is the force due to water pressures acting on the base of Wedge i
- R_i' is the force due to friction along the base of Wedge i
- K_i is the force due to effective cohesion along the base of Wedge i
- N_{12}' is the force due to effective earth pressures on the interwedge boundary
- U_{12} is the force due to water pressures on the interwedge boundary
- R_{12}' is the force due to friction along the interwedge boundary
- T_i is the reinforcement force provided through the base of Wedge i
- T_{12} is the reinforcement force transferred through the interwedge boundary

The expression for the out-of-balance horizontal reinforcement force (T) required for equilibrium is:

$$T = T_1 + T_2$$

The value of T can be derived from the expressions given in Appendix A of the Advice Note.

Equations with zero interwedge friction

If it is assumed that there is no friction on the interwedge boundary (i.e. $R_{12}' = 0$), the equation for T is given by:

$$T = \frac{W_1\left(\tan\theta_1 - \tan\phi\right) + \left(\dfrac{U_1 \tan\phi - K_1}{\cos\theta_1}\right)}{1 + \tan\theta_1 \tan\phi}$$

$$+ \frac{W_2\left(\tan\theta_2 - \lambda_s \tan\phi\right) + \lambda_s\left(\dfrac{U_2 \tan\phi - K_2}{\cos\theta_2}\right)}{1 + \lambda_s \tan\theta_2 \tan\phi}$$

The symbols in this equation that are not defined above are as follows:

- ϕ is the angle of friction of the soil
- θ_i is the angle that the base of Wedge i makes to the horizontal
- λ_s is a *sliding factor* (see below)

The *sliding factor* (λ_s) depends on the properties of the reinforcement and, in particular, on how much of the sliding surface the reinforcement occupies.

Equations with interwedge friction

If it is assumed that friction acts on the interwedge boundary (i.e. $R'_{12} \neq 0$), then the general equation for T is not determinate unless an assumption is made regarding the relative magnitudes of T_1, T_2, and T_{12}.

The simplest option is to adopt one or other of the following assumptions:

- All the reinforcement force acts on Wedge 1 (in which case $T_{12} = T_2$)
- All the reinforcement force acts on Wedge 2 (in which case $T_{12} = T_1$)

In both cases, the equation for T is:

$$T = \zeta_n \left[\frac{W_1\left(\tan\theta_1 - \tan\phi\right) + \left(\dfrac{U_1 \tan\phi - K_1}{\cos\theta_1}\right) - U_{12}\left(1 + \tan\theta_1 \tan\phi\right)}{\left(1 + \tan\theta_1 \tan\phi\right) + \left(\tan\theta_1 - \tan\phi\right)\tan\phi_{12}} \right]$$

$$+\zeta_n \left[\frac{W_2(\tan\theta_2 - \lambda_s \tan\phi) + \lambda_s\left(\frac{U_2 \tan\phi - K_2}{\cos\theta_2}\right) - U_{12}(1 + \lambda_s \tan\theta_2 \tan\phi)}{(1 + \lambda_s \tan\theta_2 \tan\phi) + (\tan\theta_2 - \lambda_s \tan\phi)\tan\phi_{12}} \right]$$

where ϕ_{12} is the angle of interwedge friction and ζ_n (zeta) is given below. The subscript *n* (= 1 or 2) denotes which wedge the reinforcement force acts on.

ζ_1 or ζ_2?

The assumption that the reinforcement force is carried solely by Wedge 1 (i.e. using ζ_1) leads to overly conservative designs for horizontal reinforcement.
The formula for ζ_1 is:

$$\zeta_1 = 1 + \left[\frac{\sin\theta_1 - \cos\theta_1 \tan\phi}{\cos\theta_1 - \sin\theta_1 \tan\phi} \right] \tan\phi_{12}$$

The alternative assumption, that the reinforcement force is carried solely by Wedge 2 (i.e. using ζ_2), leads to less conservative but more reasonable designs.
The formula for ζ_2 is:

$$\zeta_2 = 1 + \left[\frac{\sin\theta_2 - \lambda_s \cos\theta_2 \tan\phi}{\cos\theta_2 - \lambda_s \sin\theta_2 \tan\phi} \right] \tan\phi_{12}$$

Interwedge friction angle

The value of ζ_n depends on what angle of friction (ϕ_{12}) is assumed to act along the interwedge boundary. When $\phi_{12} = 0$, $\zeta_n = 1$. Appendix A of the Advice Note describes the results of a parametric study of the effects of ϕ_{12} on the maximum out-of-balance force (T_{max}) for slopes inclined at angles (β) between 40 and 70°. The figures from the Advice Note, which are reproduced here in Appendix 2, indicate that the maximum safe value for the interwedge friction angle is ½ϕ.

Critical mechanism

The *critical mechanism* at any one point in the slope is the mechanism that requires the greatest reinforcement force to establish its equilibrium. The critical mechanism is found by varying the angle of the upper wedge (θ_1) while keeping the mechanism's heel (X, Y) in the same place.

T_{max} mechanism

The T_{max} *mechanism* is the critical mechanism anywhere in the slope (including the baseline) that requires the greatest reinforcement force to establish its equilibrium. The T_{max} mechanism is used to calculate the required number of reinforcement layers (as described below).

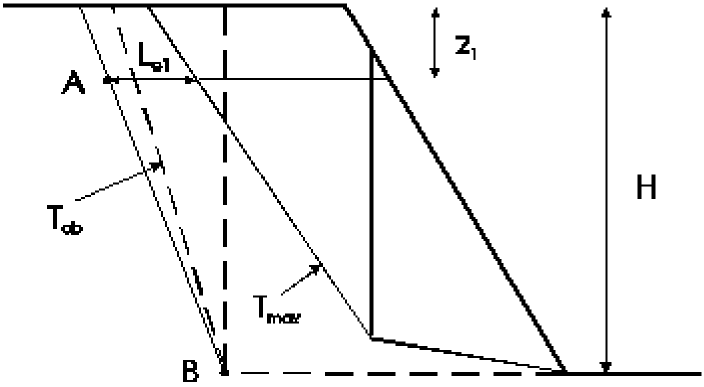
T_{ob} mechanism

The T_{ob} *mechanism* is the critical base-sliding mechanism that requires precisely zero reinforcement force to establish its equilibrium. The T_{ob} mechanism is used to calculate the lengths of the reinforcement layers (as described below).

Required reinforcement

The method of calculating the required reinforcement can be summarized as follows:

- First, a search is made for the T_{max} mechanism
- Second, the total number of reinforcement layers (n) is calculated from T_{max} and the long-term design strength of the reinforcement (P_{des})
- Third, the depth to the first layer of reinforcement (z_1) is calculated
- Fourth, the pullout length of the first layer (L_{e1}) is calculated — this defines point A on the following diagram
- Fifth, a search is made for the T_{ob} mechanism — this defines point B on the following diagram
- Sixth, the depths of the remaining layers are calculated
- Finally, the lengths of all the layers are calculated as the distance from their intersection with line AB to their intersection with the front face of the slope (if the line AB leans to the *right*, ReActiv sets it to vertical instead, as recommended in the Advice Note)



Number of layers

The total number of reinforcement layers (n) is given by the equation:

$$n = \frac{T_{max}}{P_{des}} + 1$$

where P_{des} (in kN per metre width of slope) is the long-term (factored) design strength of each reinforcement layer. Fractional values of n are not allowed: such values are rounded up to the next whole number.

The "+1" in the equation above ensures that a layer of reinforcement is provided at the base of the slope. As discussed in Appendix G of the Advice Note, this is not a source of over-design.

The terminology used in ReActiv differs from that given in the Advice Note, which uses the symbol N to represent the "minimum number of required layers". N is given by:

$$N = \frac{T_{max}}{P_{des}}$$

and N + 1 layers of reinforcement are provided.
ReActiv's symbol n is related to the Advice Note's N by:

$$n = N + 1$$

Depth to the first layer

The depth to the first reinforcement layer (z_1) is given by:

$$z_1 = \frac{0.5H}{\sqrt{n-1}}$$

where H is the height of the (lower) slope and n the total number of reinforcement layers.

Pullout length of the first layer

The pullout length of the first layer of reinforcement (L_{e1}) is given by:

$$L_{e1} = \frac{P}{\lambda_p\left(\sigma_n' \tan\phi + c'\right)}$$

where λ_p is the *pullout factor*; σ_n' is the normal effective stress acting on the reinforcement (see below); and ϕ and c′ are the soil's effective stress design parameters. The parameters ϕ and c′ in ReActiv correspond to ϕ_{des} and c'_{des} in the Advice Note.

The value of P is taken as the lesser of:

- The design strength of the reinforcement (P_{des})
- T_{max}

Normal effective stress

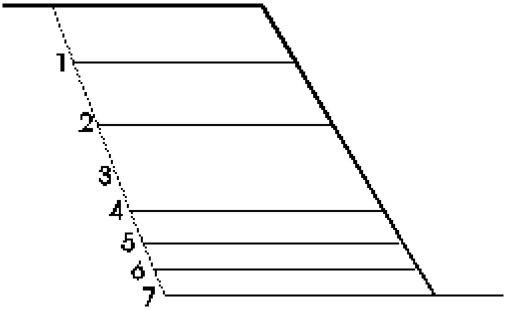
The normal effective stress (σ_n') that acts on horizontal reinforcement, assuming it is flat, is equal to the vertical effective stress in the soil (σ_v') mid-way along the pullout length of the reinforcement.

Depths of layers 2-n

The depths (z_i) of layers 2 to n are given by:

$$z_i = H\sqrt{\frac{i-1}{n-1}} \quad \text{for } i > 1$$

The diagram below illustrates a typical arrangement of layers using this formula.



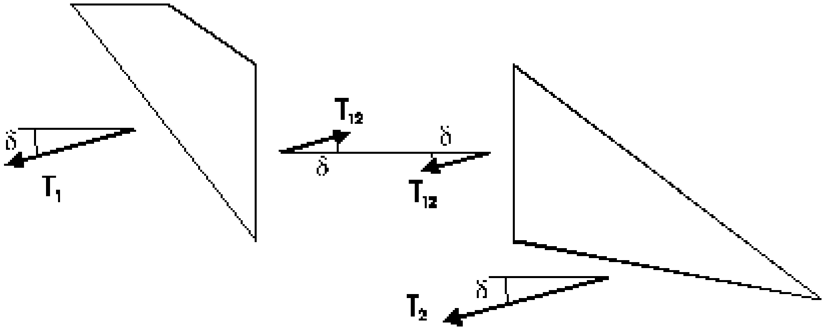
Further checks

For most practical design cases, the reinforcement layout defined in the Advice Note will adequately cover all possible intermediate two-part wedge mechanisms. ReActiv may be used to confirm this, by performing spot checks of individual mechanisms, especially for $\phi_{12} > 0$.

Two-part wedge mechanism with inclined reinforcement

The design method given in the Advice Note for inclined reinforcement is identical to that for horizontal reinforcement, except as described below:

- The equation for the total out-of-balance force (T) is more complicated because the components T_1, T_2, and T_{12} are inclined to the horizontal (see below)



- The T_{max} and T_{ob} mechanisms are called the $T_{max\delta}$ and $T_{o\delta}$ mechanisms to emphasize the fact that they are calculated for inclined reinforcement
- The average normal effective stress that acts on soil nails is not equal to the vertical effective stress in the soil

Governing equations

The general expression for the out-of-balance inclined reinforcement force (T) required for equilibrium is as given for horizontal reinforcement, except that the equation for zeta (as given below) is different.

ζ_1 or ζ_2?

The assumption that the reinforcement force is carried solely by Wedge 1 (i.e. using ζ_1) can lead to overly conservative designs for inclined reinforcement, particularly when the angle of interwedge friction (ϕ_{12}) is set to zero. This is the combination of parameters that was used to produce Table 4.1 in the Advice Note and is the most conservative set of assumptions that can be made.

The equation for ζ_1 is:

$$\zeta_1 = \left[\frac{\left(\cos\theta_1 + \sin\theta_1 \tan\phi\right) + \left(\sin\theta_1 - \cos\theta_1 \tan\phi\right)\tan\phi_{12}}{\cos\left(\theta_1 + \delta\right) + \sin\left(\theta_1 + \delta\right)\tan\phi} \right]$$

The derivation of this factor is given in the Advice Note.

The alternative assumption, that the reinforcement force is carried solely by Wedge 2 (i.e. using ζ_2), leads to less conservative but more reasonable designs. Comparing the results based on ζ_2 with solutions obtained from Caquot and Kerisel's charts (see Appendix 2), indicates that calculations based on ζ_2 are safe for interwedge friction angles (ϕ_{12}) up to ½ϕ (where ϕ is the angle of shearing resistance of the soil).

The equation for ζ_2 is:

$$\zeta_2 = \left[\frac{\left(\cos\theta_2 + \lambda_s \sin\theta_2 \tan\phi\right) + \left(\sin\theta_2 - \lambda_s \cos\theta_2 \tan\phi\right)\tan\phi_{12}}{\cos\left(\theta_2 + \delta\right) + \lambda_s \sin\left(\theta_2 + \delta\right)\tan\phi} \right]$$

$T_{max\delta}$ mechanism

The $T_{max\delta}$ mechanism is the mechanism that requires the greatest reinforcement force to establish its equilibrium. This definition is identical to that for the T_{max} mechanism: the change in notation merely emphasizes the fact that $T_{max\delta}$ is inclined at –δ to the horizontal, whereas T_{max} is horizontal. For simplicity, ReActiv uses the term T_{max} to represent both T_{max} and $T_{max\delta}$.

The $T_{max\delta}$ mechanism is used to calculate the required number of reinforcement layers (as described below).

$T_{o\delta}$ mechanism

The *$T_{o\delta}$ mechanism* is the base-sliding mechanism that requires precisely zero reinforcement force to establish its equilibrium. This definition is identical to that for the T_{ob} mechanism: the change in notation merely emphasizes the fact that the base of the $T_{o\delta}$ mechanism is inclined at –δ to the horizontal, whereas the base of the T_{ob} mechanism is horizontal. For simplicity, ReActiv uses the term T_{ob} to represent both T_{ob} and $T_{o\delta}$.

The $T_{o\delta}$ mechanism is used to calculate the lengths of the reinforcement layers (as described below).

Required reinforcement

The method of calculating the required reinforcement is identical to that described previously, except that the normal effective stress (σ'_n) that is used to calculate the pullout length of the first layer of reinforcement is no longer equal to the vertical effective stress in the soil, owing to the inclination of the reinforcement. σ'_n is calculated as described below.

Normal effective stress

The normal effective stress (σ'_n) that acts on soil nails is given by:

$$\sigma'_\phi = \left(\frac{3 + K_a}{4}\right)\sigma'_v$$

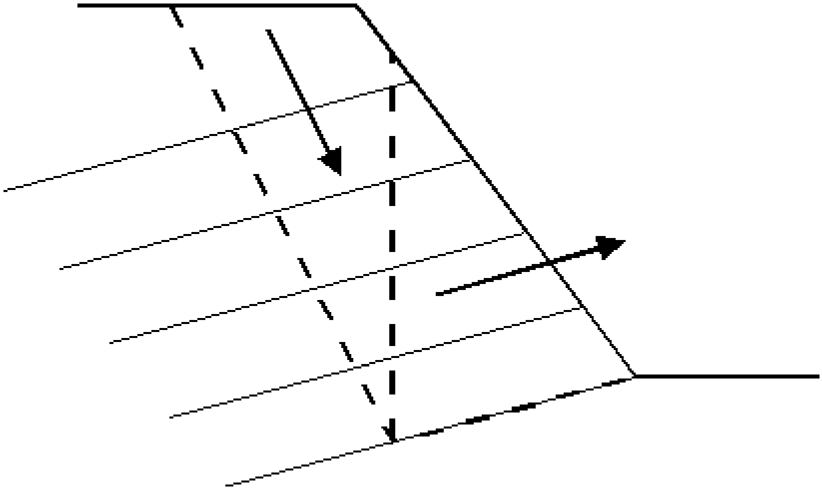
where σ'_v is the vertical effective stress in the soil at a point mid-way along the pullout length of the nail and K_a is the soil's coefficient of active earth pressure, given by:

$$K_a = \frac{1 - \sin\phi}{1 + \sin\phi}$$

where ϕ is the soil's design angle of shearing resistance.
The derivation of the equation for σ'_n is given in Appendix D of the Advice Note.

Base-sliding resistance

Base sliding occurs when the lower wedge (Wedge 2) of a two-part wedge mechanism slides directly over the surface of a layer of reinforcement (as shown below).



The base-sliding resistance of the reinforcement is incorporated in the general stability calculations presented previously via the terms R_2' and K_2, defined as follows:

$$R_2' = \lambda_s N_2' \tan\phi$$

$$K_2 = \frac{\lambda_s c' X}{\cos\delta}$$

where λ_s is a non-dimensional *sliding factor* (defined below); N_2' and X are defined previously in this chapter; δ is the angle of inclination of the reinforcement; and ϕ and c′ are the design effective stress parameters of the soil.

The sliding factor (λ_s) depends on the properties of the reinforcement and, in particular, on how much of the sliding surface the reinforcement occupies. The following table summarizes the values of λ_s that ReActiv adopts for the different types of reinforcement according to whether the angle of the lower wedge (θ_2) equals the angle of inclination of the reinforcement (–δ) or not.

Wedge angle (θ_2)	**Reinforcement**	λ_s
$\theta_2 \neq \delta$	All	1
$\theta_2 = \delta \pm 0.1°$	Geotextile Geogrid Custom	f_{ds}
	Soil nails	$f_{ds} d_h / S_h + (1 - d_h / S_h)$

In this table, f_{ds} is the reinforcement's direct-shear factor; and d_h and S_h are the effective hole diameter and horizontal spacing of the soil nails.

Compatibility with the Advice Note

The Advice Note uses the term *interface sliding factor* to quantify the reduction in shearing resistance caused by soil sliding over an interface instead of over soil. The interface sliding factor (α) is defined as:

$$\alpha = \frac{\tan \phi_{interface}}{\tan \phi_{soil}} = \frac{c'_{interface}}{c'_{soil}}$$

where ϕ is an angle of friction; c' is an effective cohesion; and the subscripts *interface* and *soil* denote values obtained in soil-on-interface and soil-on-soil tests, respectively. The values are obtained from shearing tests taken to large displacements. The soil parameters in these equations are *design* values, i.e. they include appropriate partial factors-of-safety or are large-displacement values.

The parameter f_{ds} used by ReActiv is identical to the parameter α used in the Advice Note.

Pullout resistance

The pullout resistance (P) of the reinforcement is calculated from the formula:

$$P = \lambda_p L_e \left(\sigma'_n \tan \phi + c' \right)$$

where λ_p is a non-dimensional *pullout factor* (defined below); L_e is the length of the reinforcement that extends beyond the failure mechanism; σ'_n represents the average normal effective stress acting on the pullout length of the reinforcement; and ϕ and c' are the design effective stress parameters of the soil.

The pullout factor (λ_p) depends on the properties of the reinforcement and, in particular, on its mode of failure in pullout. The following table summarizes the values of λ_p that ReActiv adopts for the different types of reinforcement.

Reinforcement	**Mode of failure**	λ_p
Geotextile	Direct-shear	$2f_{ds}$
Geogrid	Bearing failure on ribs	$2f_b$
Soil nails	Direct-shear	$\pi d_h f_{ds}/S_h$
Custom	Unknown	$2f_b$

In this table, f_{ds} and f_b are the reinforcement's direct-shear and bearing factors, respectively; and d_h and S_h are the effective hole diameter and horizontal spacing of the soil nails.

For geotextiles, geogrids, and custom reinforcement, the normal effective stress (σ'_n) is equal to the vertical effective stress (σ'_v) acting midway along the pullout length of the reinforcement, where:

$$\sigma'_v = \gamma\left(z + \frac{q}{\gamma}\right)(1 - r_u)$$

and z is the depth of soil above the reinforcement, midway along its pullout length; γ is the unit weight of the soil; q is the applied surcharge; and r_u is Bishop's pore pressure parameter for the slope.

For soil nails σ'_n is given by:

$$\sigma'_n = \frac{1}{4}(3 + K_a)\sigma'_v$$

where K_a is given by Coulomb's equation:

$$K_a = \frac{1 - \sin\phi}{1 + \sin\phi}$$

The value of ϕ in the last equation is the *design* value.

See Appendix D of the Advice Note for further discussion of the pullout resistance of soil nails.

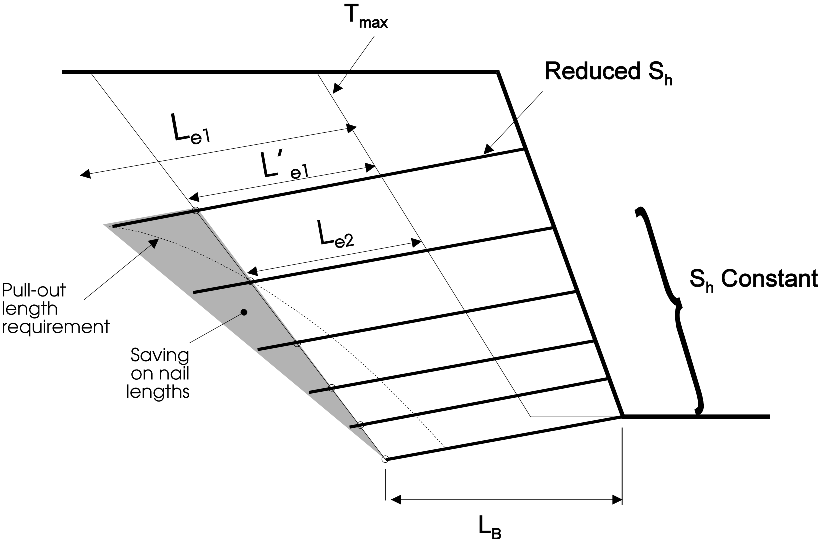
Compatibility with the Advice Note

The parameter f_b used by ReActiv is identical to the parameter α' used in the Advice Note.

Minimizing soil nail pullout lengths

Pullout lengths for the top row of soil nails can sometimes be too long to be practical. The Advice Note describes an option whereby the pullout length of the upper layer (L_{e1}) may be reduced to L'_{e1}, as shown below, by reducing the horizontal spacing of the upper layer of nails from S_{h1} to S'_{h1}, where:

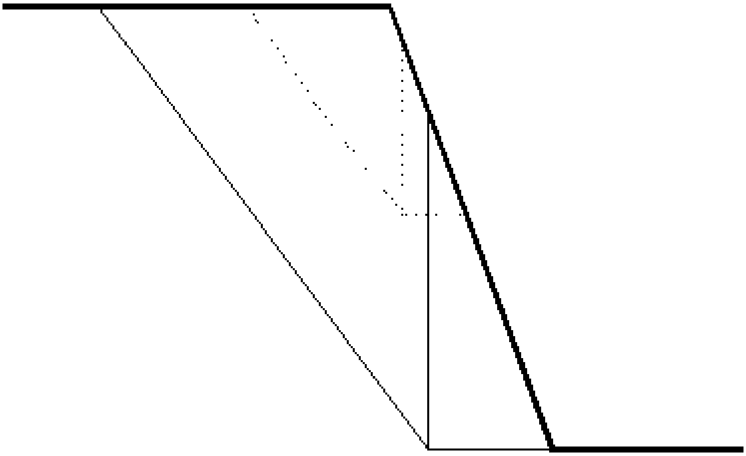
$$S'_{h1} = \frac{L'_{e1}}{L_{e1}} S_{h1}$$



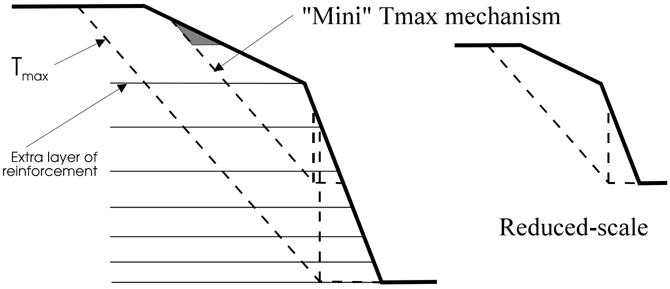
As the figure above shows, the zone of required reinforcement is now controlled by the pullout length of the second layer of nails (L_{e2}) instead of that of the first (L_{e1}).

Special considerations for Two-part slopes

The equation for layer depths assumes that all geometrically-similar but reduced-scale versions of the T_{max} mechanism (see below) will automatically be stable if the T_{max} mechanism is made stable. These reduced-scale mechanisms are higher in the slope than the T_{max} mechanism.



The geometrical similitude required for this assumption breaks down in the case of two-part slopes, where the "mini" T_{max} mechanism is more onerous than the reduced-scale T_{max} mechanism (see below), owing to the extra soil shown shaded.



Full-scale

In such situations, it is normally sufficient to provide an extra layer of reinforcement at the level of the slope crest.

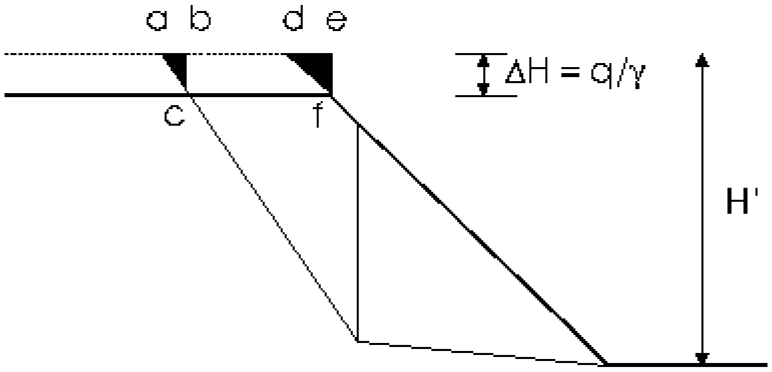
Surcharges

The Advice Note allows a uniform vertical surcharge on the slope crest to be considered either explicitly or, more simply, as an equivalent additional thickness of fill. ReActiv adopts the latter approach. When a surcharge is specified, the program determines the T_{max} and T_{ob} mechanisms based on the effective height of the slope (H′):

$$H' = H + \Delta H = H + \frac{q}{\gamma}$$

where H is the actual slope height (in metres); q is the surcharge (in kN/m^2); and γ is the unit weight of fill (kN/m^3).

This method is an approximation, and introduces small errors into the calculation of the out-of-balance force. Instead of attributing the extra weight of *bcfe* to Wedge 1 (see below), ReActiv uses the slightly smaller weight of *acfd*. ReActiv also (conservatively) overestimates the pore pressures by $r_u\gamma\Delta H$ and (unconservatively) includes cohesion on the surface *ac*.



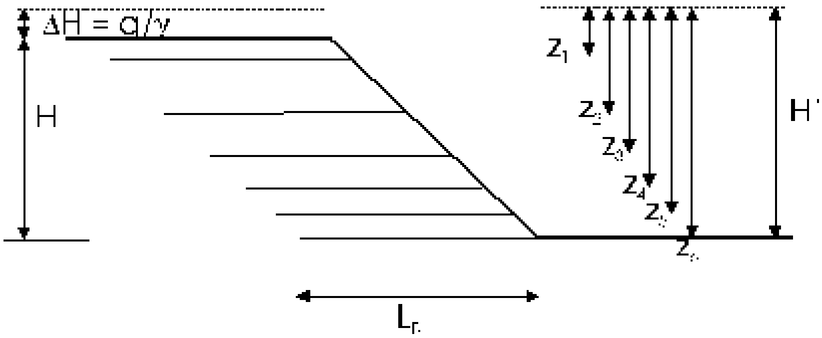
When a surcharge is present, ReActiv calculates layer spacings from the expressions:

$$z_1 = \frac{0.5H'}{\sqrt{n-1}}$$

and

$$z_i = H'\sqrt{\frac{i-1}{n-1}} \quad for\ i > 1$$

where n is the total number of layers. The depths (z_i) are measured from the top of the "equivalent" slope, as shown below.



Compatibility with the Advice Note

A number of symbols are used in the *ReActiv User Manual* that are different from those used in the Advice Note. The following table provides a "translation" between the two documents.

Symbol used in...	
ReActiv User Manual	**Advice Note**
ϕ	ϕ'_{des}
c'	c'_{des}
T_{max}	T_{max}, $T_{max\delta}$
T_{ob}	T_{ob}, $T_{o\delta}$
f_{ds}	α
f_b	α'
n	$N + 1$

Proceeding to a final design

This chapter of the *ReActiv User Manual* discusses the results obtained from the program and summarizes the steps that need to be followed in order to proceed to a final design.

The chapter also discusses ReActiv's limitations and inherent conservatism and compares ReActiv to other calculation methods.

Checking individual mechanisms

The reinforcement layout that ReActiv determines will, for most practical design cases, ensure that all possible two-part wedge mechanisms passing through the reinforced zone are stable. You can check the stability of any particular mechanism by choosing **Calculate > Single Mechanism...** from the menu bar. This will give you the *required* reinforcement force: you will have to calculate the *available* force by hand.

Appendix G of the Advice Note gives guidance on sensible mechanisms to check.

Competent foundation

ReActiv assumes the existence of a competent bearing material directly beneath the slope. If the foundation is not competent, or is not significantly better than the slope material, then underlying slip mechanisms should be checked by alternative means (for example, Janbu's or Bishop's methods, etc.). If the foundation is independently improved (e.g. by replacement or separate stabilization methods), then the reinforcement layout from ReActiv will be relevant. If the foundation is not independently improved (more likely to be the case for cuttings than for embankments), then the reinforced zone may need extending and/or increasing in density, as dictated by the results of slip calculations for mechanisms which penetrate the underlying soils.

Front facing

In most practical cases you will need to provide front face protection to the slope to guard against damage caused by ultra-violet radiation, fire, and/or vandalism. ReActiv implicitly assumes the presence of a "structural" front facing (e.g. wrap-around construction, in the case of geotextiles and geogrids, or shotcrete or similar, in the case of soil nailing).

Appendix G of the Advice Note discusses the effects of the absence of structural facings

Checking pullout of the base layer

ReActiv implicitly assumes that the T_{ob} mechanism allows sufficient pullout length on the base layer of reinforcement behind the T_{max} mechanism. In extreme cases, where the reinforcement has a long pullout length requirement (perhaps widely spaced, high strength strip reinforcement or soil nails), this may not be the case and should be checked, and the base width of the reinforcement zone extended as necessary. This is not normally necessary.

Elongation of reinforcement

Elongation of the reinforcement under working conditions needs to be checked in terms of both the serviceability requirements of the reinforced slope, and also strain compatibility with the soil. (A method for estimating front face displacements for the former can be found at the end of Section 3 of the Advice Note.) Strain compatibility with the soil is important if $\phi = \phi_{critical\ state}$ is *not* selected. The reinforcement should not be so extensible that the soil strength passes through "peak" and starts "strain softening" to below its design strength before the reinforcement has picked up its working load.

Drainage

Drainage measures should be provided as appropriate to ensure that the pore pressures assumed in the analysis will never be exceeded. The design should also be checked for the potential effects of water filled tension cracks, if it is likely that these would form behind the reinforced zone.

Inherent conservatism of a frictionless interwedge boundary

ReActiv's calculation method is based on the two-part wedge mechanism with a vertical interwedge boundary. The User may specify whether the interwedge boundary is frictional or frictionless, and may also specify what wedge the reinforcement force should be applied to. The mechanism is simple enough to check by hand-calculation, is intuitive, and is particularly suited to the case of base sliding over a planar layer of reinforcement.

The assumption of a frictionless interwedge boundary (i.e. $\phi_{12} = 0$) yields inherently conservative values of out-of-balance reinforcement force when compared to more exact solutions (e.g. Caquot & Kerisel, Sokolovsky, and the log spiral method), by typically 10 to 30% in terms of reinforcement density and 5 to 10% in terms of reinforcement length. In cases where these percentages do not represent a significant extra cost to the project as a whole, then setting $\phi_{12} = 0$ is attractive in that it is inherently conservative and relieves the designer of having to justify the actual distribution of the reinforcement force (see Chapter 8).

In cases where these percentages do represent a significant extra cost to the project as a whole, ReActiv allows the User to take into account friction on the interwedge boundary (although it is recommended that ϕ_{12} is never taken to be greater than ½ϕ). As explained in Chapter 8, this requires some assumption to be made about the *distribution* of the reinforcement force between the two wedges.

ReActiv allows you to choose between having all the reinforcement force acting on Wedge 1 or all on Wedge 2. The latter option is preferable since it yields a lower reinforcement requirement and a better conditioned set of equations. It is considered to be a reasonable assumption for most design cases and, for this reason, is the program default.

If interwedge friction is employed, then you should satisfy yourself that it is reasonable to place all the reinforcement force on Wedge 2 (if that is the option you choose). See Chapter 8 for information on doing this. You should also look at the shape of the T_{max} mechanism relative to the reinforcement layout and check that most of the reinforcement force does indeed act on Wedge 2 (note, in this context, that it is the *top* of the interwedge boundary that determines where the force from a particular layer of reinforcement acts). For borderline cases (typically for slopes with small angles), you are advised to check how different the design layout is if you adopt the alternative assumption of all the reinforcement force on Wedge 1 or change the interwedge friction angle.

Using ReActiv to check other design methods

When checking a design which does not adopt the optimum layer spacing theory embodied in the Advice Note (e.g. designs which adopt constant vertical spacing with depth or multiples of fixed vertical spacings) then ReActiv may not be used in "automatic" mode. ReActiv can however be usefully employed to identify the key mechanisms (T_{max}, T_{ob}) against which the design can be assessed. The Advice Note suggests that any design is acceptable provided that::

- The T_{max} and T_{ob} mechanisms are satisfied
- All intermediate mechanisms are sufficiently catered for

- No individual layers are locally over-stressed

The *available* force from the lengths of reinforcement projecting beyond the mechanism in question may then be compared, by hand calculation or otherwise, with the *required* force (calculated by ReActiv).

Comparison with published results

This appendix compares results obtained by GCG ReActiv with those published in the geotechnical literature by Sokolovski, Caquot and Kerisel, and Jewell. In each case, the maximum out-of-balance force (T_{max}) has been compared at varying slope angles (β). To facilitate these comparisons, T_{max} has been normalized as follows:

$$K = \frac{T_{max}}{\frac{1}{2}\gamma H^2}$$

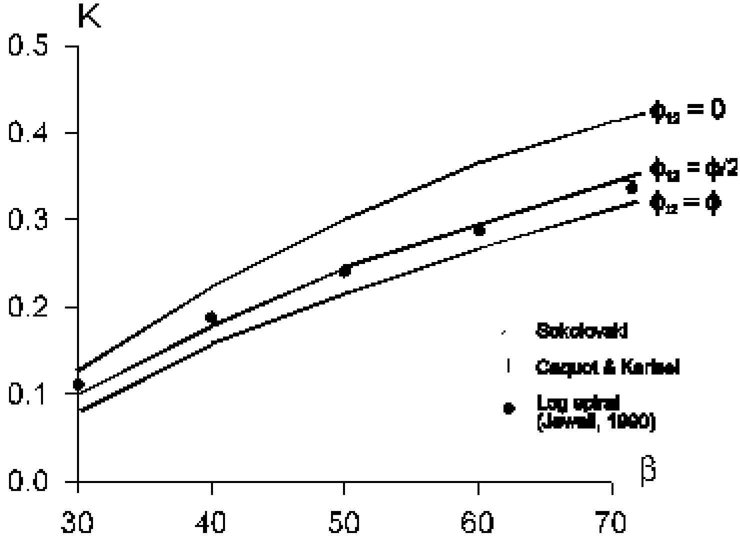
where γ is the unit weight of the soil and H is the height of the slope. Other parameters that have been varied are ϕ, c′, ϕ_{12}, δ, λ_s, i, and r_u; and whether the reinforcement force acts on Wedge 1 or 2. See Chapter 9 for a full explanation of these terms and symbols.

Horizontal reinforcement

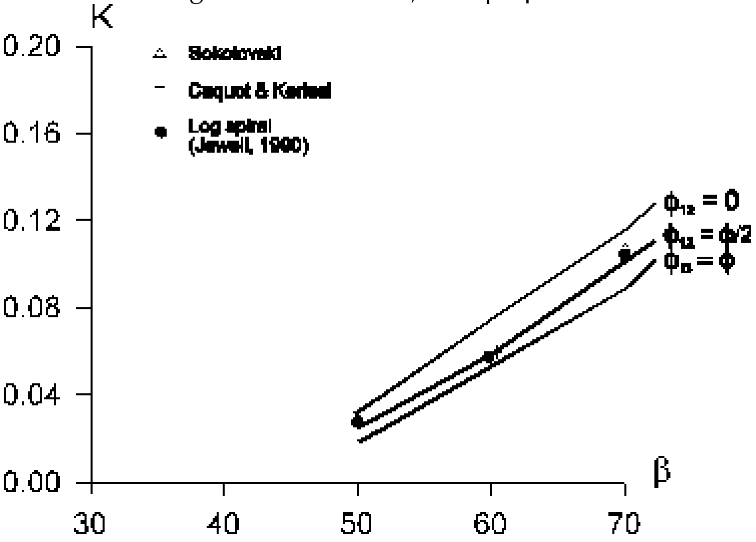
The following figures present values of K obtained by ReActiv for horizontal reinforcement with varying angles of interwedge friction ($\phi_{12} = 0$, $\phi_{12} = \phi/2$, and $\phi_{12} = \phi$). Also shown are results presented by Sokolovski, Caquot and Kerisel, and Jewell.

In most cases, setting $\phi_{12} = \phi/2$ yields results that are in reasonable agreement with the published values. In all cases, setting $\phi_{12} = 0$ yields conservative values of K (i.e. values above the published results) and setting $\phi_{12} = \phi$ yields unconservative values (i.e. values below the published results).

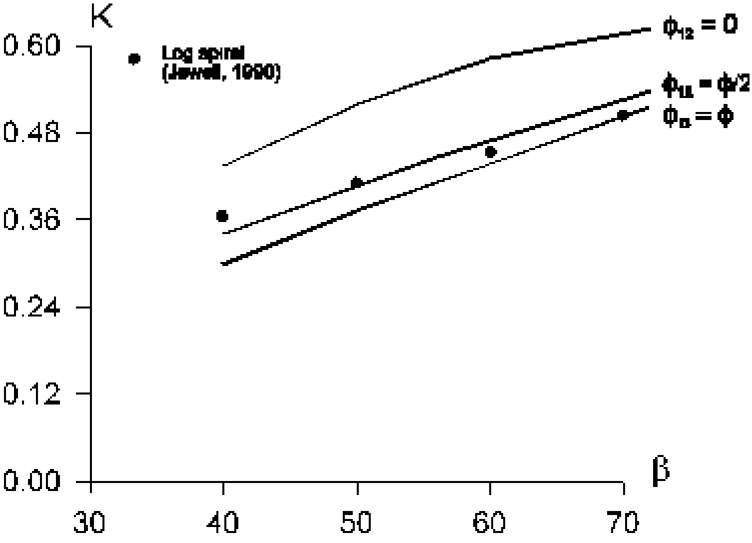
Parameters for the following figure are: $\delta = 0$, $\lambda_s = 1$, $i = 0$, $r_u = 0$, $\phi = 20°$, $c' = 0$.



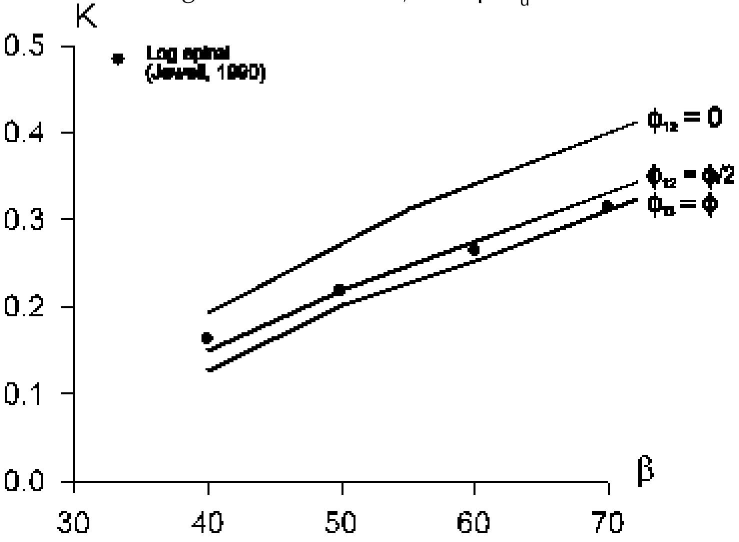
Parameters for the next figure are as above, except ϕ = 40°.



Parameters for the next figure are: δ = 0, λ_s = 1, i = 0, r_u = 0.5, ϕ = 30°, c′ = 0.



Parameters for the next figure are as above, except $r_u = 0.25$.



Inclined reinforcement

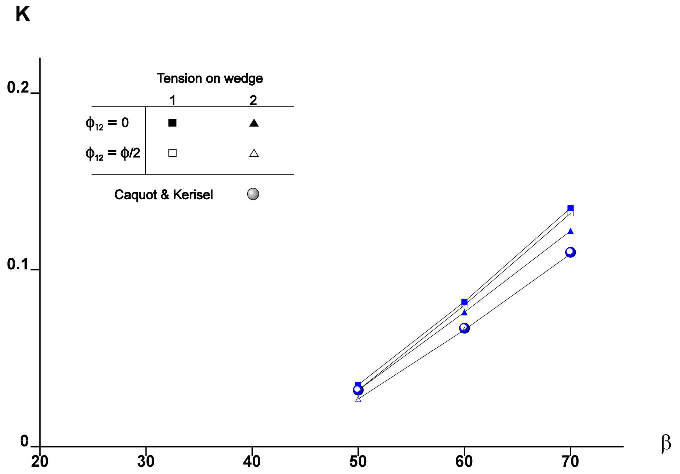
The following figures present values of K obtained by ReActiv for inclined reinforcement with varying angles of interwedge friction ($\phi_{12} = 0$ and $\phi_{12} = \phi/2$) and varying the wedge on which the tension force acts (Wedge 1 or 2). Also shown are results derived from Caquot and Kerisel.

In all cases, applying the tension force on Wedge 1 yields conservative values of K (i.e. values above the published results).

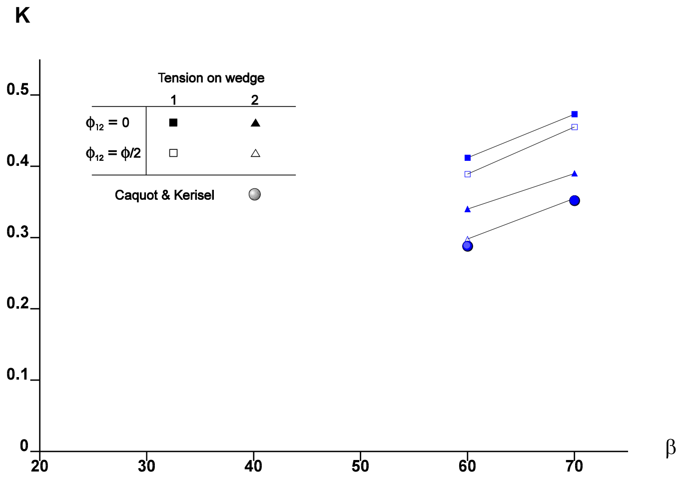
Less conservative values of K are obtained when the tension force is applied to Wedge 2 and ϕ_{12} is set to zero. However, the best fit to the published results is obtained when the tension force is applied to Wedge 2 and ϕ_{12} is set to $\phi/2$. Unfortunately, with this combination of parameters, the results are unconservative at low slope angles.

By default, ReActiv applies the tension force to Wedge 2 and sets ϕ_{12} equal to zero. This is conservative.

Parameters for the following figure are: $\delta = 10°$, $\lambda_s = 1$, $i = 0$, $r_u = 0$, $\phi = 40°$, $c' = 0$.

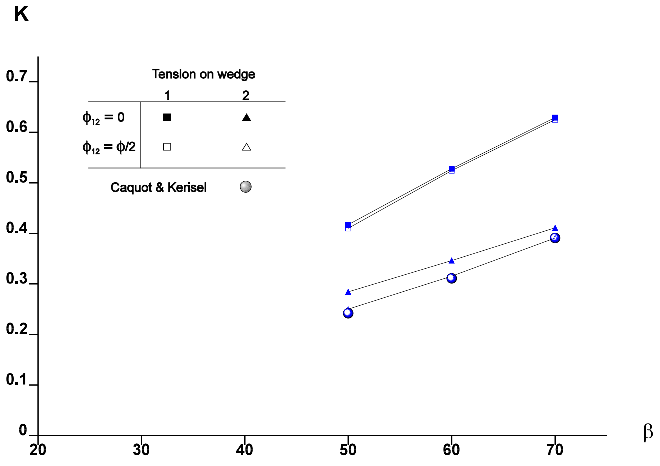


Parameters for the next figure are as above, except $\phi = 20°$.



Parameters for the next figure are: $\delta = 20°$, $\lambda_s = 1$, $i = 0$, $r_u = 0$, $\phi = 40°$, $c' = 0$.

Parameters for the next figure are as above, except $\phi = 20°$.



Soil Classification System

The Soil Classification System used by ReActiv is based on a combination of:

- The British Soil Classification System (BSCS), as described in BS 5930:1981
- The Unified Soil Classification System (USCS), as described in ASTM D2487-1069
- The German Soil Classification System (DIN), as decribed in DIN 18 196

In addition to the basic groupings of Gravel, Sand, Silt, and Clay that are common to all these systems, the Soil Classification system includes commonly-encountered soils under the headings Organic, Fill, Chalk, Rock, River Soil, and Custom.

The following table lists the soils that are included in the Soil Classification System and give the corresponding group symbols from each of the established systems listed above (where they are available).

	Class	Symbol	BSCS	USCS	DIN	States
Gravel	Unclassified*	G	G	G	G	Unpecified (Unsp)
	Well-graded	GW	GW	GW	GW	Very loose (VL)¶
	Uniformly-gr'd	GPu	GPu	GP	GE	Loose (L)
	Gap-graded	GPg	GPg	GP	GI	Medium dense (MD)
	Silty	G-M	G-M	G?-GM	GU	Dense (D)
	Clayey*	G-C	G-C	G?-GC	GT	Very dense (VD)
	Very silty*	GM	GM	GM	GU	Poorly comp'd (PC)
	Very clayey*	GC	GC	GC	GT	Well comp'd (WC)
Sand	Unclassified*	S	S	S	S	*Same as GRAVEL*
	Well-graded	SW	SW	SW	SW	
	Uniformly-gr'd	SPu	SPu	SP	SE	
	Gap-graded	SPg	SPg	SP	SI	
	Silty	S-M	S-M	S?-SM	SU	
	Clayey*	S-C	S-C	S?-SC	ST	
	Very silty*	SM	SM	SM	SU	
	Very clayey*	SC	SC	SC	ST	
Granular silt	Unclassified	M	M	M	U	Unpecified (Unsp)
	Gravelly	MG	MG	ML/MH	-	Very loose (VL)¶
	Sandy	MS	MS	ML/MH	-	Loose (L)
	Low-plasticity	ML	ML	ML	UL	Medium dense (MD)
						Dense (D)
						Very dense (VD)

	Class	Symbol	BSCS	USCS	DIN	States
Cohesive silt	Unclassified*†	M	M	M	U	*Same as CLAY*
	Int.-plast.*†	MI	MI	ML	UM	
	High-plast.*†	MH	MH-ME	MH	-	
Clay	Unclassified*†$	C	C	C	T	Unspecified (Unsp)*$
	Gravelly*†	CG	CG	CL/CH	-	Very soft (VSo)
	Sandy*†	CS	CS	CL/CH	-	Soft (So)
	Low-plast.*†	CL	CL	CL	TL	Firm (F)*$
	Int.-plast.*†$	CI	CI	CL	TM	Stiff (St)*$
	High-plast.*†$	CH	CH-CE	CH	TA	Very stiff (VSt)*$
	Laminated*†	Lam	-	-	-	Hard (H)*$
Organic	Unclassified†	O	O	O	O	*Same as CLAY*
	Organic clay†	MO	MLO/H	OL	(OU)	
	Organic silt†	CO	CLO/H	OH	OT	
	Peat†	Pt	Pt	Pt	HN/HZ	
	Loam†	Loam	-	-	-	
Granular fill	Unclassified	MdG				Unspecified
	Rock fill	RockF				Poorly-comp'd (PC)
	Slag fill	Slag				Well-compacted (WC)
	Gravel fill	GravF				
	Sand fill	SandF				
	Chalk fill	ChkF				
	Brick hardcore	Brick				
	Ashes	Ash				
	PFA	PFA				
	Clay fill†	ClayF				*Same as CLAY*
Chalk	Unclassified*	Chk				Unspecified (Unsp)
	Grade I*	Chk1				
	Grade II*	Chk2				
	Grade III*	Chk3				
	Grade IV*	Chk4				
	Grade V	Chk5				
	Grade VI	Chk6				
Rock	Marl*	Marl				Unspecified (Unsp)
	Weathered rock*	Rock				
River soil	River mud†	RivM				Unspecified (Unsp)
	Dock silt†	DockS				Very soft (VSo)
	Alluvium†	Alluv				Soft (So)

Class	Symbol	BSCS	USCS	DIN	States
Custom*†$	Cust				Unspecified (Unsp)*$

G? = G, GW, or GP; S? = S, SW, or SP; Int. = intermediate; plast. = plasticity
*may have effective cohesion (if symbol appears next to Class & State)
†may be undrained
$may be fissured (if symbol appears next to Class & State)
¶potential for liquefaction

Database of soil properties

ReActiv uses a database of soil properties to check that any parameters you enter for a soil are compatible with that soil's engineering description.

ReActiv's checking system is based on the concept that there are *normal* and *extreme* ranges for each soil parameter.

If you enter a value that is outside the *extreme* range for a particular soil parameter, ReActiv issues an error message and prevents you from proceeding until you have changed the offending value.

If you enter a value that is outside the *normal* range, ReActiv issues a warning message and allows you to proceed only if you confirm that the value entered is correct.

The default parameters are provided to assist in initial design studies only, and should not be used as a substitute for measured parameters. As in all forms of geotechnical design, parameters should be chosen on the basis of adequate site investigation, including suitable laboratory and field measurements.

The publications that have been referred to in compiling the database include:

- Terzaghi & Peck (1967)
- NAVFAC DM-7 (1971)
- Peck, Hanson, & Thornburn (1974)
- Winterkorn & Fang (1975)
- Canadian Foundation Engineering Manual (1978)
- Reynolds & Steedman (1981)

- Bell (1983)
- Mitchell (1983)
- TradeARBED's *Spundwand-Handbuch Teil 1, Grundlagen* (1986)
- Bolton (1986)
- Clayton & Militiski (1986)
- Clayton (1989)
- Tomlinson (1995)
- British Steel's *Piling Handbook* (1997)

Invaluable advice regarding the properties of various soils was provided by Professors JB Burland, PR Vaughan, and DW Hight and by Dr G Sills.

In the following table ρ_d = dry density; ρ_w = wet density; ϕ_{peak} = peak angle of friction; ϕ_{crit} = critical state angle of friction; c'_{peak} = peak effective cohesion; c'_{crit} = critical state effective cohesion; S_u = undrained shear strength; ΔS_u = rate of increase in S_u with depth.

	Parameter	Classification		Minimum		Default	Maximum	
		Class	State	Ext.	Norma		Norma	Ext.
Gravel	ρ_d (kg/m^3)	All	Unsp	1200	1400	2050	2200	2500
			VL	1200	1300	1500	1600	1800
			L	1300	1400	1650	1800	2000
			MD	1400	1500	1850	2000	2200
			D	1500	1700	2050	2200	2400
			VD	1700	2000	2250	2400	2500
			PC	1200	1400	1650	1800	2200
			WC	1400	1700	2050	2200	2500
	ρ_s (kg/m^3)	All	Unsp	1500	1800	2200	2300	2500
			VL	1500	1700	1850	1900	2100
			L	1700	1800	2000	2100	2200
			MD	1800	1900	2100	2200	2300
			D	1900	2000	2200	2300	2400
			VD	2000	2200	2250	2400	2500
			PC	1500	1800	2000	2100	2300
			WC	1800	2000	2200	2300	2500

	Parameter	Classification		Minimum		Default	Maximum	
		Class	State	Ext.	Norma		Norma	Ext.
	φ_{peak} (deg)	All	Unsp	28	35	37	50	60
			VL	28	32	34	38	40
			L	30	35	37	40	45
			MD	35	40	42	45	50
			D	40	45	47	50	55
			VD	45	50	52	55	60
			PC	28	35	37	40	50
			WC	35	45	47	50	60
	φ_{crit} (deg)	All	All	28	35	37	40	45
	c'_{peak} (kPa)	G G_C GM GC	All	0	0	0	0	10
		Others	All	Not applicable				
	c'_{crit} (kPa)	G G_C GM GC	All	0	0	0	0	5
		Others	All	Not applicable				
Sand	ρ_d (kg/m^3)	All	Unsp	1200	1275	1675	1800	2200
			VL	1200	1225	1450	1550	1750
			L	1225	1275	1500	1600	1850
			MD	1275	1350	1575	1700	1950
			D	1350	1450	1675	1800	2050
			VD	1450	1575	1800	1900	2200
			PC	1200	1275	1500	1600	1950
			WC	1275	1450	1675	1800	2200
	ρ_s (kg/m^3)	All	Unsp	1600	1800	2075	2150	2400
			VL	1600	1750	1900	1975	2000
			L	1750	1800	1950	2000	2050
			MD	1800	1850	1975	2050	2150
			D	1850	1950	2075	2150	2250
			VD	1950	2050	2175	2250	2400
			PC	1600	1800	1950	2000	2150
			WC	1800	1950	2075	2150	2400

	Parameter	Classification		Minimum		Default	Maximum	
		Class	State	Ext.	Norma		Norma	Ext.
	φ_{peak} (deg) †Reduced to allow for potential liquefaction	All	Unsp	20	30	32	40	55
			VL	20†	25†	26†	28†	30†
			L	26	30	32	35	40
			MD	29	33	34	37	45
			D	33	36	37	40	50
			VD	37	40	42	45	55
			PC	23	30	32	35	45
			WC	29	36	37	40	55
	φ_{crit} (deg)	All	All	23	30	32	35	40
	c'_{peak} (kPa) discounting natural cementation	S S_C SM SC	All	0	0	0	0	10
		Others	All			Not applicable		
	c'_{crit} (kPa)	S S_C SM SC	All	0	0	0	0	5
		Others	All			Not applicable		
Granular silt	ρ_d (kg/m^3)	All	All	1100	1275	1850	2150	2200
	ρ_s (kg/m^3)	All	All	1500	1800	2050	2150	2400
	φ_{peak} (deg) †Reduced to allow for potential liquefaction	All	Unsp	20	27	28	33	45
			VL	20†	25†	26†	28†	30†
			L	23	27	28	31	35
			MD	25	28	29	32	37
			D	27	29	30	33	40
			VD	30	32	33	36	45
	φ_{crit} (deg)	All	All	20	27	28	31	35
	c'_{peak} (kPa)	All	All	0	0	0	5	10
	c'_{crit} (kPa)	All	All	0	0	0	0	5
Cohesive silt	ρ_d (kg/m^3)	All	All	1100	1275	1850	2150	2200
	ρ_s (kg/m^3)	All	All	1500	1800	2050	2150	2400

	Parameter	Classification		Minimum		Default	Maximum	
		Class	State	Ext.	Norma		Norma	Ext.
	φ_{peak} (deg)	M	All	17	25	28	35	45
		MI		17	25	28	35	40
		MH		17	20	23	30	35
	φ_{crit} (deg)	M	All	17	22	25	30	32
		MI		20	22	25	30	32
		MH		17	18	19	22	25
	c'_{peak} (kPa)	All	VSo-So	0	0	0	0	0
			Others	0	0	0	5	10
	c'_{crit} (kPa)	All	VSo-So	0	0	0	0	0
			Others	0	0	0	0	5
	S_u (kPa)	All	Unsp	1	20	20	150	1000
			VSo	1	5	10	20	30
			So	10	20	25	40	60
			F	30	40	50	75	100
			St	60	75	100	150	200
			VSt	100	150	200	300	400
			H	200	300	375	500	1000
	ΔS_u (kPa)	All	VSo-So	-100	-10	0	4	100
			Others	-100	-10	0	8	100
Clays	ρ_d (kg/m^3)	All	Unsp	1200	1500	2050	2200	2500
			VSo	1200	1400	1650	1800	2000
			So	1300	1500	1750	1900	2100
			F	1450	1650	1900	2050	2250
			St	1600	1800	2050	2200	2400
			VSt	1750	1950	2200	2350	2450
			H	1900	2100	2300	2400	2500
	ρ_s (kg/m^3)	All	Unsp	1200	1500	2050	2200	2500
			VSo	1200	1400	1650	1800	2000
			So	1300	1500	1750	1900	2100
			F	1450	1650	1900	2050	2250
			St	1600	1800	2050	2200	2400
			VSt	1750	1950	2200	2350	2450
			H	1900	2100	2300	2400	2500

	Parameter	Classification		Minimum		Default	Maximum	
		Class	State	Ext.	Norma		Norma	Ext.
	φ_{peak} (deg)	C	All	15	20	20	33	39
		CG		18	20	24	33	39
		CS		18	20	24	33	39
		CL		20	24	27	33	39
		CI		18	20	23	30	37
		CH		15	16	20	27	31
		Lam		15	16	19	25	39
	φ_{crit} (deg)	C	All	8	20	23	33	39
		CG		18	20	24	33	39
		CS		18	20	24	33	39
		CL		18	20	23	28	30
		CI		18	20	23	28	30
		CH		8	15	18	20	22
		Lam		8	12	16	20	22
	c'_{peak} (kPa)	All	Unsp	0	0	0	10	15
			VSo	0	0	0	0	0
			So	0	0	0	0	0
			Others	0	0	2	10	15
	c'_{crit} (kPa)	All	VSo-So	0	0	0	0	0
			Others	0	0	0	0	5
	S_u (kPa)	All	Unsp	1	20	20	150	1000
			VSo	1	5	10	20	30
			So	10	20	25	40	60
			F	30	40	50	75	100
			St	60	75	100	150	200
			VSt	100	150	200	300	400
			H	200	300	375	500	1000
	ΔS_u (kPa)	All	VSo-So	-100	-10	0	8	100
			Others	-100	-10	0	8	100
Organic	ρ_d (kg/m^3)	Uncl	All	800	1000	1500	2050	2250
		MO		1000	1250	1500	1600	1750
		CO		1000	1250	1500	1600	1750
		Pt		800	1000	1200	1300	1400
		Loam		1450	1650	1900	2050	2250

	Parameter	Classification		Minimum		Default	Maximum	
		Class	State	Ext.	Norma		Norma	Ext.
	ρ_s (kg/m^3)	Uncl	All	850	1050	1650	2050	2250
		MO		1400	1500	1650	1750	1950
		CO		1400	1500	1650	1750	1950
		Pt		850	950	1250	1400	1500
		Loam		1450	1650	1900	2050	2250
	φ_{peak} (deg)	Uncl	All	18	20	23	30	39
		MO		18	20	23	30	37
		CO		18	20	23	30	37
		Pt		18	20	23	30	37
		Loam		20	24	27	33	39
	φ_{crit}(deg)	Uncl	All	18	20	23	30	39
		MO		18	20	23	30	37
		CO		18	20	23	30	37
		Pt		18	20	23	30	37
		Loam		20	24	27	33	39
	c'_{peak} (kPa)	All	All	Not applicable				
	c'_{crit} (kPa)	All	All	Not applicable				
	S_u (kPa)	All	Unsp	1	20	20	150	1000
			VSo	1	5	10	20	30
			So	10	20	25	40	60
			F	30	40	50	75	100
			St	60	75	100	150	200
			VSt	100	150	200	300	400
			H	200	300	375	500	1000
	ΔS_u (kPa)	All	VSo-So	-100	-10	0	8	100
			Others	-100	-10	0	8	100
Granular fill	ρ_d (kg/m^3)	MdG	All	600	1225	1600	1800	2500
		RockF		1400	1500	1900	2100	2200
		Slag		1000	1200	1450	1600	1800
		GravF		1200	1400	1950	2200	2500
		SandF		1200	1225	1600	1800	2200
		ChkF		1250	1300	1350	1400	1450
		Brick		1100	1300	1600	1750	1900
		Ash		600	650	1000	1000	1200
		PFA		900	1000	1350	1500	1700

	Parameter	Classification		Minimum		Default	Maximum	
		Class	State	Ext.	Norma		Norma	Ext.
	ρ_s (kg/m^3)	MdG	All	1200	1650	2000	2150	2500
		RockF		1750	1900	2100	2200	2300
		Slag		1400	1700	1850	1900	2000
		GravF		1500	1800	2150	2300	2500
		SandF		1600	1800	2050	2150	2400
		ChkF		1700	1750	1825	1850	1900
		Brick		1400	1650	1850	1950	2100
		Ash		1200	1300	1450	1500	1800
		PFA		1350	1500	1750	1800	2000
	φ_{peak} (deg)	MdG	All	23	30	35	45	60
		RockF		35	40	43	50	60
		Slag		25	30	33	40	50
		GravF		28	35	40	50	60
		SandF		23	30	32	35	40
		ChkF		25	30	32	37	43
		Brick		35	40	42	45	50
		Ash		30	35	37	40	45
		PFA		27	30	32	37	40
	φ_{crit} (deg)	MdG	All	25	30	32	35	45
		RockF		30	35	37	40	45
		Slag		25	30	32	35	45
		GravF		28	35	37	40	45
		SandF		23	30	32	35	40
		ChkF		25	30	32	35	40
		Brick		25	30	32	35	40
		Ash		27	30	33	38	42
		PFA		27	30	32	35	40
Cohesive fill	ρ_d (kg/m^3)	All	All	950	1100	1550	1750	1900
	ρ_s (kg/m^3)	All	All	1300	1500	1850	2050	2250
	φ_{peak} (deg)	All	All	15	17	21	30	35
	φ_{crit} (deg)	All	All	15	17	21	28	30
	c'_{peak} (kPa)	All	All	Not applicable				
	c'_{crit} (kPa)	All	All	Not applicable				
	S_u (kPa)	All	Unsp	1	20	20	150	1000
			VSo	1	5	10	20	30
			So	10	20	25	40	60
			F	30	40	50	75	100
			St	60	75	100	150	200
			VSt	100	150	200	300	400
			H	200	300	375	500	1000

	Parameter	Classification		Minimum		Default	Maximum	
		Class	State	Ext.	Norma		Norma	Ext.
	ΔS_u (kPa)	All	VSo-So	-100	-10	0	8	100
			Others	-100	-10	0	8	100
Chalk	ρ_d (kg/m^3)	Chk		1255	1275	1450	2250	2500
		Chk1		1525	1650	2050	2250	2500
		Chk2		1350	1400	1575	1650	1725
		Chk3		1275	1325	1450	1500	1550
		Chk4		1250	1300	1375	1425	1475
		Chk5		1225	1275	1350	1400	1450
		Chk6		1225	1275	1350	1400	1450
	ρ_s (kg/m^3)	Chk		1725	1750	1900	2450	2600
		Chk1		1925	2025	2300	2450	2600
		Chk2		1800	1850	1975	2025	2075
		Chk3		1750	1800	1900	1925	1950
		Chk4		1750	1775	1850	1875	1900
		Chk5		1725	1750	1825	1850	1900
		Chk6		1725	1750	1825	1850	1900
	φ_{peak} (deg)	Chk		25	30	35	45	55
		Chk1		25	30	35	45	55
		Chk2		25	30	34	43	52
		Chk3		25	30	34	41	49
		Chk4		25	30	33	39	46
		Chk5		25	30	32	37	43
		Chk6		25	30	32	35	40
	φ_{crit} (deg)	All		25	30	32	35	40
	c'_{peak}(kPa)	Chk		0	0	0	20	100
		Chk1		0	0	10	20	100
		Chk2		0	0	5	20	50
		Chk3		0	0	5	20	50
		Chk4		0	0	2	10	20
		Chk5		0	0	0	0	0
		Chk6		0	0	0	0	0
	c'_{crit}(kPa)	All		0	0	0	0	5
Rock	ρ_d (kg/m^3)	All		2050	2100	2250	2300	2500
	ρ_s (kg/m^3)	All		2050	2100	2250	2300	2500
	φ_{peak} (deg)	All		27	30	33	38	42
	φ_{crit} (deg)	All		27	30	33	38	42

	Parameter	Classification		Minimum		Default	Maximum	
		Class	State	Ext.	Norma		Norma	Ext.
	c'_{peak} (kPa)	All		0	0	5	10	20
	c'_{crit} (kPa)	All		0	0	0	0	5
River Soil	ρ_d (kg/m^3)	All	Unsp VSo So	1200 1200 1200	1250 1250 1400	1600 1600 1650	1800 1800 1800	2000 2000 2000
	ρ_s (kg/m^3)	All	Unsp VSo So	1200 1200 1200	1250 1250 1400	1600 1600 1650	1800 1800 1800	2000 2000 2000
	φ_{peak} (deg)	All	All	15	16	22	33	39
	φ_{crit} (deg)	All	All	15	16	22	33	39
	c'_{peak} (kPa)	All	All	Not applicable				
	c'_{crit} (kPa)	All	All	Not applicable				
	S_u (kPa)	All	Unsp VSo So	1 1 10	20 5 20	20 10 25	40 20 40	60 30 60
	ΔS_u (kPa)	All	All	-100	-10	0	4	100
Custom	ρ_d (kg/m^3)	Uncl	Unsp	600	1200	2000	2400	2500
	ρ_s (kg/m^3)	Uncl	Unsp	850	1200	2000	2400	2600
	φ_{peak} (deg)	Uncl	Unsp	10	20	30	50	60
	φ_{crit} (deg)	Uncl	Unsp	8	20	25	35	45
	c'_{peak} (kPa)	Uncl	Unsp	0	0	0	10	100
	c'_{crit} (kPa)	Uncl	Unsp	0	0	0	0	5
	S_u (kPa)	Uncl	Unsp	1	5	20	300	1000
	ΔS_u (kPa)	Uncl	Unsp	-100	-10	0	10	100