Module Interface Specification for Slope Stability Analysis Program (SSP)

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1 Revision History

Date	Version	Notes
11/12/18	1.0	Initial updates based on template

2 Symbols, Abbreviations and Acronyms

See Section 2 of the SRS Documentation, available in the GitHub repository for the project.

Contents

3 Introduction

The following document details the Module Interface Specifications for SSP, a program for determining the critical slip surface and corresponding factor of safety for a given sloped mass of soil.

Complementary documents include the System Requirement Specifications and Module Guide. The full documentation and implementation can be found at the GitHub repository for the project.

4 Notation

The structure of the MIS for modules comes from Hoffman and Strooper (1995), with the addition that template modules have been adapted from Ghezzi et al. (2003). The mathematical notation comes from Chapter 3 of Hoffman and Strooper (1995). For instance, the symbol := is used for a multiple assignment statement and conditional rules follow the form $(c_1 \Rightarrow r_1 | c_2 \Rightarrow r_2 | \ldots | c_n \Rightarrow r_n)$.

The following table summarizes the primitive data types used by SSP.

Data Type	**Notation**	**Description**
Character	char	A single symbol or digit
Boolean	$\mathbb{B}$	A value from the set {true, false}
Real	$\mathbb{R}$	Any number in $(-\infty, \infty)$.

The specification of SSP uses some derived data types: sequences, strings, and tuples. Sequences are ordered lists of elements of the same data type, denoted by brackets enclosing the type of the data elements. If a sequence has fixed dimensions, the notation of the type will include the dimensions in superscript. Strings are sequences of characters. Tuples contain a list of values, potentially of different types, each associated with a field identifier. When a tuple is referenced in this document, a link to an appendix section that specifies the fields of the tuple will be provided. In addition, SSP uses functions, which are defined by the data types of their inputs and outputs. Local functions are described by giving their type signature followed by their specification.

5 Numerical Algorithms

Morgenstern Price (Section 9)

The non-linear nature of the systems of equations in the Morgenstern Price solver algorithm requires that solutions to the equations for the unknown values: *F_MP* (IM1), *Lam* (IM2) and *E_force* (IM3) are solved iterativley, with an initial guess for two of the values, typically *F_MP* and *Lam*.

RFEM (Section 10)

The non-linear nature of the systems of equations in the RFEM solver algorithm, requires that the solution is done iteratively. The process implemented in the program is as follows. The stiffness constants are calculated as in DD**??** of the SRS, assuming no displacements, and the applied load *gLoad* is calculated as in GD**??** of the SRS. This is used to calculate the displacements *gDisp* as in IM**??**. The calculated displacements can then be used to recalculate the stifness constants, and the reactive force *dLoad* IM??. Calculations repeat until the applied load, and the reactive force are in equilibrium.

Genetic Algorithm (Section 11)

The uses a genetic algorithm to find the vertex coordinates of the slip surface that minimizes the factor of safety, as seen in IM4. The genetic algorithm will generate new slip surfaces based on merging and mutating previously known slip surfaces with low factors of safety. When a minimum factor of safety cant be found after several iterations the factor of safety is considered minimized, and the critical slip has been found.

6 Module Decomposition

The following table is taken directly from the Module Guide document for this project.

Level 1	**Level 2**
Hardware-Hiding	
Behaviour-Hiding	Control
	Input
	Output
	Genetic Algorithm
	Kinematic Admissibility
	Slip Weighting
	Slip Slicing
	Morgenstern-Price Calculation
	Slice Property Calculation
Software Decision	Array Data Structure
	Random Number Generation
	Plotting

Table 1: Module Hierarchy

7 MIS of the Control Module

7.1 Module Name: Control.m

7.2 Uses

7.2.1 Imported Access Programs

Uses Input Module - section 8, **Passes** N/A, **Receives** *params_layers*, *params_piez*, *params_search*, *params_load*, *params_soln*

Uses Genetic Algorithm Module - section 11, **Passes** *params_layers*, *params_piez*, *params_piez*, *params_load*, *params_soln*, **Receives** *cslip*

Uses Output Module - section 16, **Passes** *params_layers*, *params_piez*, *params_load*, *params_soln*, *cslip*, **Receives** N/A

7.3 Interface Syntax

7.3.1 Exported Access Programs

Name	**In**	**Out**	**Exceptions**
Control	-	-	-

7.4 Interface Semantics

7.4.1 State Variables

params_layers : struc_layers	(Appendix 17.1.1)
params_piez : struc_piez	(Appendix 17.1.2)
params_soln : struc_soln	(Appendix 17.1.4)
params_search : struc_search	(Appendix 17.1.3)
params_load : struc_load	(Appendix 17.1.5)
cslip : $[\mathbb{R}]^{2,\text{nslip}}$	Sequence of vertex coordinates describing the geometry of the critical slip surface of the slope. Sequence length value *nslip* is defined by the Genetic Algorithm Module (section 11).

7.4.2 Access Program Semantics

Input:
Control does not receive any external input.

Exceptions:
There are no potential exceptions for control.

Output:
Control does not return any values; however, it does control the overall operation of the program. This is done through a series of function calls to the functions provided by the imported modules. The basic flow of the data is: Input, Genetic Algorithm, Output.

8 MIS of the Input Module

8.1 Module Name: Input.m

8.2 Interface Syntax

8.2.1 Exported Access Programs

Name	**In**	**Out**	**Exceptions**
Input	'string' (file); bools; reals	struc; struc; struc; struc; struc	input file error

8.3 Interface Semantics

8.3.1 Environment Variables

board : keyboard

in_file : file

8.3.2 Access Program Semantics

Input:
Accepts a path to a file name. file type is readable by Matlab, and is constructed in the format seen in appendix **??**. Command line prompts will control user input values as boolean or real values through the keyboard environment.

Exceptions:
An input data file that does not follow intended input format will generate an input file error.

Output:

params_layers : struc_layers (Appendix 17.1.1)

params_piez : struc_piez (Appendix 17.1.2)

params_search : struc_search (Appendix 17.1.3)

params_soln : struc_soln (Appendix 17.1.4)

params_load : struc_load (Appendix 17.1.5)

9 MIS of the Morgenstern Price Solver Module

9.1 Module Name: MorgPriceSolver.m

9.2 Uses

9.2.1 Imported Access Programs

Uses PropertySorter - section 12, **Passes** *evalslip*, *params_layers*, *params_piez* **Recieves** *params_soilInterior*, *params_soilBase*, *params_internalForce*, *params_angles*

9.3 Interface Syntax

9.3.1 Exported Access Programs

Name	**In**	**Out**	**Exceptions**
Morgenstern Price Solver	Sequence; struc; struc; struc; struc	Real	Non Converging; Spurious *F_MP*

9.4 Interface Semantics

9.4.1 Local Constants

F_MinLim : $\mathbb{R}$	The minimum factor of safety value that the solution must be above to not be considered spurious. [*F_MinLim*=0.5]
max_iter : $\mathbb{R}$	The max number of iterations the algorithm will perform before the solution is considered non converging. [*max_iter*=20]
eps_F : $\mathbb{R}$	The value the absolute difference between the factor of safety calculated by the algorithm between consecutive iterations must be below for the answer to be considered converged. [*eps_F*=1E-6]
eps_Lam : $\mathbb{R}$	The value the absolute difference between the interslice normal to shear force ratio calculated by the algorithm between consecutive iterations must be below for the answer to be considered converged. [*eps_Lam*=1E-6]

9.4.2 State Variables

Lam : $\mathbb{R}$	The interslice normal to shear force ratio. From IM2 of the SRS.
E_force : $[\mathbb{R}]^{1,n+1}$	Sequence of the value of the interslice normal force exerted between slices. A value for each interslice, including ends. Sequence length value n is defined by the input *evalslip*. From IM3 of the SRS.
Del_F : $\mathbb{R}$	The difference between the factor of safety of the current iteration and the previous iteration. When converged the value will not be changing and *Del_F* will be small.
Del_Lam : $\mathbb{R}$	The difference between the interslice normal to shear force ratio of the current iteration and the previous iteration. When converged the value will not be changing and *Del_Lam* will be small.

9.4.3 Access Program Semantics

Input:

evalslip : $[\mathbb{R}]^{2,n+1}$	Vertex coordinates for the slip surface being evaluated. Identifies shape of the slope, and slice points. Sequence length value of n is defined by the Slicer module (section 13).
params_layers : struc_layers	(Appendix 17.1.1)
params_piez : struc_piez	(Appendix 17.1.2)
params_soln : struc_soln	(Appendix 17.1.4)
params_load : struc_load	(Appendix 17.1.5)

Exceptions:

A solution which does not converge to a consistent solution, where the change in calculated factor of safety (Del_F) between iterations is less than eps_F, and the change in interslice normal to shear force ratio (Del_Lam) is less than eps_Lam, in less than max_iter iterations will be considered non converging exception case. A solution with a final calculated a factor of safety less than F_MinLim will be considered a spurious factor of safety exception case. Solutions that trigger these exception cases will output a factor of safety (F_MP) of 1000.

Output:

$F\_MP : \mathbb{R}$ — The factor of safety of the slope, as calculated by the Morgenstern Price solution method, measuring the stability of the slope. From IM1 of the SRS.

10 MIS of the RFEM Solver Module

10.1 Module Name: RFEMSolver.m

10.2 Uses

10.2.1 Imported Access Programs

Uses Property Sorter - section 12, **Passes** *evalslip*, *params_layers*, *params_piez* **Receives** *params_soilInterior*, *params_soilBase*, *params_internalForce*, *params_angles*

10.3 Interface Syntax

10.3.1 Exported Access Programs

Name	**In**	**Out**	**Exceptions**
RFEM Solver	Sequence; struc; struc; struc; struc	Real; Sequence; Sequence; Sequence	Non Converging

10.4 Interface Semantics

10.4.1 Local Constants

$F\_MinLim : \mathbb{R}$ — The minimum factor of safety value that the solution must be above to not be considered spurious. [F_MinLim=0.5]

10.4.2 State Variables

$gLoad : [\mathbb{R}]^{1,2n}$	Sequence of the applied load placed on the slice elements. x-ordinate and y-ordinate value for each slice. Sequence length value n is defined by the input *evalslip*. From GD**??** of SRS.
$dLoad : [\mathbb{R}]^{1,2n}$	Sequence of the internal resistive force exerted by the slice elements that oppose the applied load forces. x-ordinate and y-ordinate value for each slice. Sequence length value n is defined by the input *evalslip*. From DD**??** of SRS.
$gDisp : [\mathbb{R}]^{1,2n}$	Sequence of the total displacement the slice elements have experienced. x-ordinate and y-ordinate value for each slice. Sequence length is defined by the input *evalslip*. From IM**??** of SRS.

10.4.3 Access Program Semantics

Input:

$evalslip : [\mathbb{R}]^{2,n+1}$	Sequence of vertex coordinates for the slip surface being evaluated. Identifies shape of the slope, and slice points. Sequence length value n is defined by the Slicer module (section 13).
params_layers : struc_layers	(Appendix 17.1.1)
params_piez : struc_piez	(Appendix 17.1.2)
params_soln : struc_soln	(Appendix 17.1.4)
params_load : struc_load	(Appendix 17.1.5)

Exceptions:
A calculated global factor of safety of less than *F_MinLim*, will be considered non converging and the factor of safety *F_RFEM*, and slice local factors of safety *FLoc_RFEM* will be set equal to 1000, and the displacement vectors *DispX* and *DispY* will be set to empty vectors.

Output:

F_RFEM : $\mathbb{R}$	The factor of safety of the slip surface as calculated by the RFEM solution method, measuring the stability of the slope. From IM**??**.
FLoc_RFEM : $[\mathbb{R}]^{1,n}$	Sequence of the factors of safety for the individual slices in the slip surface, identifying the sections of the slope most vulnerable to failure. A value for each slice. Sequence length value n is defined by the input *evalslip*. From IM**??** of the SRS.

$DispX : [\mathbb{R}]^{1,n}$	Sequence of the displacements the slice elements of the slope will experience in the x-ordinate direction to establish equilibrium. Sequence length n is defined by the input *evalslip*. From IM**??** of the SRS.
$DispY : [\mathbb{R}]^{1,n}$	Sequence of the displacements the slice elements of the slope will experience in the y-ordinate direction to establish equilibrium. Sequence length n is defined by the input *evalslip*. From IM**??** of the SRS.

11 MIS of the Genetic Algorithm Module

11.1 Module Name: GenAlgModule.m

11.2 Uses

11.2.1 Imported Access Programs

Uses MorgPrice Module - section 9, **Passes** *evalslip*, *params_layers*, *params_piez*, *params_soln*, *params_load*, **Receives** F_MP_i

Uses Slicer Module - section 13, **Imports** $slip_i$, **Receives** *evalslip*

Uses Kin Admissibility Module - section 14, **Imports** $slip_i$, *strat1*, **Receives** *KinPass*, $slip_i$

Uses Slip Weights Module - section 15, **Imports** *pool*, **Receives** *pool*

11.3 Interface Syntax

11.3.1 Exported Access Programs

Name	In	Out	Exceptions
GenAlg	struc; struc; struc; struc; struc	Array	None

11.4 Interface Semantics

11.4.1 Local Constants

nslip : $\mathbb{R}$ — The number of vertices the generated slip surfaces will be described by. [nslip=13]

Mpool : $\mathbb{R}$ — The number of slip surfaces that will be in the pool of potential critical slip surfaces. [Mpool=40]

11.4.2 State Variables

pool : $[[\mathbb{R}]^{2,\text{nslip}}, \mathbb{R}, \mathbb{R}]^{1,\text{Mpool}}$ — A sequence of data describing the slip surfaces that are currently being considered as possible critical slip surfaces. Contains three data elements describing the slope: A sequence of coordinates describing the geometry of the slip surface ($[\mathbb{R}]^{2,\text{nslip}}$), the factor of safety of the slip surface ($\mathbb{R}$), and a weighting value describing the surfaces factor of safety relative to the other slip surfaces in the pools factors of safety ($\mathbb{R}$).

11.4.3 Access Program Semantics

Input:

params_layers : struc_layers	(Appendix 17.1.1)
params_piez : struc_piez	(Appendix 17.1.2)
params_search : struc_search	(Appendix 17.1.3)
params_soln : struc_soln	(Appendix 17.1.4)
params_load : struc_load	(Appendix 17.1.5)

Exceptions:
There are no potential exceptions for GenAlg.

Output:

cslip : $[\mathbb{R}]^{2,\text{nslip}}$ — Sequence of vertex coordinates describing the geometry of the critical slip surface of the slope.

12 MIS of the Property Sorter Module

12.1 Module Name: PropertySorter.m

12.2 Interface Syntax

12.2.1 Exported Access Programs

Name	**In**	**Out**	**Exceptions**
Property Sorter	Sequence; struc; struc	struc; struc; struc; struc	None

12.3 Interface Semantics

12.3.1 Access Program Semantics

Input:

evalslip : $[\mathbb{R}]^{1,n}$	Sequence of vertex coordinates for the slip surface being evaluated. Identifies shape of the slope, and slice points. Sequence length value n is defined by the Slicer module (section 13).
params_layers : struc_layers	(Appendix 17.1.1)
params_piez : struc_piez	(Appendix 17.1.2)

Exceptions:
There are no potential exceptions for Property Sorter.

Output:

params_internalForce : struc_intForce	(Appendix 17.1.6)
params_angles : struc_angles	(Appendix 17.1.7)
params_soilInterior : struc_soilInt	(Appendix 17.1.8)
params_soilBase : struc_soilBase	(Appendix 17.1.9)

13 MIS of the Slip Slicer Module

13.1 Module Name: Slicer.m

13.2 Interface Syntax

13.2.1 Exported Access Programs

Name	**In**	**Out**	**Exceptions**
Slicer	Sequence; bool	Sequence	None

13.3 Interface Semantics

13.3.1 Local Constants

n : $\mathbb{R}$ The number of slices the slip surface will be broken into for evaluation. [n=36]

13.3.2 Assumption

A straight line describing the slip surface is assumed between adjacent vertex coordinates given in the input *slip*.

13.3.3 Access Program Semantics

Input:

slip : $[\mathbb{R}]^{2,\text{nslip}}$ Sequence of vertex coordinates of the slip surface being sliced.

evnslc : $\mathbb{B}$ Slicing method switch, an element from the *params_soln* structure (Appendix 17.1.4).

Exceptions:
There are no potential exceptions for Slip Slicer.

Output:

evalslip : $[\mathbb{R}]^{1,n}$ Sequence of vertex coordinates for the slip surface being evaluated. Identifies shape of the slope, and slice points.

14 MIS of the Kinematic Admissibility Module

14.1 Module Name: KinAdm.m

14.2 Interface Syntax

14.2.1 Exported Access Programs

Name	In	Out	Exceptions
Kin Adm	Sequence; Sequence; struc	bool; Sequence	None

14.3 Interface Semantics

14.3.1 Assumption

A straight line describing the slip surface is assumed between adjacent vertex coordinates given in the input *slip*.

14.3.2 Access Program Semantics

Input:

slip : $[\mathbb{R}]^{2,\text{nslip}}$	Sequence of vertex coordinates of the slip surface being tested. Sequence length value *nslip* is defined by the Genetic Algorithm module (section 11).
strat1 : $[\mathbb{R}]^{2,\text{nvtx}}$	Sequence of the coordinates of the vertexes from the uppermost stratigraphic layer of the slope. Sequence length value *nvtx* is defined by the given input file.
params_soln : struc	(Appendix 17.1.4)

Exceptions:
There are no potential exceptions for KinAdm.

Output:

KinPass : $\mathbb{B}$	Identifies if the input slip surface (*slip*) has passed the admissibility criterion for a slip surface. If true than the slip surface has passed. If false than the slip surface has failed.

slipPass : $[\mathbb{R}]^{1,\text{nslip}}$ Sequence of the slip surface given as input (*slip*) with end vertexes adjusted to ensure they are on the slope surface.

15 MIS of the Slip Weighting Module

15.1 Module Name: SlipWeighter.m

15.2 Interface Syntax

15.2.1 Exported Access Programs

Name	**In**	**Out**	**Exceptions**
Slip Weighting	Sequence; Real	Sequence	None

15.3 Interface Semantics

15.3.1 Access Program Semantics

Input:

pool_In $[[\mathbb{R}]^{2,\text{nslip}}, \mathbb{R}, \mathbb{R}]^{1,\text{Mpool}}$: A sequence of data sets describing the slip surfaces that are currently being considered as possible critical slip surfaces. Contains three data elements describing the slope: coordinates describing the geometry of the slip surface ($[\mathbb{R}]^{2,\text{nslip}}$),the factor of safety of the slip surface ($\mathbb{R}$), and a weighting value describing the surfaces factor of safety relative to the other slip surfaces in the pools factors of safety ($\mathbb{R}$). Sequence length values *nslip*, and *Mpool* are defined by the Genetic Algorithm Module (section 11).

Mpool : $\mathbb{R}$ The number of slip surfaces in the pool of possible critical slip surfaces being compared and weighting. constant defined in the Genetic Algorithm module (section 11).

Exceptions:
There are no potential exceptions for Slip Weighter.

Output:

pool_Out $[[\mathbb{R}]^{2,\text{nslip}}, \mathbb{R}, \mathbb{R}]^{1,\text{Mpool}}$: The sequence given in *pool_In*, with the weight data element recalculated, and the sequence reordered in terms of ascending factors of safety.

16 MIS of the Output Module

16.1 Module Name: Output.m

16.2 Uses

16.2.1 Imported Access Programs

Uses Slicer Module - section 13, **Passes** *cslip*, *evnslc*, **Receives** *eval_cslip*

Uses Morgenstern Price Module - section 9, **Passes** *eval_cslip*, *params_layers*, *params_piez*, *params_load*, *params_soln* **Recieves** *F_MP_Final*

Uses RFEM Module - section 10, **Passes** *eval_cslip*, *params_layers*, *params_piez*, *params_load*, **Receives** *F_RFEM_Final*, *FLoc_RFEM_Final*, *DispX_Final*, *DispY_Final*

16.3 Interface Syntax

16.3.1 Exported Access Programs

Name	**In**	**Out**	**Exceptions**
Output	Sequence; struc; struc; struc; struc	-	None

16.4 Interface Semantics

16.4.1 State Variables

$F\_MP\_Final : \mathbb{R}$ — The factor of safety as calculated by the Morgenstern Price solution method for the critical slip surface, measuring the stability of the slope.

$F\_RFEM\_Final : \mathbb{R}$ — The factor of safety as calculated by the RFEM solution method for the critical slip surface, measuring the stability of the slope.

$FLoc\_RFEM\_Final : [\mathbb{R}]^{1,n}$ — Sequence of the factors of safety for the individual slices along the critical slip surface, identifying the sections of the slope most vulnerable to failure, as calculated by the RFEM solution method. Sequence length value n is defined by the Slicer Module (section 13).

DispX_Final : $[\mathbb{R}]^{1,n}$	Sequence of the displacement the slice elements of the slope will experience in the x-ordinate direction to achieve equilibrium for the critical slip surface, as calculated by the RFEM solution method. Sequence length value n is defined by the Slicer Module (section 13).
DispY_Final : $[\mathbb{R}]^{1,n}$	Sequence of the displacement the slice elements of the slope will experience in the y-ordinate direction to achieve equilibrium for the critical slip surface, as calculated by the RFEM solution method. Sequence length value n, is defined by the Slicer Module (section 13).

16.4.2 Access Program Semantics

Input:

cslip : $[\mathbb{R}]^{2,\text{nslip}}$	Sequence of vertex coordinates for the critical slip surface of the slope.
params_layers : struc_layers	(Appendix 17.1.1)
params_piez : struc_piez	(Appendix 17.1.2)
params_soln : struc_soln	(Appendix 17.1.4)
params_load : struc_load	(Appendix 17.1.5)

Exceptions:
There are no potential exceptions for Output.

Output:
Output does not return any values; however, it creates a plot of the critical slip surface *cslip* as a part of the slope geometry *strat* (from *params_layers*). The plot also displays the displacements the slice elements experience as calculated by the RFEM method in *DispX_Final* and *DispY_Final*. A second plot displaying the value of the local factors of safety at each element *FLoc_RFEM_Final*, and the global factors of safety calculated by the Morgenstern Price module *F_MP_Final*, and by the RFEM module *F_RFEM_Final* on the same plot as straight lines across each element.

References

Carlo Ghezzi, Mehdi Jazayeri, and Dino Mandrioli. *Fundamentals of Software Engineering*. Prentice Hall, Upper Saddle River, NJ, USA, 2nd edition, 2003.

Daniel M. Hoffman and Paul A. Strooper. *Software Design, Automated Testing, and Maintenance: A Practical Approach*. International Thomson Computer Press, New York, NY, USA, 1995. URL `http://citeseer.ist.psu.edu/428727.html`.

17 Appendix

17.1 Parameter Tables

17.1.1 Layer Parameters

The elements in the structure of the containers for the parameters of different slope layers. Assumed that the parameters will be entered such that sequence progresses from the uppermost stratigraphic layer at the first index, to the lowest stratigraphic layer at the last index. *nlayer* refers to the number of soil layers in the slope, and is defined by the input file.

Parameter	Description
$strat : [[\mathbb{R}]^{2,\mathrm{nvtx}}]^{1,\mathrm{nlayer}}$	Sequence of coordinate sequences describing the vertexes of each layer. The value *nvtx* is defined by the input file, and can be different for each sequence.
$phi : [\mathbb{R}]^{1,\mathrm{nlayer}}$	Sequence of the effective angle of friction for each stratigraphic layer.
$coh : [\mathbb{R}]^{1,\mathrm{nlayer}}$	Sequence of the effective cohesion for each stratigraphic layer.
$gam : [\mathbb{R}]^{1,\mathrm{nlayer}}$	Sequence of the dry unit weight of soil for each stratigraphic layer.
$gams : [\mathbb{R}]^{1,\mathrm{nlayer}}$	Sequence of the saturated unit weight of soil for each stratigraphic layer.
$E : [\mathbb{R}]^{1,\mathrm{nlayer}}$	Sequence of the Young's modulus for each stratigraphic layer.
$nu : [\mathbb{R}]^{1,\mathrm{nlayer}}$	Sequence of the poissons ratio for each stratigraphic layer.

17.1.2 Piezometric Parameter

The elements in the structure for parameters relating to the piezometric surface existing on the slope. *npz* refers to the number of vertexes describing the piezometric surface, and is defined by the input file.

Parameter	Description
$piez : [\mathbb{R}]^{2,\mathrm{npz}}$	Sequence of vertex coordinates describing the geometry of the water table. If there is no water table than *piez* is an empty array.
$gamw : \mathbb{R}$	The unit weight of water.

17.1.3 Search Range Parameters

The elements in the structure for parameters relating to the range of coordinates the critical slip surface will be searched for in.

Parameter	Description
Xext : $[\mathbb{R}]^{1,2}$	Sequence of the range of x-ordinates that the exit point of the slip will be searched for in. Exit refers to the point of the slip at lower elevation that the slope mass will move towards during failure.
Xent : $[\mathbb{R}]^{1,2}$	Sequence of the range of x-ordinates that the entry point of the slip will be searched for in. Entry refers to the point of the slip at higher elevation that the slope mass will move away from during failure.
Ylim : $[\mathbb{R}]^{1,2}$	Sequence of range of y-ordinates that the slip will be searched for in. The larger value should be greater than the max y-ordinate of the slope. The smaller Ylim value is the deepest the slip surface is expected to descend to.

17.1.4 Solution Parameters

The elements in the structure for parameters relating to method in which the solution method will be approached.

Parameter	Description
ltor : $\mathbb{B}$	Direction the slope is expected to experience failure in. If true than the side of the slope with a greater x-ordinate value is at a lower elevation. If false than the side of the slope with a greater x-ordinate is at a higher elevation.
ftype : $\mathbb{B}$	Switch between functions to use for interslice shear/normal inclination function. If true then the inclination function is a constant (Spencer's method). If false then the inclination function is a half-sine (standard Morgenstern Price method).
evnslc : $\mathbb{B}$	Switch between method of slicing a slip surface to when preparing for analysis. If true then slice slip surface into equal x-ordinate widths. If false then slice distance between vertices into even number of slices.
cncvu : $\mathbb{B}$	Switch for concave slip surface admissibility criterion. If true then an admissible slip surface must be concave upwards towards the surface. If false then an admissible slip surface does not need to pass this criterion.

obtu : $\mathbb{B}$	Switch for angle limit slip surface admissibility criterion. If true then an admissible slip surface must have all interior angles greater than a set limit. If false then an admissible slip surface does not need to pass this criterion.

17.1.5 Load Force Parameters

The elements in the structure for parameters relating to the forces acting on a slice caused by external sources or loads. n refers to the number of slices composing the slip surface.

Parameter	**Description**
Kc : $\mathbb{R}$	The seismic load factor. The ratio of the weight force of the slope that be exerted outwards as a result of vibrations of the earth's surface. From DD**??** of the SRS.
Q : ??	An applied load being exerted into the slope surface. From DD**??** of the SRS.
omega : ??	The angle the applied load is being exerted into the slope surface. From DD**??** of the SRS.

17.1.6 Internal Force Parameters

The elements in the structure for parameters relating to the forces acting on a slice caused by the slope, and water in the slope acting on itself. n refers to the number of slices composing the evaluation slip surface, and is defined by the Slicer module (section 13).

Parameter	**Description**
Ub : $[\mathbb{R}]^{1,n}$	Sequence of the force acting on the basal surface of a slice as a result of pore water pressure within the slice. Value for each slice. From DD2 of the SRS.
Ut : $[\mathbb{R}]^{1,n}$	Sequence of the force acting on the upper surface of a slice as a result of pore water pressure standing water on the surface. Value for each slice. From DD3 of the SRS.
W : $[\mathbb{R}]^{1,n}$	Sequence of the downward force acting on the slice caused by the mass of the slice and the force of gravity. Value for each slice. From DD1 of the SRS.

H : $[\mathbb{R}]^{1,n-1}$	Sequence of the force acting into the interslice surfaces as a result of pore water pressure within the adjacent slices. Value for each interslice. From DD4 of the SRS.

17.1.7 Angle Parameters

The elements in the structure for parameters relating to the angles of the slice surfaces. n refers to the number of slices composing the slip surface, and is defined by the input *evalslip* given to the Property Sorter module (section 12).

Parameter	Description
Alpha : $[\mathbb{R}]^{1,n}$	Sequence of the angle that the basal surface of the slice makes with the horizontal. Value for each slice. From DD?? of the SRS.
Beta : $[\mathbb{R}]^{1,n}$	Sequence of the angle that the upper surface of the slice makes with the horizontal. Value for each slice. From DD?? of the SRS.

17.1.8 Soil Interslice Properties

The elements in the structure for parameters relating to the soil properties of the slope, as calculated at the interslice interfaces of an evaluation slip. Calculation is based on the ratio of the interface that is in different stratigraphic layers, and the values of the effective angle of friction in the different layers. Interest is only with the interior interslice interfaces therefore for a slope of n slices, there will be $n-1$ interior interslice interfaces. The value n is defined by the input *evalslip* given to the Property Sorter module (section 12).

Parameter	Description
phi_IS : $[\mathbb{R}]^{1,n-1}$	Sequence of the vector of the effective angle of friction calculated at each interslice interface.
coh_IS := $[\mathbb{R}]^{1,n-1}$	Sequence of the vector of the effective cohesion calculated at each interslice interface.
E_IS := $[\mathbb{R}]^{1,n-1}$	Sequence of the vector of the Youngs modulus calculated at each interslice interface.
nu_IS := $[\mathbb{R}]^{1,n-1}$	Sequence of the vector of the Poisson ratio calculated at each interslice interface.

17.1.9 Soil Base Properties

The elements in the structure for parameters relating to the soil properties of the slope, as calculated at the basal surfaces of an evaluation slip. Calculation is based on the ratio of the basal surface that is in different stratigraphic layers, and the values of the effective angle of friction in the different layers. An evaluation slip of n slices will have n basal surfaces, and the value of n is defined by the input *evalslip* given to the Property Sorter module (section 12).

Parameter	**Description**
phi_Base : $[\mathbb{R}]^{1,n}$	Sequence of the vector of the effective angle of friction calculated at each slice basal surface in an evaluation slip.
coh_Base : $[\mathbb{R}]^{1,n}$	Sequence of the vector of the effective cohesion calculated at each slice basal surface in an evaluation slip.
E_Base : $[\mathbb{R}]^{1,n}$	Sequence of the vector of the Young's modulus calculated at each slice basal surface in an evaluation slip.
nu_Base : $[\mathbb{R}]^{1,n}$	Sequence of the vector of the Poisson ratio calculated at each slice basal surface in an evaluation slip.