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. The document is intended to ease understanding of the design of SSP and should be used as a resource for any maintenance of SSP.

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 $(-\infty, \infty)$
integer	$\mathbb{Z}$	a number without a fractional component 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 10)

The non-linear nature of the systems of equations in the Morgenstern-Price solver algorithm requires that the equations for the factor of safety (IM1), the interslice normal-to-shear force ratio (IM2), and the interslice normal forces (IM3) are solved iteratively, with an initial guess for two of the values, typically the factor of safety and interslice normal-to-shear force ratio.

Genetic Algorithm (Section 11)

SSP uses a genetic algorithm to find the coordinates of the critical slip surface vertices that minimize the factor of safety, as described in IM4. The genetic algorithm generates a set of initial potential slip surfaces, and subsequent generations are created by merging and mutating slip surfaces with low factors of safety from the previous generation. The minimum factor of safety after several generations is assumed to correspond to the critical slip surface.

[This section is not on the template. I've left it in for now because the information does seem useful, but maybe this is not the right place for it? Maybe this should go to an appendix? —BM]

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	Sequence Data Structure Random Number Generation Plotting

Table 1: Module Hierarchy

7 MIS of the Control Module

7.1 Module

Control

7.2 Uses

Input (Section 8), Output (Section 9), GenAlg (Section 11), Sequence (Section 16)

7.3 Syntax

7.3.1 Exported Constants

N/A

7.3.2 Exported Data Types

N/A

7.3.3 Exported Access Programs

Name	In	Out	Exceptions
Control	string	-	-

7.4 Semantics

7.4.1 State Variables

N/A

7.4.2 Environment Variables

N/A

7.4.3 Assumptions

The access program is called with a string parameter.

7.4.4 Access Routine Semantics

control(*fname*):

- transition:

  Modifies the state of the Input Module, Genetic Algorithm Module, and Output Module.

7.4.5 Local Functions

N/A

8 MIS of the Input Module

8.1 Module

Input

8.2 Uses

Sequence (Section 16)

8.3 Syntax

8.3.1 Exported Constants

N/A

8.3.2 Exported Data Types

coord	=	tuple of (x : $\mathbb{R}$, y : $\mathbb{R}$)
coords	=	[coord]
paramsLayers	=	tuple of (strat : coords, phi : $\mathbb{R}$, coh : $\mathbb{R}$, gam : $\mathbb{R}$, gams : $\mathbb{R}$) (Appendix 19.1.1)
paramsPiez	=	tuple of (piez : coords, gamw : $\mathbb{R}$) (Appendix 19.1.2)
paramsSearch	=	tuple of (Xext, Xetr, Ylim : $[\mathbb{R}]^{1x2}$) (Appendix 19.1.3)
paramsSoln	=	tuple of (ltor, ftype, evenslc, cncvu, obtu : $\mathbb{B}$) (Appendix 19.1.4)

8.3.3 Exported Access Programs

Name	In	Out	Exceptions
load_params	string	-	fileNotExist, badFileExtension, unexpectedInput
verify_params	-	-	badSlopeGeometry, badEffAngleFriction, badCohesion, badDryUnitWeight, badSatUnitWeight, badPiezGeometry, badWatUnitWeight
strat	-	coords	-
slopeX	-	$[\mathbb{R}]$	-
slopeY	-	$[\mathbb{R}]$	-
phi	-	$\mathbb{R}$	-
coh	-	$\mathbb{R}$	-
gam	-	$\mathbb{R}$	-
gams	-	$\mathbb{R}$	-
piez	-	coords	-
piezX	-	$[\mathbb{R}]$	-
piezY	-	$[\mathbb{R}]$	-
gamw	-	$\mathbb{R}$	-
Xext	-	$[\mathbb{R}]^{1x2}$	-
Xetr	-	$[\mathbb{R}]^{1x2}$	-
Ylim	-	$[\mathbb{R}]^{1x2}$	-
ltor	-	$\mathbb{B}$	-
ftype	-	$\mathbb{B}$	-
evenslc	-	$\mathbb{B}$	-
cncvu	-	$\mathbb{B}$	-
obtu	-	$\mathbb{B}$	-

8.4 Semantics

8.4.1 State Variables

params_layers : paramsLayers
params_piez : paramsPiez
params_search : paramsSearch
params_soln : paramsSoln

8.4.2 Environment Variables

in_file : String

- *in_file* represents a file stored in the file system of the hardware running SSP.

8.4.3 Assumptions

- load_params is called before any of the other access programs.
- The guesses for potential minimum and maximum x and y values of the critical slip surface, as described in *in_file*, lie within the boundaries of the given slope geometry.

8.4.4 Access Routine Semantics

load_params(*fname*):

- transition:

  params_layers, *params_piez*, *params_search*, *params_soln* := *params_layers'*, *params_piez'*, *params_search'*, *params_soln'*
  where *params_layers'*, *params_piez'*, *params_search'*, and *params_soln'* are populated based on the contents of *in_file*.

- exceptions:

  exc := (*fname* does not exist in file system ⇒ fileNotExist
  | *fname*[(|*fname*| - 5)..(|*fname*| - 1)] = ".out" ⇒ badFileExtension
  | *in_file* is not formatted correctly ⇒ unexpectedInput)

verify_params():

- exceptions:

$$exc := (\neg(\forall i \in [0..|params\_layers.strat|-2])(params\_layers.strat[i].x - params\_layers.strat[i+1].x \leq 0) \Rightarrow \text{badSlopeGeometry}$$
$$|\ \neg(0 < params\_layers.phi < 90) \Rightarrow \text{badEffAngleFriction}$$
$$|\ \neg(0 < params\_layers.coh) \Rightarrow \text{badCohesion}$$
$$|\ \neg(0 < params\_layers.gam) \Rightarrow \text{badDryUnitWeight}$$
$$|\ \neg(0 < params\_layers.gams) \Rightarrow \text{badSatUnitWeight}$$
$$|\ \neg(\forall i \in [0..|params\_piez.piez|-2])(params\_piez.piez[i].x - params\_piez.piez[i+1].x \leq 0)$$
$$\vee params\_piez.piez[0].x \neq params\_layers.strat[0].x$$
$$\vee params\_piez.piez[|params\_piez.piez|-1].x$$
$$\neq params\_layers.strat[|params\_layers.strat|-1].x \Rightarrow \text{badPiezGeometry})$$

strat():

- output:

$$out := params\_layers.strat$$

slopeX():

- output:

$$out := params\_layers.strat[0].x || params\_layers.strat[1].x || \ldots || params\_layers.strat[|params\_layers.strat|-1].x$$

slopeY():

- output:

$$out := params\_layers.strat[0].y || params\_layers.strat[1].y || \ldots || params\_layers.strat[|params\_layers.strat|-1].y$$

phi():

- output:

$$out := params\_layers.phi$$

coh():

- output:

$$out := params\_layers.coh$$

gam():

- output:

$$out := params\_layers.gam$$

gams():

- output:

$$out := params\_layers.gams$$

piez():

- output:

$$out := params\_piez.piez$$

piezX():

- output:

$$out := params\_layers.piez[0].x || params\_layers.piez[1].x || \\ \ldots || params\_layers.piez[|params\_layers.piez| - 1].x$$

piezY():

- output:

$$out := params\_layers.piez[0].y || params\_layers.piez[1].y || \\ \ldots || params\_layers.piez[|params\_layers.piez| - 1].y$$

gamw():

- output:

$$out := params\_piez.gamw$$

Xext():

- output:

$$out := params\_search.Xext$$

Xetr():

- output:

$$out := params\_search.Xetr$$

Ylim():

- output:

$$out := params\_search.Ylim$$

ltor():

- output:

$$out := params\_soln.ltor$$

ftype():

- output:

$$out := params\_soln.ftype$$

evenslc():

- output:

$$out := params\_soln.evenslc$$

cncvu():

- output:

$$out := params\_soln.cncvu$$

obtu():

- output:

$$out := params\_soln.obtu$$

8.4.5 Local Functions

N/A

9 MIS of the Output Module

9.1 Module

Output

9.2 Uses

Sequence (Section 16), Plot (Section 17)

9.3 Syntax

9.3.1 Exported Constants

N/A

9.3.2 Exported Data Types

N/A

9.3.3 Exported Access Programs

Name	In	Out	Exceptions
verify_output	-	-	
output		-	-

9.4 Semantics

9.4.1 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.

9.4.2 Access Routine 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 19.1.1)
params_piez : struc_piez	(Appendix 19.1.2)
params_soln : struc_soln	(Appendix 19.1.4)
params_load : struc_load	(Appendix **??**)

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 the factor of safety calculated by the Morgenstern-Price module *F_MP_Final*.

10 MIS of the Morgenstern Price Solver Module

10.1 Module

MorgPriceSolver

10.2 Uses

Input (Section 8), PropertySorter (Section 12), Sequence (Section 16)

10.3 Syntax

10.3.1 Exported Constants

N/A

10.3.2 Exported Data Types

N/A

10.3.3 Exported Access Programs

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

10.4 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]

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]

10.4.2 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.

10.4.3 Access Routine 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 19.1.1)
params_piez : struc_piez	(Appendix 19.1.2)
params_soln : struc_soln	(Appendix 19.1.4)
params_load : struc_load	(Appendix **??**)

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.

11 MIS of the Genetic Algorithm Module

11.1 Module

GenAlg

11.2 Uses

11.2.1 Imported Access Programs

Input (Section 8), MorgPriceSolver (Section 10), Slicer (Section 13), KinAdm (Section 14), SlipWeighter (Section 15), Sequence (Section 16), Rand (Section 18)

11.3 Syntax

11.3.1 Exported Constants

N/A

11.3.2 Exported Data Types

N/A

11.3.3 Exported Access Programs

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

11.4 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 Routine Semantics

Input:

params_layers : struc_layers (Appendix 19.1.1)

params_piez : struc_piez (Appendix 19.1.2)

params_search : struc_search (Appendix 19.1.3)

params_soln : struc_soln (Appendix 19.1.4)

params_load : struc_load (Appendix ??)

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

PropertySorter

12.2 Uses

Input (Section 8), Sequence (Section 16)

12.3 Syntax

12.3.1 Exported Constants

N/A

12.3.2 Exported Data Types

N/A

12.3.3 Exported Access Programs

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

12.4 Semantics

12.4.1 Access Routine 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 19.1.1)
params_piez : struc_piez	(Appendix 19.1.2)

Exceptions:
There are no potential exceptions for Property Sorter.

Output:

params_internalForce : struc_intForce	(Appendix 19.1.5)
params_angles : struc_angles	(Appendix 19.1.6)
params_soilInterior : struc_soilInt	(Appendix 19.1.7)
params_soilBase : struc_soilBase	(Appendix 19.1.8)

13 MIS of the Slip Slicer Module

13.1 Module

Slicer

13.2 Uses

Sequence (Section 16)

13.3 Syntax

13.3.1 Exported Constants

N/A

13.3.2 Exported Data Types

N/A

13.3.3 Exported Access Programs

Name	In	Out	Exceptions
Slicer	Sequence; bool	Sequence	None

13.4 Semantics

13.4.1 Local Constants

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

13.4.2 Assumption

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

13.4.3 Access Routine 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 19.1.4).

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

KinAdm

14.2 Uses

Input (Section 8), Sequence (Section 16)

14.3 Syntax

14.3.1 Exported Constants

N/A

14.3.2 Exported Data Types

N/A

14.3.3 Exported Access Programs

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

14.4 Semantics

14.4.1 Assumption

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

14.4.2 Access Routine 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 19.1.4)

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

SlipWeighter

15.2 Uses

Sequence (Section 16)

15.3 Syntax

15.3.1 Exported Constants

N/A

15.3.2 Exported Data Types

N/A

15.3.3 Exported Access Programs

Name	In	Out	Exceptions
Slip Weighting	Sequence; Real	Sequence	None

15.4 Semantics

15.4.1 Access Routine Semantics

Input:

pool_In $[[\mathbb{R}]^{2,\mathrm{nslip}}, \mathbb{R}, \mathbb{R}]^{1,\mathrm{Mpool}}$	:	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 ($[\mathbb{R}]^{2,\mathrm{nslip}}$),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 $[[\mathbb{R}]^{2,\mathrm{nslip}}, \mathbb{R}, \mathbb{R}]^{1,\mathrm{Mpool}}$	:	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 Sequence Data Structure Module

16.1 Module

Sequence

16.2 Uses

N/A

16.3 Syntax

16.3.1 Exported Constants

N/A

16.3.2 Exported Data Types

[T] = sequence of T, where T is any type

16.3.3 Exported Access Programs

Name	In	Out	Exceptions
[_]	Any number of values of type T	[T]	-
_[_]	[T], $\mathbb{Z}$	T	
_[_.._]	[T], $\mathbb{Z}$, $\mathbb{Z}$	[T]	-

16.4 Semantics

16.4.1 State Variables

N/A

16.4.2 Environment Variables

N/A

16.4.3 Assumptions

N/A

16.4.4 Access Routine Semantics

[_](Any number of values):

- output:

  $out :=$ A sequence containing the arguments passed to the function.

$\_[\_](list,\ int)$:

- output:

$$out := list[int]$$

$\_[\_..\_](list,\ int1,\ int2)$:

- output:

$$out := list[int1..int2]$$

16.4.5 Local Functions

N/A

16.4.6 Considerations

This module is the sequence data type and operations on sequences implemented by Matlab.

17 MIS of the Plotting Module

17.1 Module

Plot

17.2 Uses

N/A

17.3 Syntax

17.3.1 Exported Constants

N/A

17.3.2 Exported Data Types

N/A

17.3.3 Exported Access Programs

Name	**In**	**Out**	**Exceptions**
plot	$[\mathbb{R}]$, $[\mathbb{R}]$	-	-

17.4 Semantics

17.4.1 State Variables

N/A

17.4.2 Environment Variables

screen : $[\mathbb{Z}]$

- *screen* represents the colour values for each pixel on the screen of the hardware running SSP.

17.4.3 Assumptions

N/A

17.4.4 Access Routine Semantics

plot(x, y):

- transition:

  Modifies *screen* to display a plot with x on the horizontal axis and y on the vertical axis.

17.4.5 Local Functions

N/A

17.4.6 Considerations

This module is the plot function implemented by Matlab.

18 MIS of the Random Number Generation Module

18.1 Module

Rand

18.2 Uses

N/A

18.3 Syntax

18.3.1 Exported Constants

N/A

18.3.2 Exported Data Types

N/A

18.3.3 Exported Access Programs

Name	In	Out	Exceptions
rand	-	$\mathbb{R}$	-

18.4 Semantics

18.4.1 State Variables

N/A

18.4.2 Environment Variables

N/A

18.4.3 Assumptions

N/A

18.4.4 Access Routine Semantics

rand():

- output:

  out coloneqq A random number in the interval (0,1).

18.4.5 Local Functions

N/A

18.4.6 Considerations

This module is the rand function implemented by Matlab.

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.

19 Appendix

19.1 Parameter Tables

19.1.1 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 upper-most 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
$strat$: $[[\mathbb{R}]^{2,\text{nvtx}}]^{1,\text{nlayer}}$	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 : $[\mathbb{R}]^{1,\text{nlayer}}$	Sequence of the effective angle of friction for each stratigraphic layer.
coh : $[\mathbb{R}]^{1,\text{nlayer}}$	Sequence of the effective cohesion for each stratigraphic layer.
gam : $[\mathbb{R}]^{1,\text{nlayer}}$	Sequence of the dry unit weight of soil for each stratigraphic layer.
$gams$: $[\mathbb{R}]^{1,\text{nlayer}}$	Sequence of the saturated unit weight of soil for each stratigraphic layer.
E : $[\mathbb{R}]^{1,\text{nlayer}}$	Sequence of the Young's modulus for each stratigraphic layer.
nu : $[\mathbb{R}]^{1,\text{nlayer}}$	Sequence of the poissons ratio for each stratigraphic layer.

19.1.2 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
$piez$: $[\mathbb{R}]^{2,\text{npz}}$	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.

19.1.3 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.

19.1.4 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.

19.1.5 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.

19.1.6 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.

19.1.7 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.

19.1.8 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.