Stress_CSM8

A spreadsheet tool for determining the one-dimensional stress field within the ground for hydrostatic fluid conditions using the Finite Difference Method (FDM).

USER'S MANUAL

J. A. Knappett (2012)

This user's manual and its associated spreadsheet ('Stress_CSM8.xls') accompanies **Craig's Soil Mechnics, 8th Edition** (J.A. Knappett & R.F. Craig).

1. INTRODUCTION

This manual will explain how to use the spreadsheet analysis tool 'Stress_CSM8.xls' to determine the total stress, pore pressure and effective stress distributions with depth within layered soil profiles using a simple finite difference method. The spreadsheet has the following features:

- Ability to model up to 10 distinct soil layers of different unit weight;
- Model soil up to 150 m thick;
- Model a water table (WT) both below and above the surface of the ground;
- Include hydraulically confined layers where artesian conditions exist;
- Model surcharge loading at the surface of the ground (e.g. embankments, fill);
- Automatically produce an A4 output sheet with the stress profiles shown graphically.

This manual is structured as follows:

Section 2 The basic structure of both the workbook (Stress_CSM8.xls) and the worksheet used to perform the analyses will be described and the principle of operation will be highlighted.

Section 3 This section will describe how to use this simple tool to analyse a range of different ground conditions by considering worked examples from the main text.

2. PROGRAMME DESCRIPTION

The spreadsheet analysis tool consists of two worksheets. The first, *Data input*, is the worksheet which is used to interact with the spreadsheet. There are various cells for inputting data, and the graphical output (i.e. a graph showing the profiles of total stress, pore pressure and effective stress with depth) is also shown on this worksheet. The second worksheet, *Calculations*, is non-editable and performs the various calculations on the input data to determine the stresses/pressures over a fine depth scale (every 0.1 m, up to 150 m BGL), and the extraction of data for automatic plotting over a depth range defined by the user. The structure of the workbook is shown in Figure 1.

Data input:

In the **Project ID** section, basic information relating to the project or example being analysed is inputted, along with details of user who prepared the calculations for auditing purposes. This information is not required for analysis, but appears in the header boxes when the output sheet is printed, and should be included as a matter of course. If the workbook is use to analyse data from a borehole log or CPT sounding (see Chapter 6 in main text) then the identifier (ID) of the hole/sounding or grid coordinates may be input for reference.

The **Soil & groundwater data** section is where all of the information required for calculation is input by the user. Up to 10 soil layers, each with a distinct unit weight can be included. Unit weight should be saturated if the material is below the WT and dry if the material is above the WT. These should be input with Layer 1 being the uppermost layer. By inputting the thickness of each layer, the spreadsheet will automatically determine the depths BGL of the top and bottom of each layer. The depth of the WT BGL is also given (N.B. for WT below the ground surface, the value should be positive). If a surcharge (e.g. due to fill material) is acting on the surface to increase the total stress, the thickness and unit weight may be entered. If only the surcharge pressure is known, an equivalent unit weight and thickness should be input, the product of which will give the appropriate pressure. If a layer is under artesian pressure, the level of the piezometric surface above ground level (AGL) can be input – this is the height AGL of the water level as measured in a standpipe sunk into the artesian layer, and is therefore suited to the input of measurements taken directly from the field. If the WT is below ground level, the spreadsheet will automatically calculate the additional head in the artesian layer and add this to the hydrostatic pressure to get the correct overall pore water pressure in the layer. Finally, the user can enter a depth range over which the resulting stress/pressure profiles will be plotted, by varying the values of z_{min} and z_{max} (N.B. as for WT depth, these values should be positive to indicate depths BGL).

In the **Output data** section, the profiles of total stress, pore pressure and effective stress are plotted over the depth range specified by z_{min} and z_{max}. An equivalent borehole log is plotted to the right of this data over the same depth scale, showing graphically the layering in the soil. All calculations are done automatically and immediately (i.e. there is no need to press F9 following data input).

The **Data query** section allows for direct numerical output of the total stress, pore pressure and effective stress at any depth specified by the user, for use in subsequent analyses.

The sheets are protected so that only data input cells can be edited by the user. The entire Calculations worksheet is similarly protected. This is to prevent accidental over-typing of formulae which may affect the functionality of the spreadsheet. However, the protection is not password protected, so the protection may be removed (Tools > Protection > Unprotect Sheet… in Microsoft Excel) if users wish to investigate the calculation procedures used.

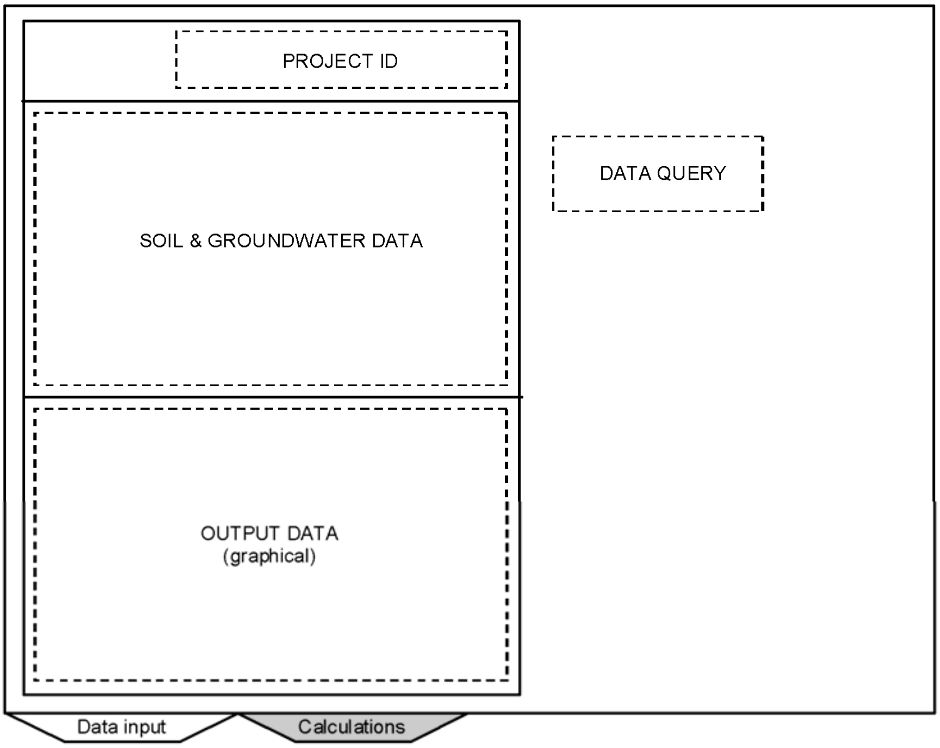

Figure 1: Workbook structure

3. MODELLING

To illustrate how the spreadsheet may be used to model different ground and groundwater conditions, this section will consider the worked examples (3.1 and 3.2) presented in the main text. Output sheets from Stress_CSM8 for all of these examples are provided in the Appendix.

Example 3.1 – WT below ground surface, layered soil

The problem geometry is shown in Figure 2. This problem demonstrates:

- how to model ground with multiple soil layers;
- how to model a layer of soil through which the WT passes (i.e. WT below ground surface);
- how to model a zone of capillary suction.

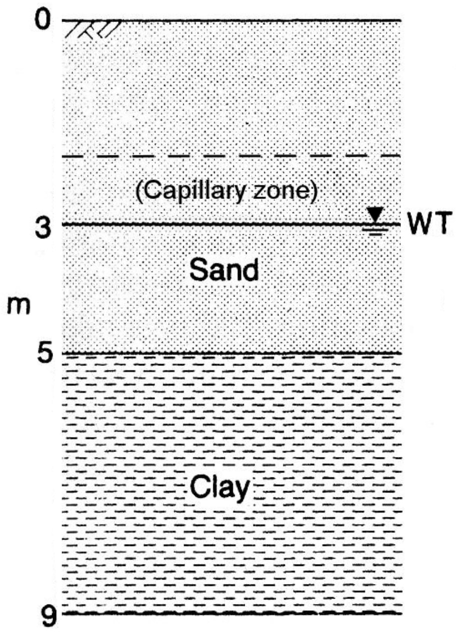

Figure 2: Example 3.1

Initially, the case of no capillary suction is considered. Because the WT passes through the sand layer, the soil above (0 – 3 m) and below (3 – 5 m) will have different unit weights (dry = 17 kN/m^3 and saturated = 20 kN/m^3 respectively). These therefore need to be modelled as separate layers within Stress_CSM8. The layering is entered as shown in Figure 3; the WT depth is set at 3 m and the plotting range from z_{min} = 0 to z_{max} = 9 m.

Using the Data query, the values of total stress, pore pressure and effective stress at 3, 5 and 9 m can be obtained for comparison with the values calculated by hand in Example 3.1 of the main text. A comparison of these values is shown in Table 1. The profiles of stress plotted against depth are compared in Figure 4

Soil layering:

Layer	thickness (m)	γ (kN/m³)	Artesian head AGL (m)
Sand (D)	3	17	0
Sand (S)	2	20	0
Clay	4	19	0
4			
5			
6			
7			
8			
9			
10			

Groundwater conditions:

WT depth BGL = 3 m

γ_w = 9.81 kN/m³

Surcharge:

γ = 0 kN/m³

thickness = 0 m

surcharge = 0 kPa

Plot depth range:

z_{min} = 0 m

z_{max} = 9 m

Figure 3: Data input, Example 3.1

Table 1: Comparison of Stress_CSM8 and hand calculations, Example 3.1

Depth (m)	Method	Total stress, σ_v (kPa)	Pore pressure, u (kPa)	Effective stress, σ'_v (kPa)
3	Hand calculation	51.0	0	51.0
	Stress_CSM8	51.00	0.00	51.00
5	Hand calculation	91.0	19.6	71.4
	Stress_CSM8	91.00	19.62	71.38
9	Hand calculation	167.0	58.9	108.1
	Stress_CSM8	167.00	58.86	108.14

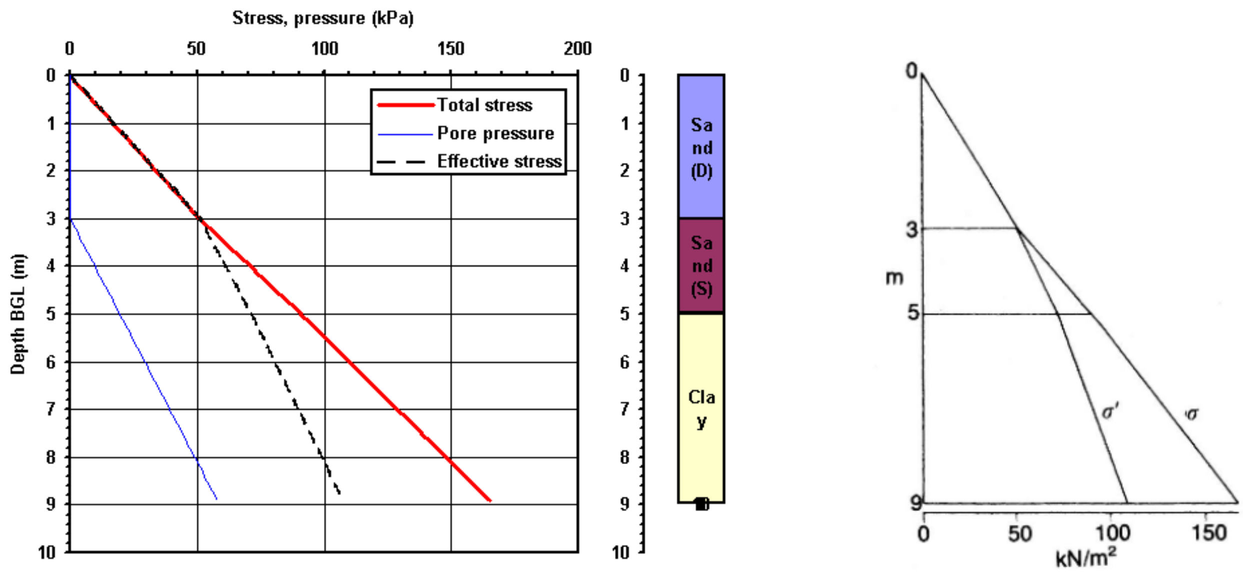

Figure 4: Comparison stress profiles from (a) Stress_CSM8 and (b) main text, Figure 3.2

For the case of a 1 m thick zone of capillary suction in the sand above the WT, as noted in the main text, the only effect is to increase the unit weight of the sand from dry to saturated between 2 – 3 m. This may be accomplished in Stress_CSM8 by altering the thickness of the upper two layers, so that the dry layer is 2 m thick and the saturated layer is 3 m thick, leaving the WT at the same depth. The resulting values of stress/pressure using the query tool are compared to the 'no capillary zone' case considered previously in Table 2. It can be seen that, as described in the main text, the effect of the capillary zone is to increase both total and effective stresses by 3 kPa below 3 m depth.

Table 2: Comparison of values, capillary zone versus no capillary zone, Example 3.1

Depth (m)	Method	Total stress, σ_v (kPa)	Pore pressure, u (kPa)	Effective stress, σ'_v (kPa)
3	No suction	51.00	0.00	51.00
	Capillary zone	54.00	0.00	54.00
5	No suction	91.00	19.62	71.38
	Capillary zone	94.00	19.62	74.38
9	No suction	167.00	58.86	108.14
	Capillary zone	170.00	58.86	111.14

Example 3.2 – WT at surface, surcharge

The problem geometry is shown in Figure 5. This problem additionally demonstrates:

- how to model WT at the ground surface;
- how to model the effect of a surcharge acting at the ground surface.

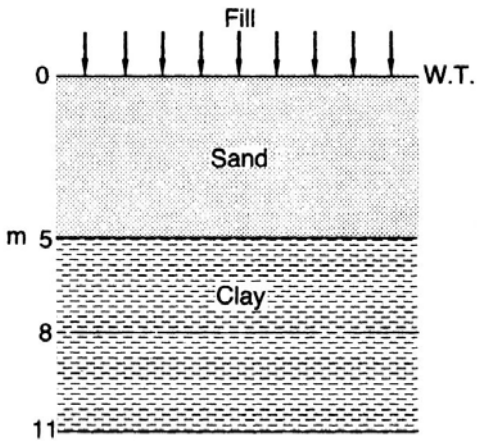

Figure 5: Example 3.1

The fill has a unit weight of 20 kN/m^3 and is 4 m thick. As the WT is at the ground surface in this example, the sand layer can be modelled as a single layer, with γ_{sat} = 19 kN/m^3. The layering is entered as shown in Figure 6; the WT depth is set at 3 m and the plotting range from z_{min} = 0 to z_{max} = 9 m. These parameters, modelling the applied surcharge pressure, always give the stress conditions <u>after dissipation has finished</u>.

Immediately after the fill has been placed, there has been no time for dissipation to have taken place, so the effective stress conditions in the clay will be unchanged from their original values. The original effective stress may be obtained by setting the thickness of the fill (or unit weight, or both) equal to zero so there is no surcharge. Note however that the total stress and pore pressure from such an analysis will not match those under immediate surcharge loading – both values will be increased by the surcharge pressure (80 kPa). Many years after fill placement, the pore pressures have dissipated and the analysis parameters shown in Figure 6 will give the correct values of all three stress/pressure components. These values are compared in Table 3.

Table 3: Comparison of values for surcharge loading, Example 3.2

Case	Model for σ'_v	σ_v (kPa)	u (kPa)	σ'_v (kPa)	σ'_v from main text (kPa)
Immediate	No surcharge	155.00 ***+80***	78.48 ***+80***	76.52	76.5
After dissipation	Surcharge	235.00	78.48	156.52	156.5

Soil layering:

Layer	thickness (m)	γ (kN/m^3)	Artesian head AGL (m)
Sand	5	19	0
Clay	6	20	0
3			
4			
5			
6			
7			
8			
9			
10			

Groundwater conditions:

WT depth BGL = 0 m

γ_w = 9.81 kN/m^3

Surcharge:

γ = 20 kN/m^3

thickness = 4 m

surcharge = 80 kPa

Plot depth range:

z_{min} = 0 m

z_{max} = 11 m

Figure 6: Data input, Example 3.2

Modelling the case of WT above ground surface

One further special (but relatively common) case must be considered. It is often necessary to analyse ground conditions when the WT is significantly above the ground surface. Examples may be the soil forming a river bed or, for larger depths, seabed, or ground which has been flooded. Under these conditions, the WT has two effects:

1. to increase the hydrostatic pore pressure at the ground surface;
2. the weight of the water applies additional total stress (i.e. surcharge) at the ground surface.

In Stress_CSM8, this is modelled by combining the WT depth and surcharge parameters. For a WT of height *H* above the ground surface, the following parameters are set:

Groundwater conditions:
- WT depth BGL = -*H*

Surcharge:
- γ = 9.81
- thickness = *H*