

Layered elastic analysis of stabilised pavements

The purpose of this guideline is to provide simple instructions to CIRCLY¹ 4 users to analyse one or more stabilised layers. This guideline does not replace the CIRCLY 4 User Manual or the training courses run by MINCAD Systems, the supplier of CIRCLY 4.

The examples chosen in the guideline illustrate a simple procedure to navigate through the program to efficiently achieve results. The first example is to determine the design traffic loading (in terms of SARs and ESAs) of a heavily bound insitu stabilised layer for a rural highway with a sprayed-seal wearing surface. The second example is to determine the thickness of a stabilised layer for a rural local road given a design ESAs. The overall data files may be downloaded at www.auststab.com.au/circly/

The last section of this guideline provides some warnings for users of layered elastic programs due to inherent assumptions and numerical calculations.

1 EXAMPLE A

In this example, the pavement engineer is trying to establish the traffic life of a 350 mm thick heavily bound cementitious pavement base with a sprayed seal surface. Material properties of the road are subgrade CBR 12% (Poisson's ratio of 0.45) and the 28-day flexural modulus for the cemented layer is 5,000 MPa (Poisson's ratio of 0.20). In accordance with current practice, the pavement will be analysed with full-axle loading, dual wheels and a tyre pressure of 750 kPa (refer to Figure 1).

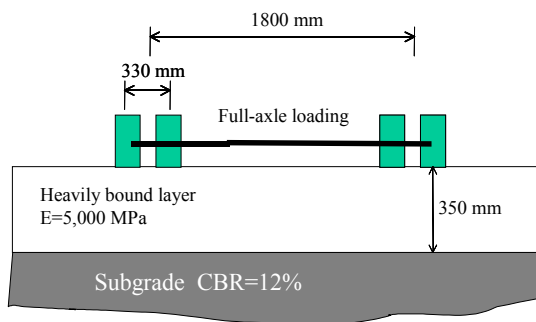


Figure 1 Cross-section of road with material properties.

Stages to determine pavement traffic life are summarised in Table 1. In the instructions the:

- ◇ command, say **Edit**, refers to the pull down menu command line and sub-lines (see Figure 2).
- ◇ Text in italics refers to text type in by the user.

- ◇ Text highlighted, such as **Spectrum Components**, refers to pop-up window headers
- ◇ Text between “” refers to options in the left hand column of a pop-up window to select.

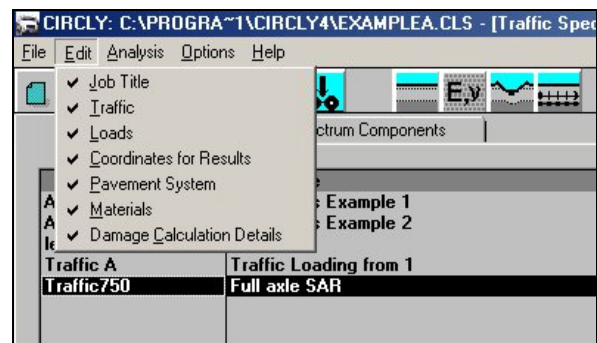


Figure 2 CIRCLY can be operated with the pull-down menu or ICONS.

In the results of this pavement analysis the cumulative damage factor (CDF) for the cement bound layer and subgrade were 1.07×10^{-9} and 1.39×10^{-13} respectively. The inverse of the CDF is the allowable number of standards axle repetitions (ie 9.35×10^8). This value would then be divided by the traffic constant to derive the allowable ESAs for the pavement thickness and properties. In this instance, if the traffic constant was assumed as 10, the allowable ESAs for this pavement configuration would be 9.35×10^7 . The subgrade failure mode is unlikely to occur with a much lower CDF than the stabilised layer.

¹ CIRCLY is a layered elastic analysis program. Refer to <http://www.mincad.com.au/>

Table 1 Steps to run pavement thickness analysis in CIRCLY for Example A.

Step	Instructions	Ref. Figure
1	Select File New type in Job Name <i>ExampleA</i> (The job name is the filename)	-
2	Select Edit Job Title type in <i>Recovery Highway, Tamworth</i>	-
3	Select Edit Traffic Select New type in <i>Traffic750</i> select OK type in <i>Full axle – SAR</i>	3
4	Select Edit Loads Select from Load Groups “ESAF750”. If not in list, select New type in <i>ESAF750</i> select OK type in <i>ESA, full axle (pressure=750kPa)</i> for “Title”, <i>ESAF750</i> for “Category”, 1 for “Rows”, 1 for “Type”, 92.3 for “Radius”, 0.75 for “Stress” and 0.00 for “Exponent”.	4
5	Check in Load Locations that there are four rows of data. Otherwise add the following “X” values per line –165, 165, 1635 and 1965 (This represents two sets of dual wheels). All “Y” values are 0, “Scaling Factor” values are 1.00 & “Theta” values are 0.00.	5
6	Select Edit Traffic Select Spectrum Components , Select New select <i>ESAF750</i> from Load Groups list and then OK . Type in 1 for “Movements”.	6
7	Select Edit Coordinates for Results select “line of equally spaced points” (default), type 0 for X (min)”, 1200 for “X (max)”, 10 for “X (del)”, 0 for “Y” and select “One pulse per axle”.	7
8	Select Edit Pavement System select New under Layered System and type in <i>Stab350</i> and then OK . Type in <i>One stabilised layer 350 thick</i>	-
9	Select Components select New and from “Select Material Types” list select “Cement Stabilised” and then OK . From “Select Material” select “Cem5000” and then OK . Type in “thickness” 350.	8
10	Select Components select New and from “Select Material Types” list select “Subgrade (Austroads)” and then OK . From “Select Material” select “SubCBR12” and then OK . Type in “thickness” 0.	-
11	Select Edit Damage Calculation Details and ensure “Calculation damage factor” is selected. The traffic multiplier may be changed at this step by clicking at the value you seek to change. In this example a traffic multiplier is kept at 1.0 for the cemented layer to determine the number of standard axle repetitions.	9
12	Select File Save to save input conditions. The file can also be renamed at anytime and the program saves the input conditions after analysis.	-
13	Select Analysis Run Analysis and review values under “CDF” heading.	9

Additional notes to Table 1

- (a) The coordinates for the analysis in step 6 are based on sufficient spacing of points during analysis and an allowance for full axle loading.
- (b) 0 thickness was selected on the assumption that the subgrade is infinite in depth.
- (c) For insitu stabilisation the interface between the stabilised layer and subgrade is rough.
- (d) Selecting Cem5000 assumes the 12th power law for fatigue of a cement bound layer.

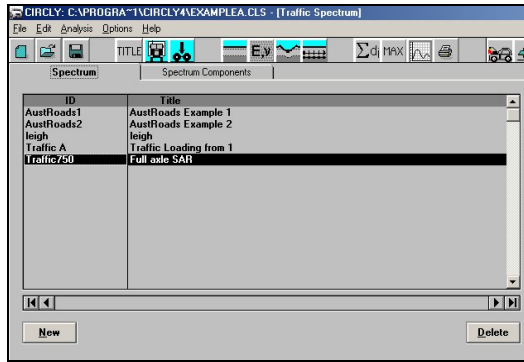


Figure 3 Type in one standard axle. Step 3 for example A.

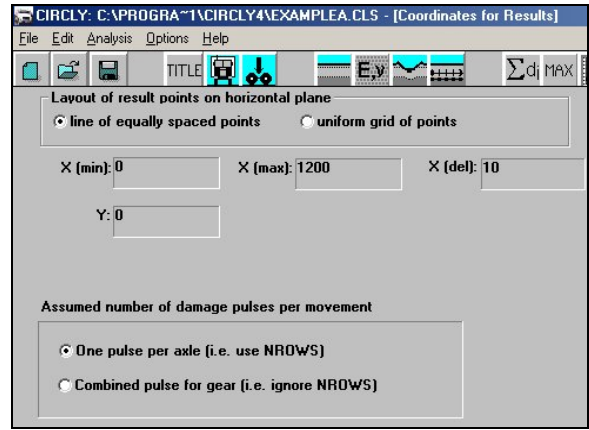


Figure 7 Select appropriate limits and increments for analysis. Step 7 for example A.

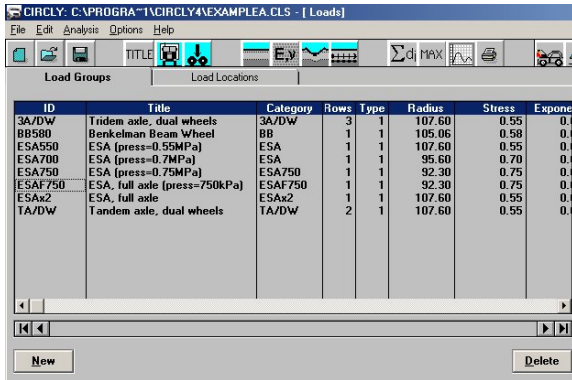


Figure 4 Select full axle configuration. Step 4 for example A.

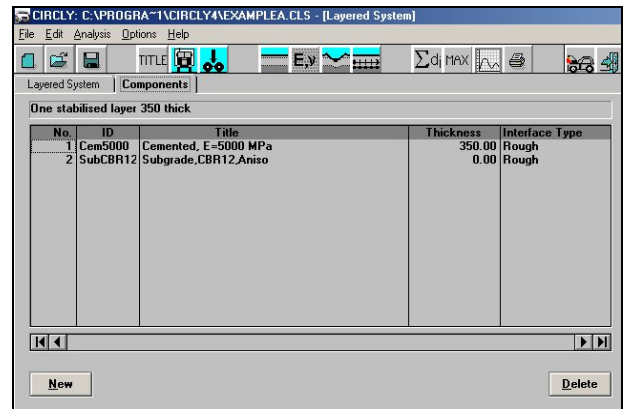


Figure 8 Build up layer information starting from surface layer. Step 9 for example A.

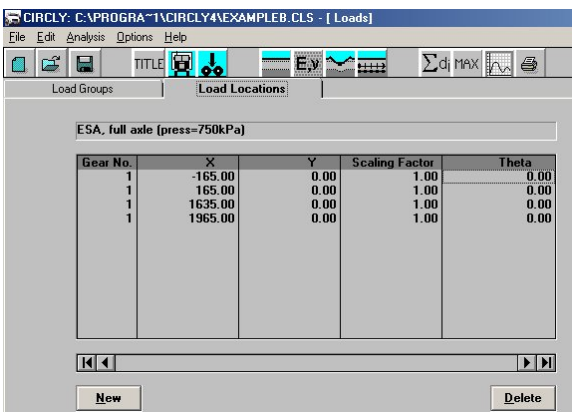


Figure 5 Ensure that there is four load locations for full axle configuration. Step 5 for example A.

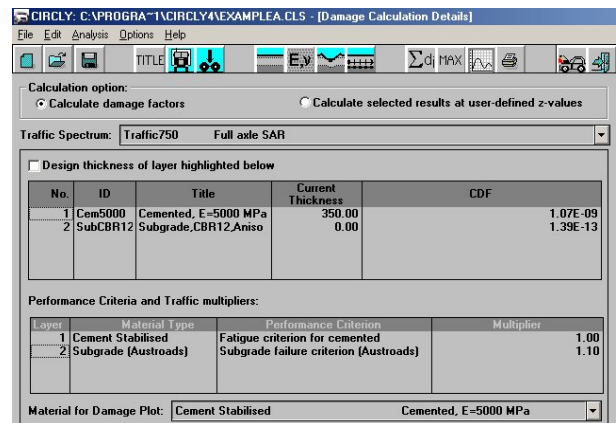


Figure 9 Basic results display. Step 12 for example A.

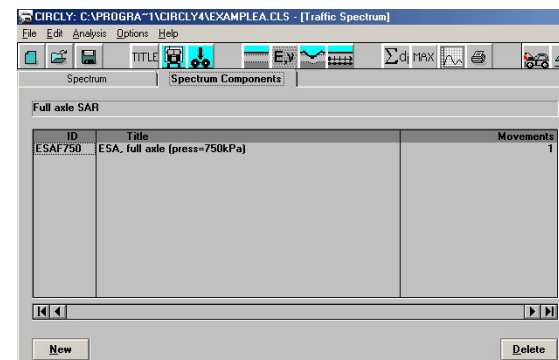


Figure 6 Select one movement (ie one axle configuration). Step 6 for example A.

2 EXAMPLE B

In this example, the pavement engineer is trying to establish the minimum thickness for a lightly bound stabilised layer for an estimated design traffic life of 8×10^5 ESAs. In addition, the pavement is insitu stabilised with a cementitious binder with a design flexural modulus of 3,500 MPa and topped with 30 mm of asphalt. The design subgrade CBR is 10%.

In accordance with current design practice, the pavement will be analysed with full-axle loading, dual wheels and a tyre pressure of 750 kPa (refer to Figure 10) and the asphalt layer will be ignored, as typically asphalt layers less than 40 mm in thickness on a bound layer with this modulus is unlikely to dominate the bound layer analysis outcome.

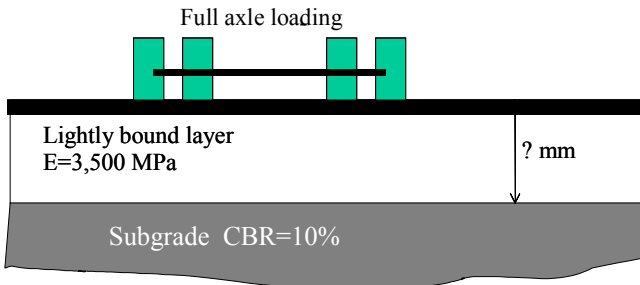


Figure 10 Cross-section of road with material properties.

The design thickness from the analysis is 266 mm. Construction tolerances should take into account the probability of the actual pavement being constructed less than 270 mm.

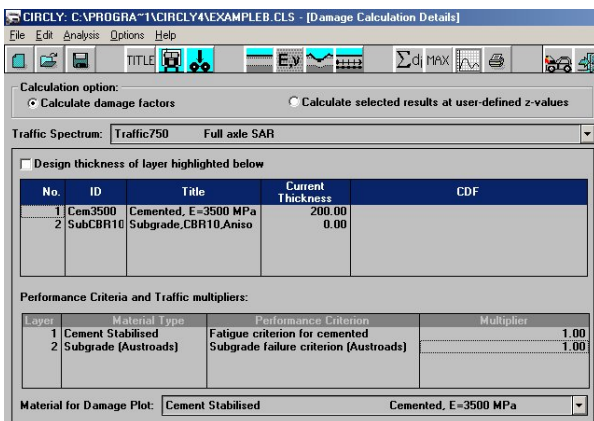


Figure 11 Step 10 for example B.

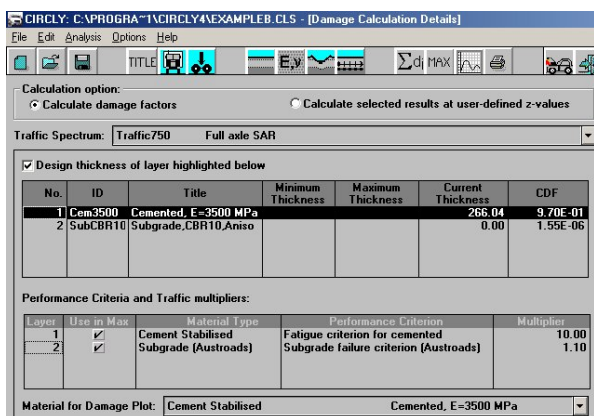


Figure 12 Step 12 for example B.

3 LAYERED ELASTIC ANALYSIS LIMITS

The analysis of pavement materials is based on various assumptions. These guidelines are not intended to cover all these assumptions, but highlight two instances where the engineer may find that the model may not predict the desired outcome.

CIRCLY like other layered elastic programs assumes infinite horizontal layers of material in the analysis. However, if a road is constructed such that the fog line is near or adjacent to the edge of the batter as shown in Figure 13, the assumption of an infinite layer is not longer applicable. This pavement detail should be avoided for all types of pavement and there is no analysis solution offered in this guideline.

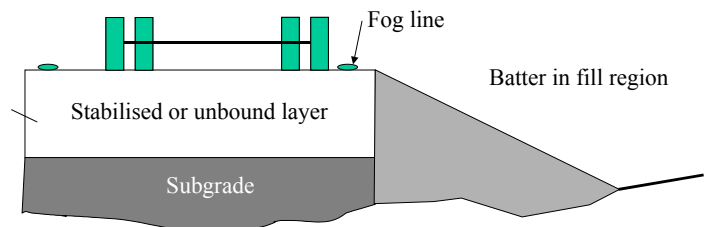


Figure 13 Layered elastic analysis is not appropriate for this pavement profile.

Another instance where pavement modelling may give erroneous results is when a bound cementitious layer is modelled as two or more thin layers to take into consideration where sufficient compaction equipment is unavailable and lower modulus values are applied in the lower layer in the model. Figure 14 is an example of a 350 mm thick heavily bound cemented layer with a flexural modulus of 5,000 MPa and supported on a subgrade with a CBR of 5% (Poisson's ratio of 0.45). Several CIRCLY runs were carried out where the heavily bound "stiff" layer (S1) has been replaced by a lower modulus (ie 2,000 MPa) cemented layer at the bottom of the insitu deep-lift stabilised layer. The total thickness of the two layers has remained at 350 mm.

Figure 14 shows what can happen to the number of standard axle load repetitions when the thickness of the lower layer is reduced to thin layers with the outcome providing designers with erroneous results.

Table 2 Steps to run pavement thickness analysis in CIRCLY for Example B. It has been assumed that Example A has not been run in the steps below.

Step	Instructions	Ref. Figure
1	Select File New type in Job Name <i>ExampleB</i>	-
2	Select Edit Job Title type in <i>Recovery Road, Singleton</i>	-
3	Select Edit Traffic Select New type in <i>Traffic750</i> select OK type in <i>Full axle – SAR</i>	-
4	Select Edit Loads Select from Load Groups “ESAF750”. Check in Load Locations that there are four rows of data. Refer to step 5 in Table 1 if the load locations need to be entered.	4 & 5
5	Select Edit Traffic Select Spectrum Components , Select New select ESAF750 from Load Groups list and then OK . Type in <i>80000</i> for “Movements”.	-
6	Select Edit Coordinates for Results select “line of equally spaced points” (default), type <i>0</i> for X (min)”, <i>1200</i> for “X (max)”, <i>10</i> for “X (del)”, <i>0</i> for “Y” and select “One pulse per axle”.	-
7	Select Edit Pavement System select New under Layered System and type in <i>Bound</i> and then OK . Type in <i>Bound layer (3,500 MPa)</i>	-
8	Select Components select New and from “Select Material Types” list select “Cement Stabilised” and then OK . From “Select Material” select “Cem3500” and then OK . Type in “thickness” <i>200</i> (This is a trial thickness).	-
9	Select Components select New and from “Select Material Types” list select “Subgrade (Austroads)” and then OK . From “Select Material” select “SubCBR10” and then OK . Type in “thickness” <i>0</i> .	-
10	Select Edit Damage Calculation Details and ensure “Calculation damage factor” is selected. Select checkbox titled “Design thickness of layer highlighted below” and select layer No.1 to determine thickness for design traffic. The traffic multiplier should be changed at this step by clicking at the value you seek to change. In this example the traffic multiplier is 10.0 for the cemented layer and 1.1 for the subgrade.	11 & 12
11	Select File Save to save input conditions.	-
12	Select Analysis Run Analysis and value for layer 1 under “CDF” heading should be approximately 1.0 and the “Current Thickness” is the design thickness for the stabilised layer.	12

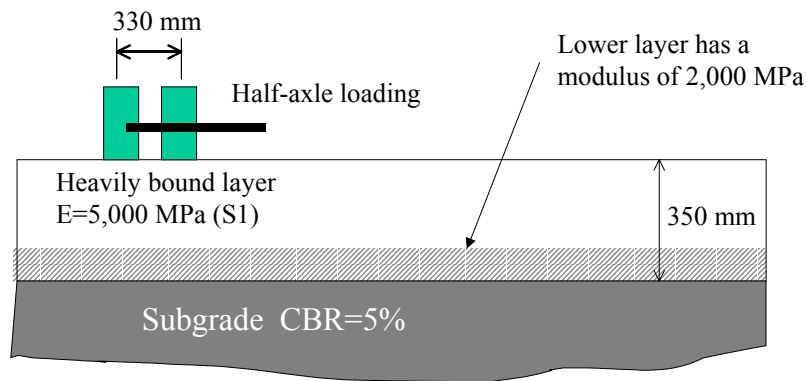


Figure 13 Insitu deep-lift bound layers with varying modulus. The total bound layer is 350 mm in thickness and is supported on a subgrade CBR of 5%.

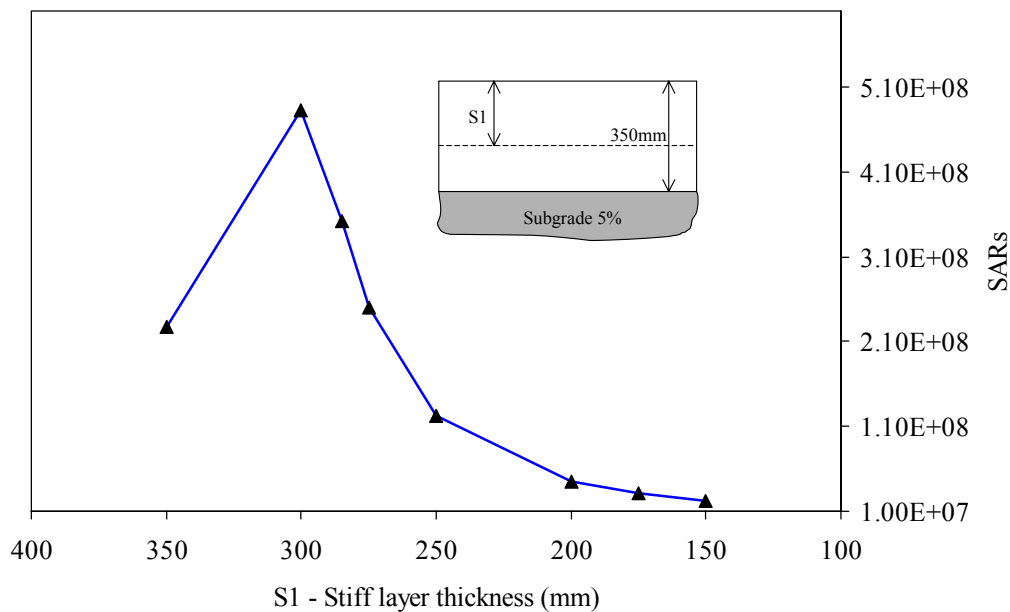


Figure 14 Allowable standard axle load repetitions for deep-lift bound layers with varying modulus.

CIRCLY is an analysis tool and designers should be aware of the limitations to their tools. More importantly, data entered into CIRCLY and other layered elastic programs should represent what is likely to happen in the field, and designers need to carefully consider their assumptions when using density gradients (or stiffness) of materials with depth of layer.

