PaveMOSS - A Pavement Overlay Design System

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Abstract:

This paper describes the development and details the features of a Computer Aided Design program that optimises the pavement quantities for pavement overlay and road widening reconstruction projects. It also proposes a rethink of the methodology of design standards with particular reference to the road template, in the allowance for adjustment of crossfall and of vertical alignment to better fit the purpose and to minimise the cost of this type of construction

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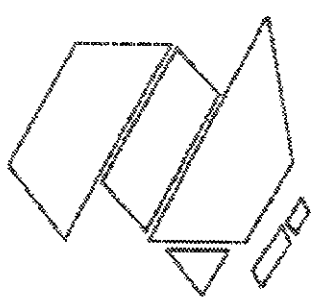


1. Background

The Department of Transport and other State Road Authorities in Australia have steadily increased their expenditure on the rehabilitation of their existing road assets to a point where this type of work commands a large proportion of the total budget.

A high percentage of these funds is spent on existing roads that are near the end of their accepted useable life. Reconstruction of these types of roads generally requires overlaying of the existing surface with paving material and widening of the carriageway and shoulders.

This is a trend world-wide.

There has been a need for some time to streamline the design process and at the same time review the design standards to give a more economical (in terms of pavement volumes) reconstruction project cost.

2. Why PaveMOSS?

Reuse of the existing road asset has a two fold benefit:

- Reduction in the cost of construction to meet present and future traffic requirements
- Conservation of the ever dwindling supply of the earth's naturally occurring road making materials and minimising the effect on the environment in extracting this material.

The existing Computer Aided Design and Drafting (CADD) and/or manual processes for pavement overlay design is time consuming and does not always result in the most economical outcome.

There is a need for a system to be fast, accurate, a good fit for the purpose, optimise pavement quantities and set world best practice. In other words, a design program that will give the designer the ability to output to the road constructors a design that will give the best value for the road dollar.

Queensland Transport developed a concept to meet these needs and negotiated with Moss Systems Australasia to co-develop the system. A business agreement has been signed by both parties to market, support and further develop the package.

PaveMOSS has met the expected outcomes.

3. Development of PaveMOSS

PaveMOSS (Pavement Overlay Design System) is a hybrid system that has been developed with the objective of using template cross section methodology in conjunction with MOSS string modelling technology to undertake and automate pavement overlay design. The program enables the design of pavement overlay and/or widening schemes, employing a process that applies crossfalls between predetermined tolerances and by its optimisation process, applying an optimum grade to establish control lines together with the varying crossfalls that results in the minimum pavement quantity without compromising minimum designed pavement depth.

PaveMOSS comprises a suite of programs based around a subset of the MOSS computer engineering system. The system has been developed to allow the user to apply overlay and widening designs to existing roadways in an automated and interactive process that is very easy to use.

There are a choice of four design methods:

- Overlay Design of Existing Pavement (includes widening if required) see Figure 1.
- Controlled Lift (fixed edge design) see Figure 2.
- Controlled Lift and Extensions (widening schemes) see Figure 3.
- Roadway Design (rural road design via templates) see Figure 4.

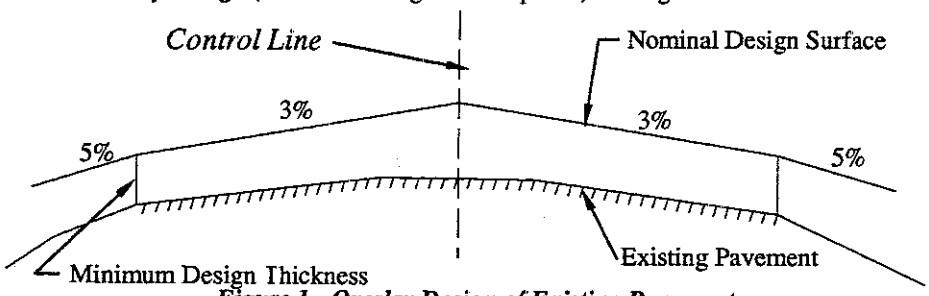


Figure 1 - Overlay Design of Existing Pavement

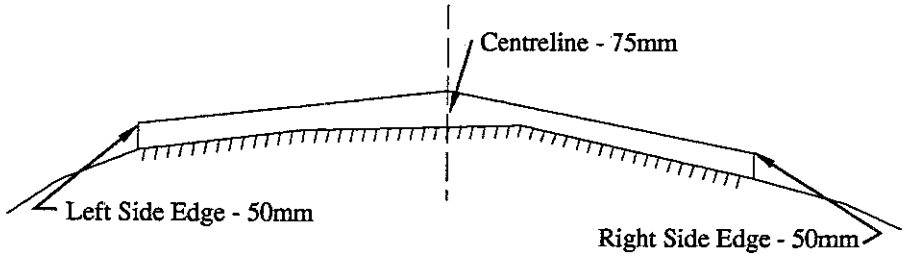


Figure 2 - Controlled Lift (FIXED EDGES)

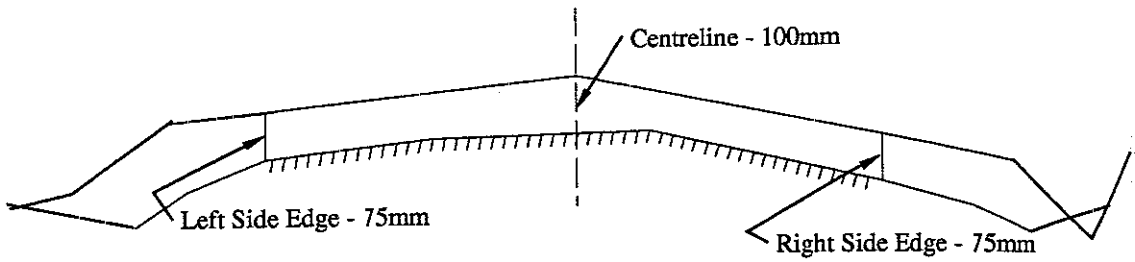


Figure 3 - Controlled Lift - with Extensions

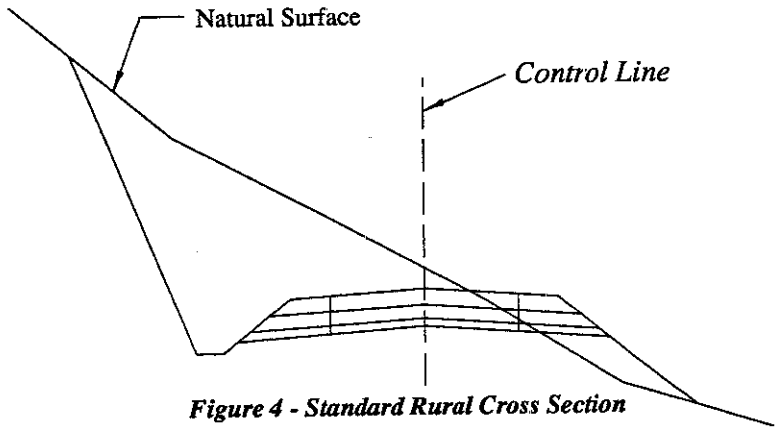


Figure 4 - Standard Rural Cross Section

4. Features

The concept of the program is one where the emphasis is on the optimisation of the overlay pavement quantities by selecting a best fit to the existing pavement profile. There are several innovations in the program over the previous manual/computer design process and generally accepted design standards. They are:-

(a) Ability to achieve a best fit profile using conventional crossfalls and templates;

(b) Controlled lift with overlay pavement depth independently nominated at centre line and edges;

(c) Introduction of "flapping" the crossfall profile for other than controlled lift. The designer may elect to allow the program to vary the crossfall say 0.5% in a positive or negative direction from the nominal 3.0% (see Figure 5);

(d) Optimises the pavement quantities to the minimum necessary while still meeting the pavement design requirements, including corrector course;

(e) Ability of the designer to review the effects of the pavement layer over the whole job as the program compares the designed road surface profile with that of the existing road. In previous systems, designers only had the ability to check profiles and depth of pavement at designated cross sections;

(f) The program will also calculate all earthworks including drains and batters and can, when needed, handle full design where existing pavement is of no value or where the design may call for a small deviation such as the upgrading of a horizontal curve.

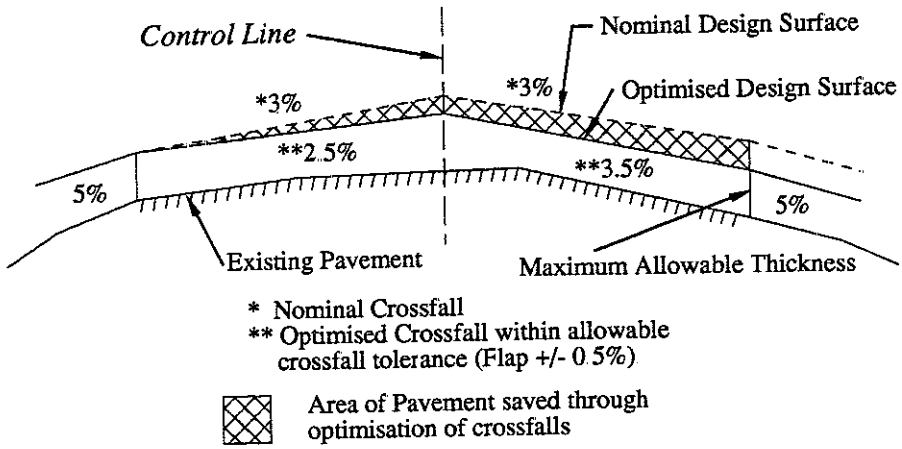


Figure 5 - Optimised Design Cross Section

The outcome of the design using the feature in (c) is to create a road for the travelling public that:-

- looks right, that is, the variance in the crossfall and the vertical alignment over what could be called a conventional design is not apparent to the driver either by eye or riding comfort ;
- riding comfort is within the expected level for that particular class of road;
- stretches the construction dollar as far as possible while still meeting the structural (pavement design) criteria necessary for the design traffic.

5. Design Input

The program is user friendly and requires only a basic knowledge of the MOSS system by the designer.

Input into the program is by a simple screen menu for:-

- Horizontal Alignment
  - Existing road centre line (3D moss string) or
  - Master alignment developed in PaveMOSS or
  - Master alignment developed in MOSS

- Survey Information (can be in any format)
  - Note existing pavement edges are to be a continuous string
- Overlay Design Template
  - Pavement segments (width)
  - Shoulder segments (width)
  - Side drains and batters
  - Pavement crossfall (including flapping)
  - Existing edge of pavement cut back distance (see Figure 6)

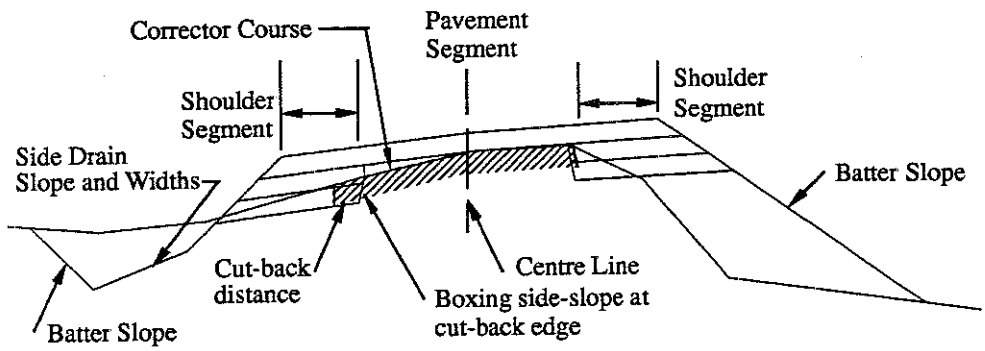
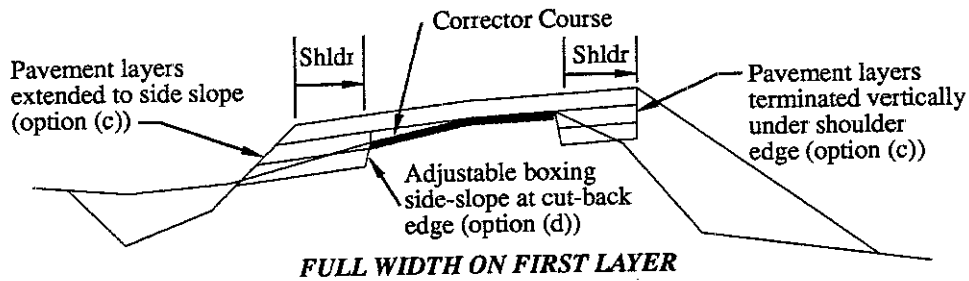
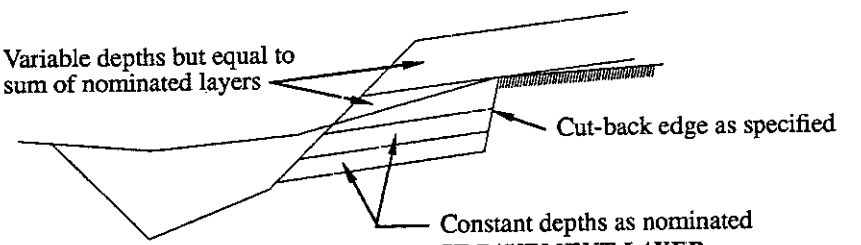


Figure 6 - Overlay Design Template

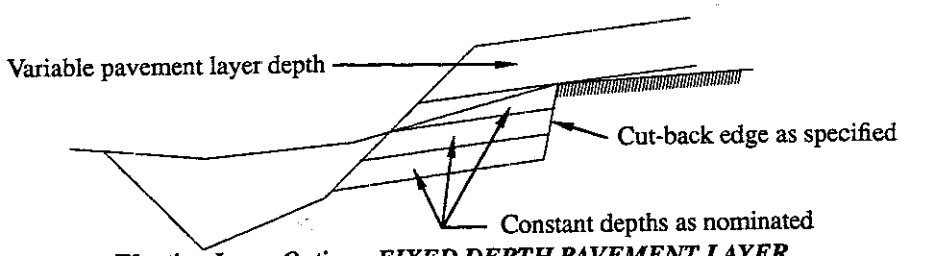
- Pavement Configuration
  - Overlay depths
  - Depths of layers in widening (5 allowed)
  - Pavement depth variability setting
    - full width first layer
    - first layer floats to cut back edge while maintaining total depth of pavement layers
    - Float to existing cut back with fixed depths below first layer
      see figure 7
- Total Reconstruction Section
  - Provide grade details
  - Pavement depths as for widening



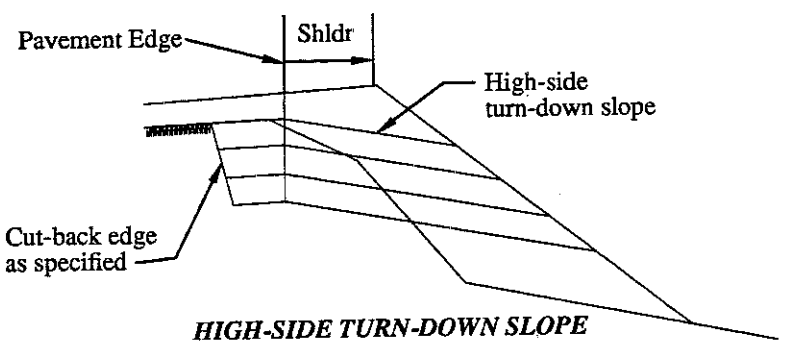
FULL WIDTH ON FIRST LAYER



Floating Layer Option - FIRST PAVEMENT LAYER



Floating Layer Option - FIXED DEPTH PAVEMENT LAYER



HIGH-SIDE TURN-DOWN SLOPE

Figure 7

6. Design Reports

The outputs from the program come in both graphical and text report form. The designer analyses the results to adjust the design if necessary to meet the desired outcomes.

The outputs given to the designer are as follows:-

- Vertical Alignment

Vertical alignment is produced in a graphical form as shown in Figure 8 and indicates the calculated grade in relation to the existing road surface. This grade is presented as a series of chords and angles. Some designers have difficulty in thinking in this dimension as against the more conventional tangent and vertical curve alignment. The program has a feature to calculate a cubic spline to smooth out the vertical alignment if required.

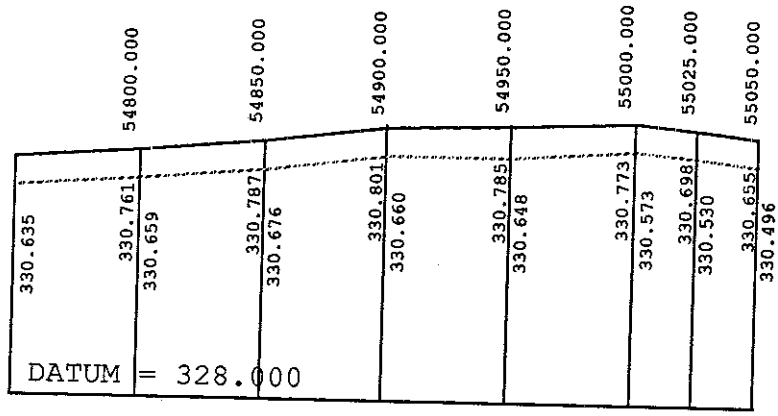


Figure 8 - Vertical Profile

The designer can accept the optimised chord grading output but also has the option to introduce standard IP grading or other standard MOSS (interactive) functions.

If vertical curves are fitted it will invariably result in greater pavement quantities than needed to satisfy the pavement design.

This doesn't mean that the optimisation process in the program has calculated chords and angles that meet acceptable standards of rideability and comfort. The graphical output, together with a report called "Vertical Design Speed Check", will give the designer enough data to make adjustments if necessary.

The Vertical Design Speed Check report analyses the relationship of the series of chords and angles to the design speed and is based on Chapter 7 of the Austroads 1989 publication "Guide to Geometric Design of Rural Roads". The output is in the form of values for K (speed coefficient) and indicates points which fall below the design speed (see Figure 9).

VERTICAL PROFILE ANALYSIS FOR DESIGN SPEED OF 120 km/h

CHAINAGE	LEVEL	G1%	G2%	ACG%	TYPE	K	SPEED
55150.000	330.871	0.224000	-0.064000	-0.288000	HOG	174.	120.
55200.000	330.839	-0.064000	-0.748000	-0.684000	HOG	73.	100.**
55250.000	330.465	-0.748000	-1.448000	-0.700000	HOG	71.	100.**
55300.000	329.741	-1.448000	-2.168000	-0.720000	HOG	69.	100.**
55350.000	328.657	-2.168000	-2.904990	-0.736990	HOG	49.	90.**
55386.110	327.608	-2.904990	-2.858229	0.046761	SAG	297.	120.
55400.000	327.211	-2.858229	-2.732000	0.126229	SAG	396.	120.
55450.000	325.845	-2.732000	-2.354000	0.378000	SAG	132.	120.

Figure 9 - Vertical Design Speed Check

- Cross Section

The cross section output is in graphical form and indicates position of pavement layers, road profile and construction information in the form of offset distances and heights (see figure 12). This output demonstrates the flexibility of the program. The designer is able to select the configuration of the pavement layers, in particular the designer has the ability to allow the first and second layer depth to float so as to match the cut back edge of the existing pavement. Note that the total design depth of both layers would still be achieved, see figure 7.

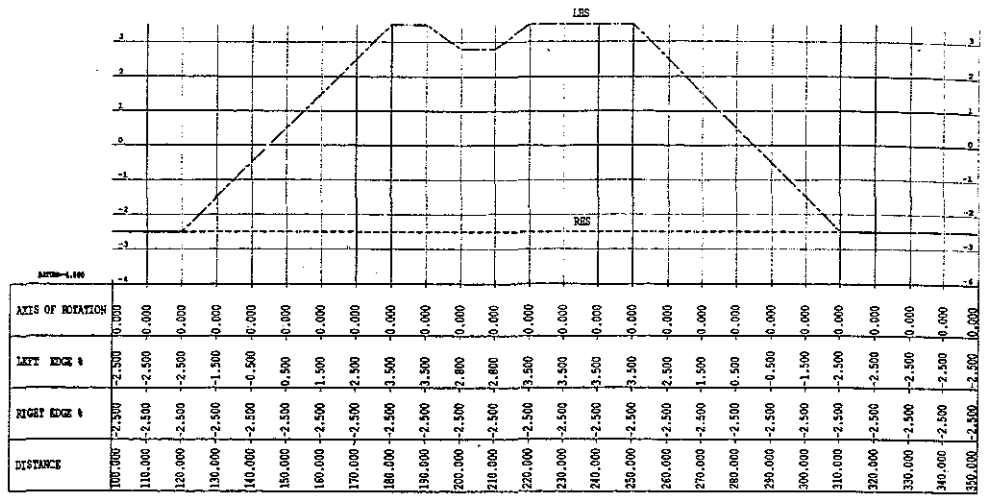
- Superelevation and Crossfall Diagram

The graphical output for the design superelevation and crossfalls can be in two forms:

(a) as a % change to the centre line of the road, or

(b) as a rise or fall value above or below the centre line of the road

See figure 10.



DISTANCE	AXIS OF ROTATION	LEFT EDGE %	RIGHT EDGE %
100.000	0.000	-2.500	-2.500
110.000	0.000	-2.500	-2.500
120.000	0.000	-2.500	-2.500
130.000	0.000	-1.500	-2.500
140.000	0.000	-0.500	-2.500
150.000	0.000	0.500	-2.500
160.000	0.000	1.500	-2.500
170.000	0.000	2.500	-2.500
180.000	0.000	3.500	-2.500
190.000	0.000	3.500	-2.500
200.000	0.000	2.800	-2.500
210.000	0.000	2.800	-2.500
220.000	0.000	3.500	-2.500
230.000	0.000	3.500	-2.500
240.000	0.000	3.500	-2.500
250.000	0.000	3.500	-2.500
260.000	0.000	2.500	-2.500
270.000	0.000	1.500	-2.500
280.000	0.000	0.500	-2.500
290.000	0.000	-0.500	-2.500
300.000	0.000	-1.500	-2.500
310.000	0.000	-2.500	-2.500
320.000	0.000	-2.500	-2.500
330.000	0.000	-2.500	-2.500
340.000	0.000	-2.500	-2.500
350.000	0.000	-2.500	-2.500

Superelevation Diagram - Percentages

Figure 10 - Superelevation Diagram - Percentages

- Overlay Volumes

This graphic output is a plan view of the road surface indicating the relationship between the design profile and the existing surface. It indicates, by different colours, the variation in overlay depths between cross section.

It offers the designer a facility not available before in that it calculates accurately any high or low points between design cross sections thus allowing the designer to adjust to meet the desired pavement design, see figure 11.

- Overlay Sensitivity/Probe

Within the program the designer can analyse the design using the display of the isopach triangulation, e.g. he can probe the pavement to identify the location of pavement greater than the nominated depth.

The designer may also elect to lower the whole of the designed overlay by a set amount say 20mm to identify areas that would still meet the overlay design and areas where it may be more prudent to scarify the existing pavement or areas for total reconstruction.

- Quantities

The program calculates the earthwork quantities both cut and fill. It also calculates the individual quantities of pavement layers including any corrector courses if desired.

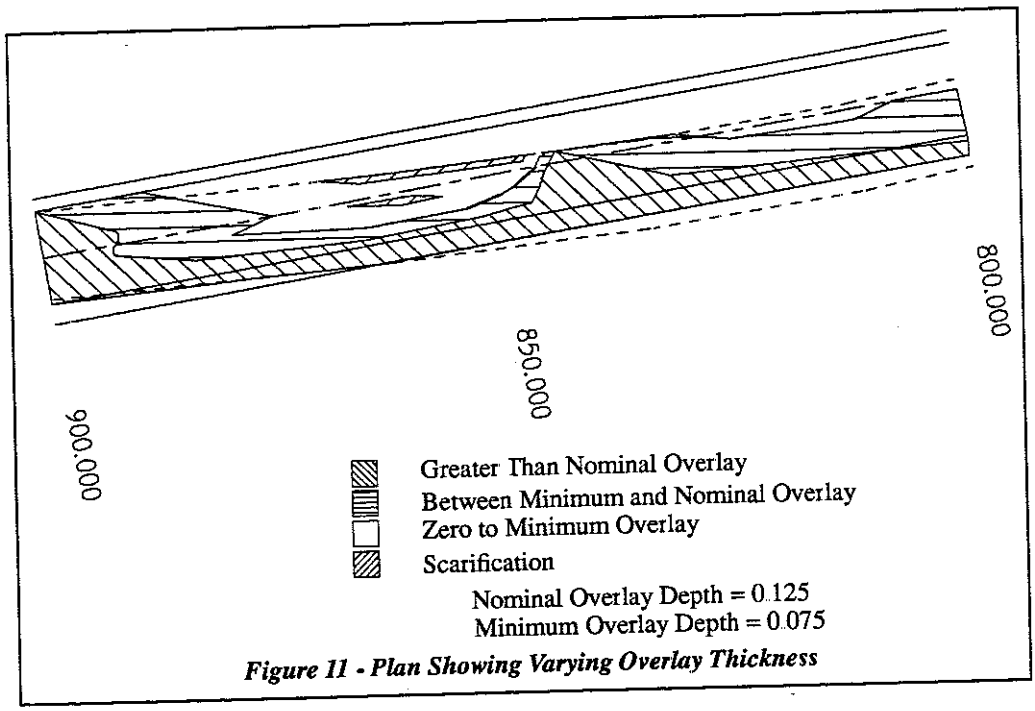


Figure 11 - Plan Showing Varying Overlay Thickness

7. Design Outputs

The final design output can be in graphical, as for Design Input, report or electronic configuration.

- Graphical Output

Graphical output is in the form of annotated cross section as shown in Figure 12 and as a working drawing showing plan and vertical alignments.

- Report Configuration

An ASCII file is available for formatting into construction tables to suit the client's needs.

- Electronic

This output can be adapted to download into construction programs such as those used for pavers.

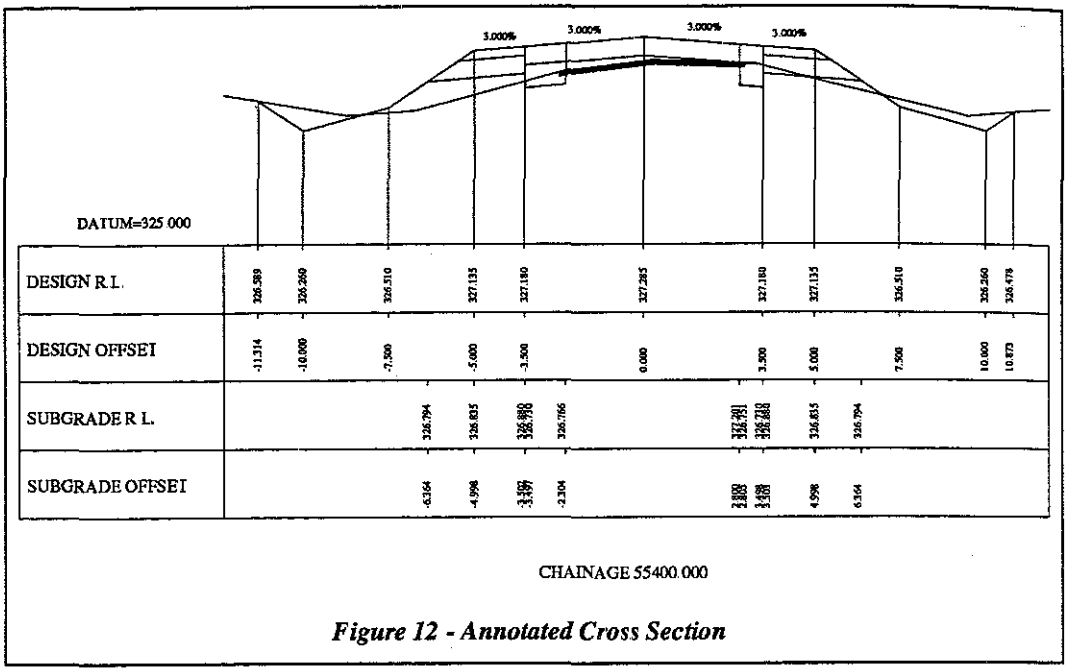


Figure 12 - Annotated Cross Section

8. Current Standing

The PaveMOSS program is available now as Version 3.0. It was previously released as version 2 in July 1992.

There have been 45 licences sold to date in Australia and Malaysia.

Several road authorities in the USA are trialing the system and considerable interest is being shown in other countries.

9. Conclusion

PaveMOSS offers a cost effective, innovative and easy to use solution to what has been a very tedious and time consuming process. The benefits of the system are high, including automation of the design and analysis process, with designers needing only a moderate knowledge of the underlying MOSS system.

The system is saving Queensland Transport up to one month in design time for each project and a reduction in pavement quantities which will save the department $3million in a full year.