ASCP
AUSTRALIAN SOCIETY FOR CONCRETE PAVEMENTS

ASCP Forum 25 March 2025

Thickness Design Procedure.
Q : Is The Erosion Analysis Needed When a LMC Subbase is Included ?

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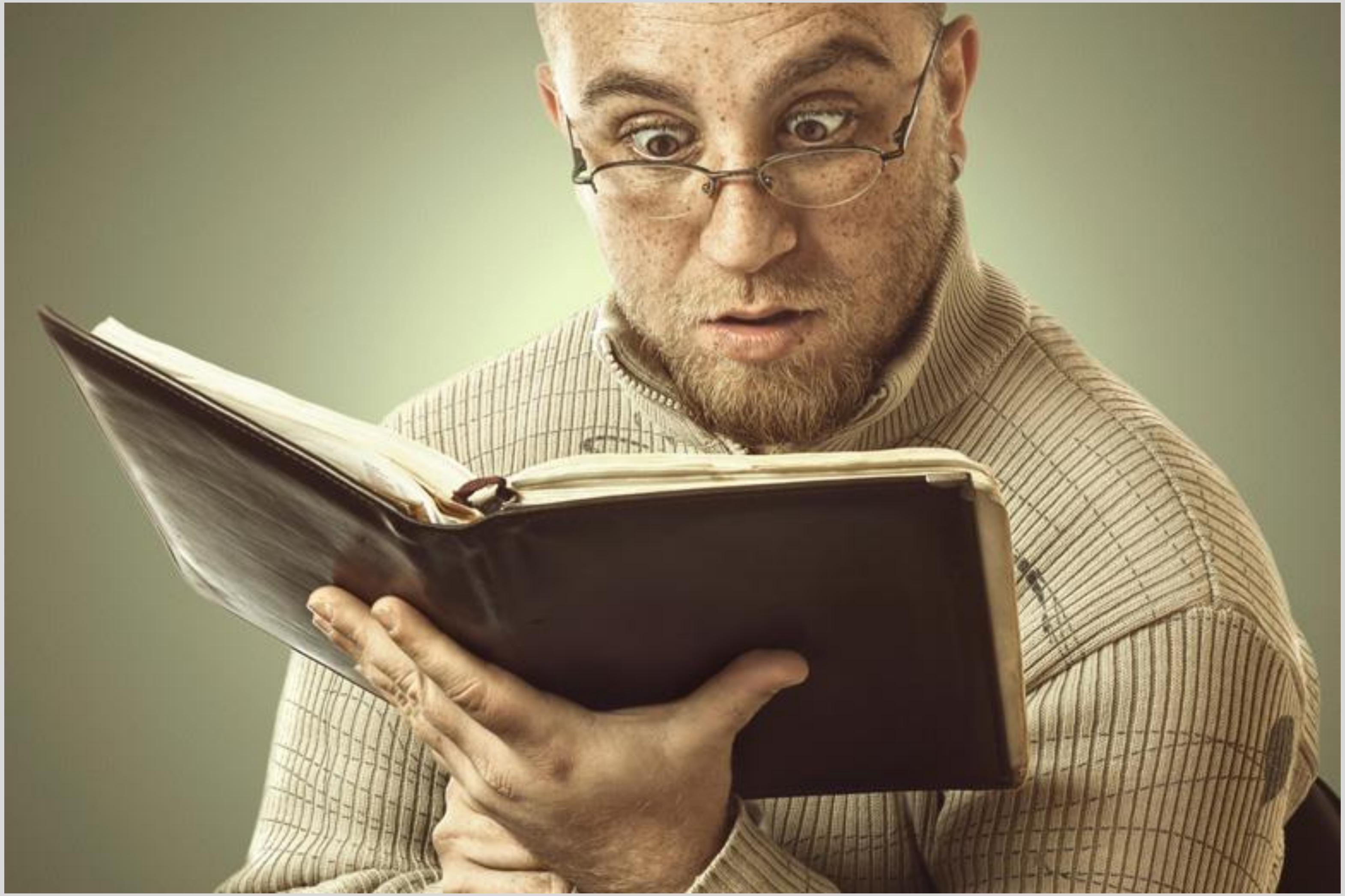
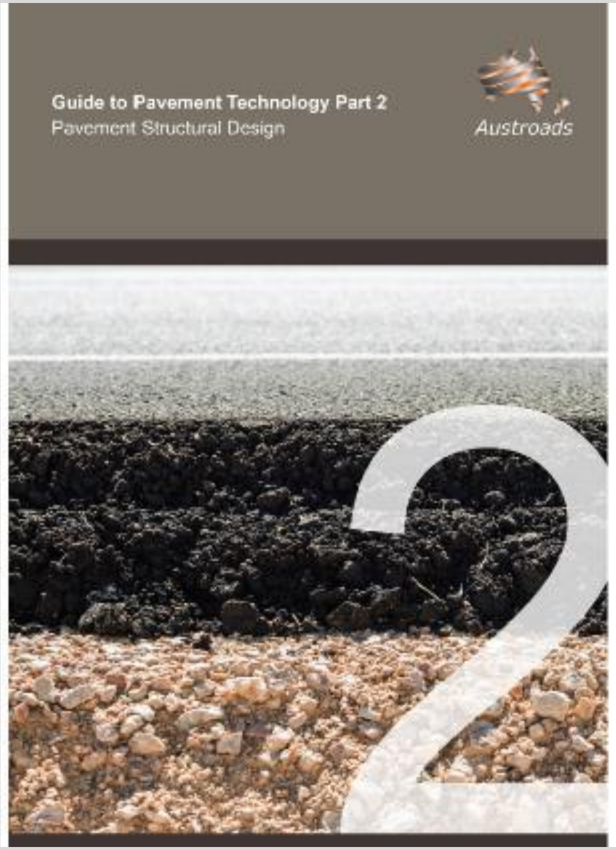
Honorary Member ASCP

Alternative title:

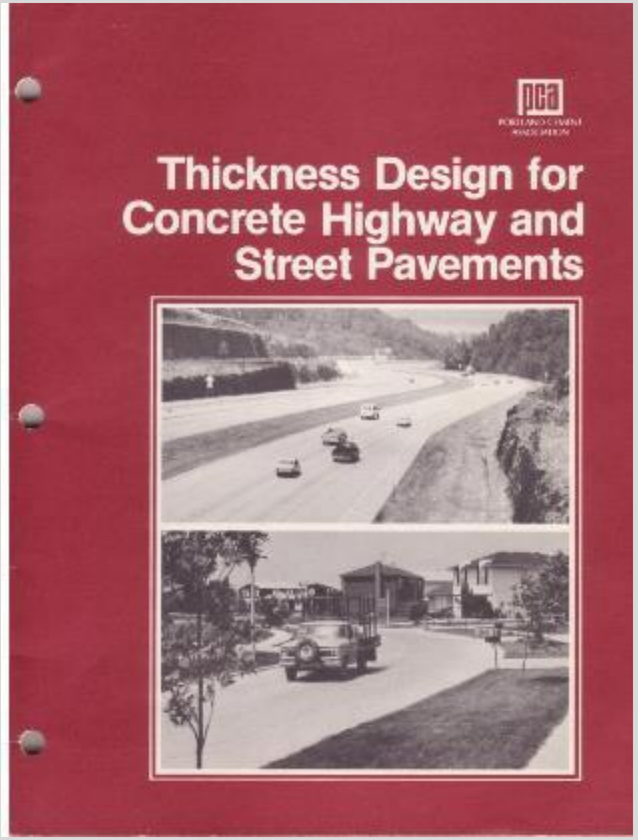
Proverb : There are none so blind as those who do not read



Austroads thickness design procedure : Introduced 1992

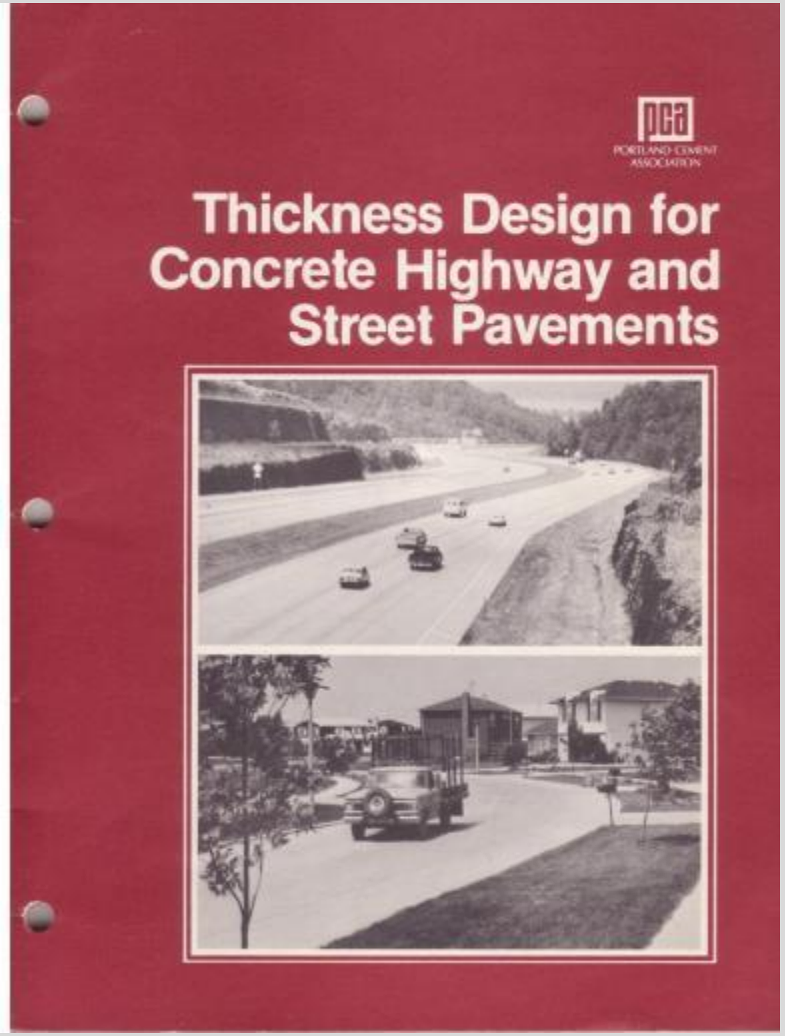


Austroads



PCA Engineering Bulletin
1984

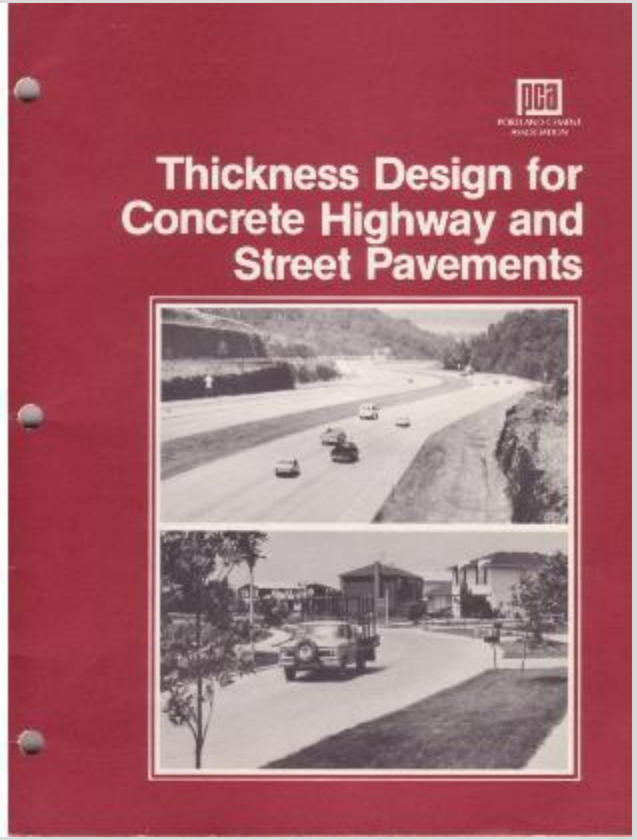
Legendary Bob Packard
Principal Paving Engineer
PCA

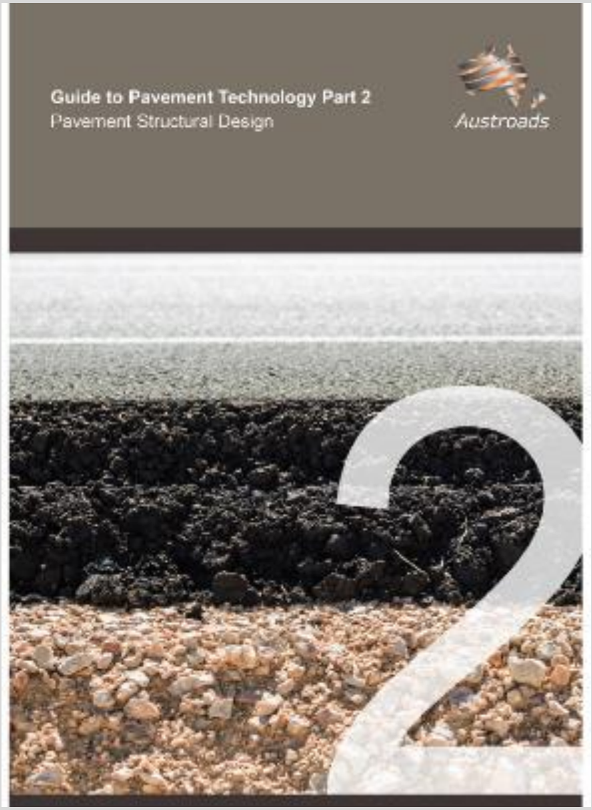


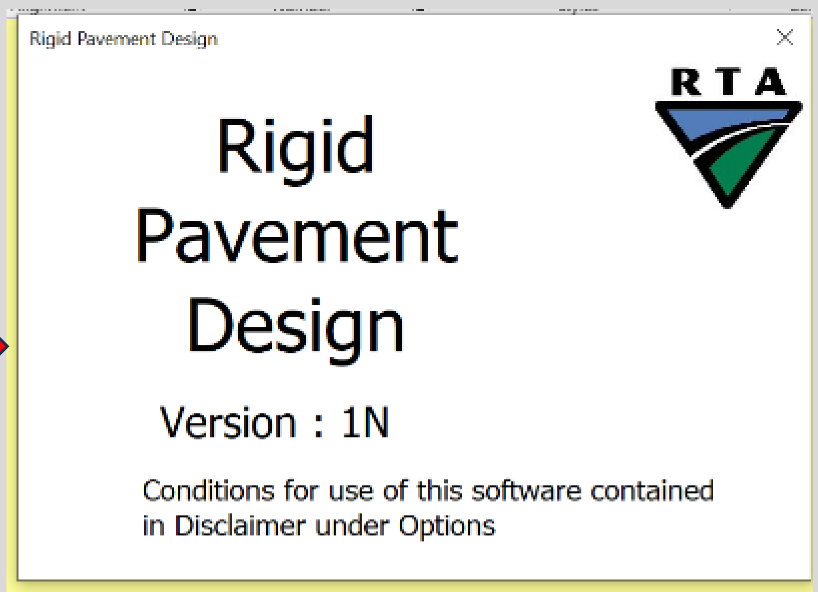
It has been around for 40 years !!

- How many people have a copy?
- How many people have read it?
- How many people have absorbed it?

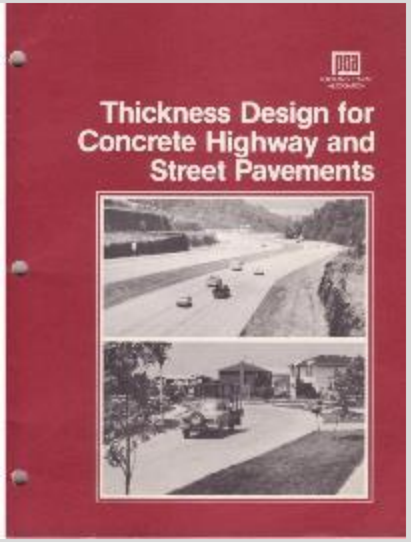
In addition to the written Austroads Guide, software packages using the PCA equations/coefficients with direct input of traffic TLDs have been developed such as NSW RTA (TfNSW)

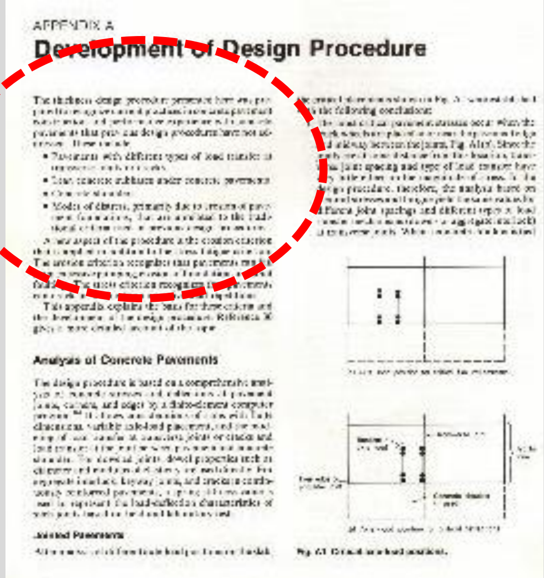






PCA 1984. Development of design procedure – Appendix A





APPENDIX A

Development of Design Procedure

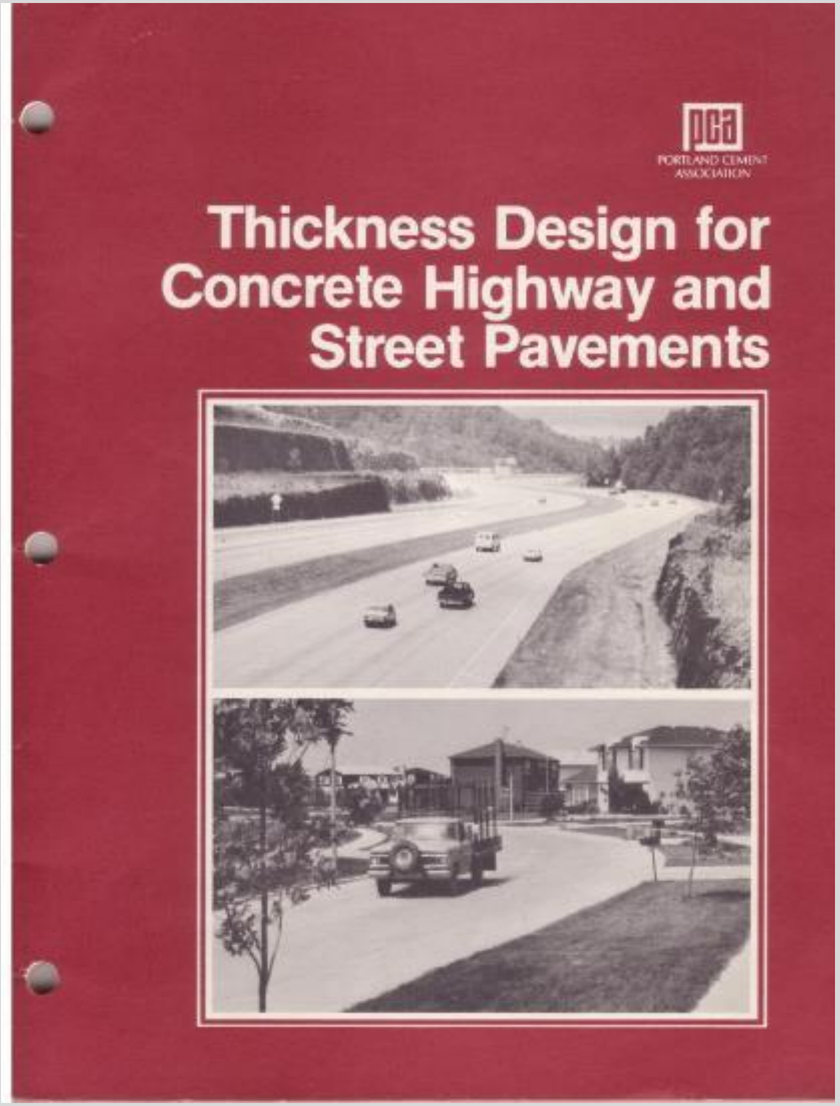
Analysis of Concrete Pavements

Jointed Pavements

The thickness design procedure presented here was prepared to recognize current practices in concrete pavement construction and performance experience with concrete pavements that previous design procedures have not addressed. These include:

- Pavements with different types of load transfer at transverse joints or cracks
- Lean concrete subbases under concrete pavements
- Concrete shoulders
- Modes of distress, primarily due to erosion of pavement foundations, that are unrelated to the traditional criteria used in previous design procedures

PCA Engineering Bulletin



Two design streams :

Provide thickness to meet the following

- **Fatigue Analysis**

Mitigate rupture from repeated loads

- **Erosion Analysis**

Mitigate joint/crack faulting arising from subbase erosion caused by joint/crack deflections under repeated loads

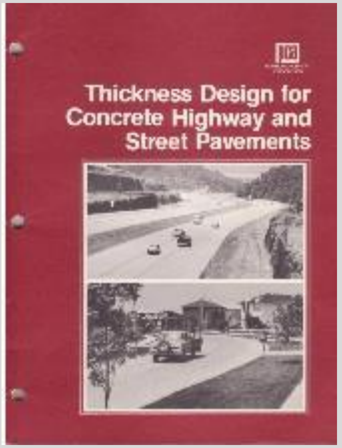
(late) Bob Packard

We had many discussions in 1980s/1990s

He agreed that erosion was the end result but the cause was joint/crack deflections.

In hindsight the erosion analysis may possibly have been better labeled as a joint/crack deflection analysis.

But as published it is the erosion analysis.

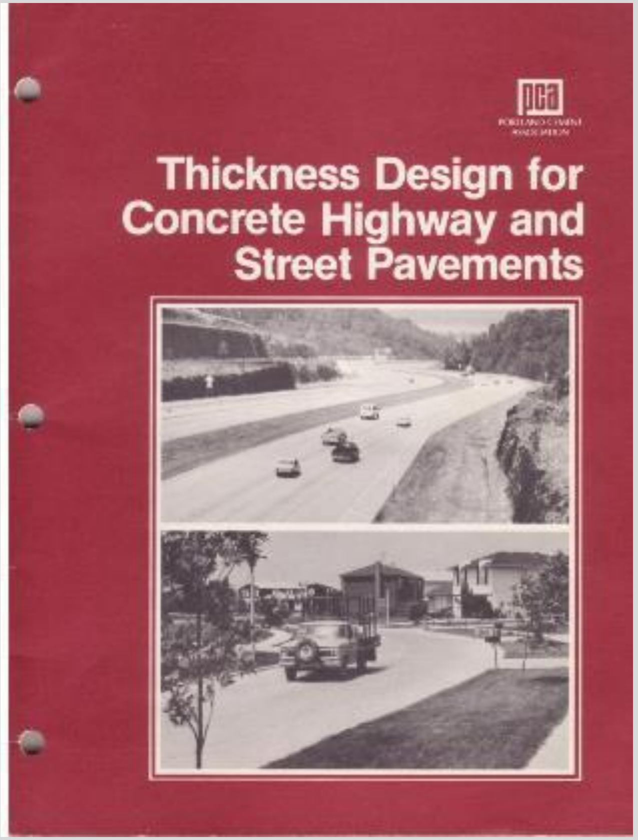


Two step procedure :

- Design on the basis that there is no LMC subbase
- Use chart – Appendix B - for composite pavement including LMC subbase (*)

(*) The LMC subbase can be either unbonded or bonded.
Practice here is for an unbonded subbase

This will be compared with Australian approach where a LMC subbase has been standard in concrete highways for about 50 years and is included “upfront” in thickness design with substantially increased design CBR



American document written in the American pavement context in 1980s.

Step one.

- Does not assume the presence of any subbase
- Unbound subbase does not improve design CBR

- Design on the basis of foundation CBR

However :

Step two.

If you are considering a lean concrete subbase, the thickness is modified to yield an equivalent combination of concrete base and concrete subbase. Appendix B

One important note :

For **highway traffic loading**;

- An undoweled joint deflects more than a doweled joint/CRCP crack for a given truck load.
- for **undoweled joi**nts the erosion analysis controls the design
- for **doweled joints/CRCP** the fatigue analysis controls the design.

But for either pavement type and using software it does both fatigue and erosion analysis as a matter of course

Worked example to illustrate

Assume subgrade CBR 3%. 300mm SMZ CBR 15%

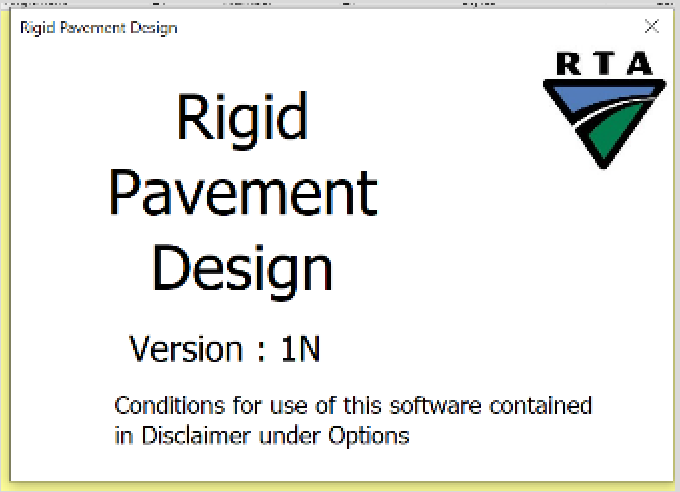
SMZ 300mm CBR 15%

Subgrade 700mm CBR 3%

Equivalent CBR (*) = $(0.3 \times 15^{0.333} + 0.7 \times 3^{0.333})^{3}$ = **5%**

(*) Japanese formula - Austroads

Base thickness without LMC Subbase



(or derivative software)

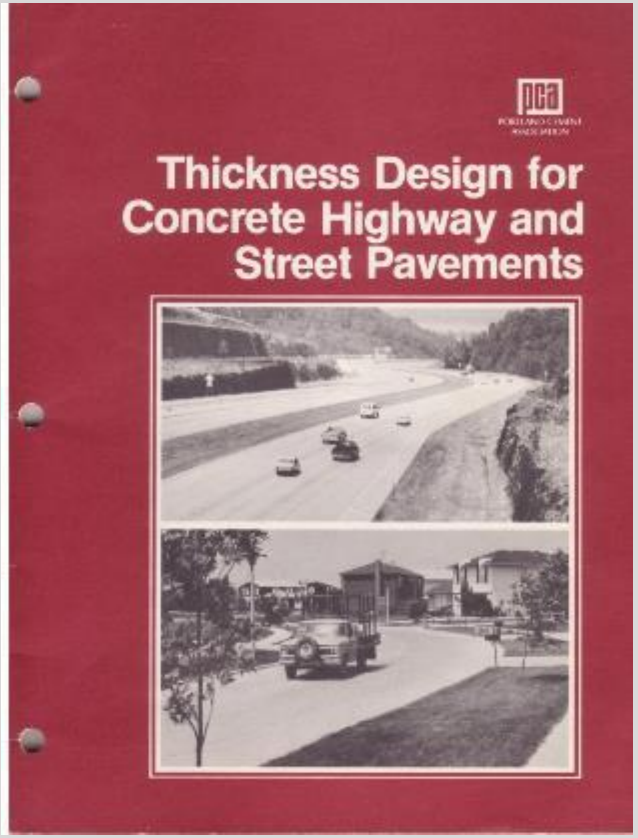
<u>Illustrative example – highway design</u>

- Undoweled joints
- Concrete shoulder
- 1 x 10^8 HVAG (Austroads TLD)
- Effective subgrade strength 5% (*)
- Concrete flexural strength 4.5 MPa
- Load safety factor 1.3 (**)

(*) see previous slide
(**) I would use 1.2 but stick to1.3 here

Without LMC, i.e. CBR5% - Base thickness ~ 315mm

Appendix B. Design of concrete pavements with Lean Concrete Lower course



APPENDIX B

Design of Concrete Pavements with Lean Concrete Lower Course

Following is the thickness design procedure for composite concrete pavements incorporating a lower layer of lean concrete, either as a subbase constructed separately or as a lower layer in monolithic construction. Design considerations and construction practices for such pavements are discussed in References 50 through 52.

Lean concrete is stronger than conventional subbase materials and is considered to be nonerodable. Recognition of its superior structural properties can be taken by a reduction in thickness design requirements.

Analysis of composite concrete pavements is a special case where the conventional two-layer theory (single slab on a foundation) is not strictly applicable.

The design procedure indicates a thickness for a two-layer concrete pavement equivalent to a given thickness of normal concrete. The latter is determined by the procedures described in Chapters 3 and 4. The equivalence is based on providing thickness for a two-layer concrete pavement that will have the same margin of safety* for fatigue and erosion as a single-layer normal concrete pavement.

In the design charts, Figs. B1 and B2, the required layer thicknesses depend on the flexural strengths of the two concrete materials as determined by CSA A23.2-8C.[19] Since the quality of lean concrete is often specified on the basis of compressive strength, Fig. B3 can be used to convert this to an estimated flexural strength (modulus of rupture) for use in preliminary design calculations.

Lean Concrete Subbase

The largest paving use of lean concrete has been as a subbase under a conventional concrete pavement. This is nonmonolithic construction where the surface course of normal concrete is placed on a hardened lean concrete subbase. Usually, the lean concrete subbase is built at least 600 mm wider than the pavement on each side to support the tracks of the slipform paver. This extra width is structurally beneficial for wheel loads applied at pavement edge.

The normal practice has been to select a surface thickness about twice the subbase thickness, for example, 220 mm of concrete on a 100 or 120 mm subbase.

Fig. B1 shows the surface and subbase thickness requirements set to be equivalent to a given thickness of normal concrete without a lean concrete subbase.

A sample problem is given to illustrate the design procedure. From laboratory tests, concrete mix designs have been selected that give moduli of rupture of 4.5 and 2.0 MPa,** respectively, for the surface concrete and the lean concrete subbase. Assume that a 260-mm-thickness requirement has been determined for a pavement without lean concrete subbase by the procedures set forth in Chapter 3 or 4.

As shown by the dashed example line in Fig. B1, designs equivalent to the 260-mm pavement are: (1) 185-mm concrete on a 130-mm lean concrete subbase, and (2) 200-mm concrete on a 100-mm lean concrete subbase.

Monolithic Pavement

In some areas, a relatively thin concrete surface course is constructed monolithically with a lean concrete lower layer. Local or recycled aggregates can be used for the lean concrete, resulting in cost savings and conservation of high-quality aggregates.

*The criteria are that (1) stress ratios in either of the two concrete layers not exceed that of the reference pavement, and (2) erosion values at the subbase-subgrade interface not exceed those of the reference pavement. Rationale for the criteria is given in Reference 50 plus two additional considerations: (1) erosion criteria is included in addition to the fatigue approach given in the reference and (2) for nonmonolithic construction, some structural benefit is added because the subbase is conventionally wider than the pavement.

**Flexural strength of lean concrete to be used as a subbase is usually selected to be between 1.0 to 1.7 MPa (compressive strength, 5.2 to 8.3 MPa); these relatively low strengths are used to minimize reflective cracking from the unjointed subbase (usual practice is to leave the subbase unjointed) through the concrete surface. If, contrary to current practice, joints are placed in the subbase, the strength of the lean concrete would not have to be restricted to the lower range.

Two options:

Bonded or debonded

Australian practice since 1975 has been for debonded

PCA Engineering Bulletin 1984 – Appendix B
Design of Concrete Pavements with Lean Concrete Lower Course

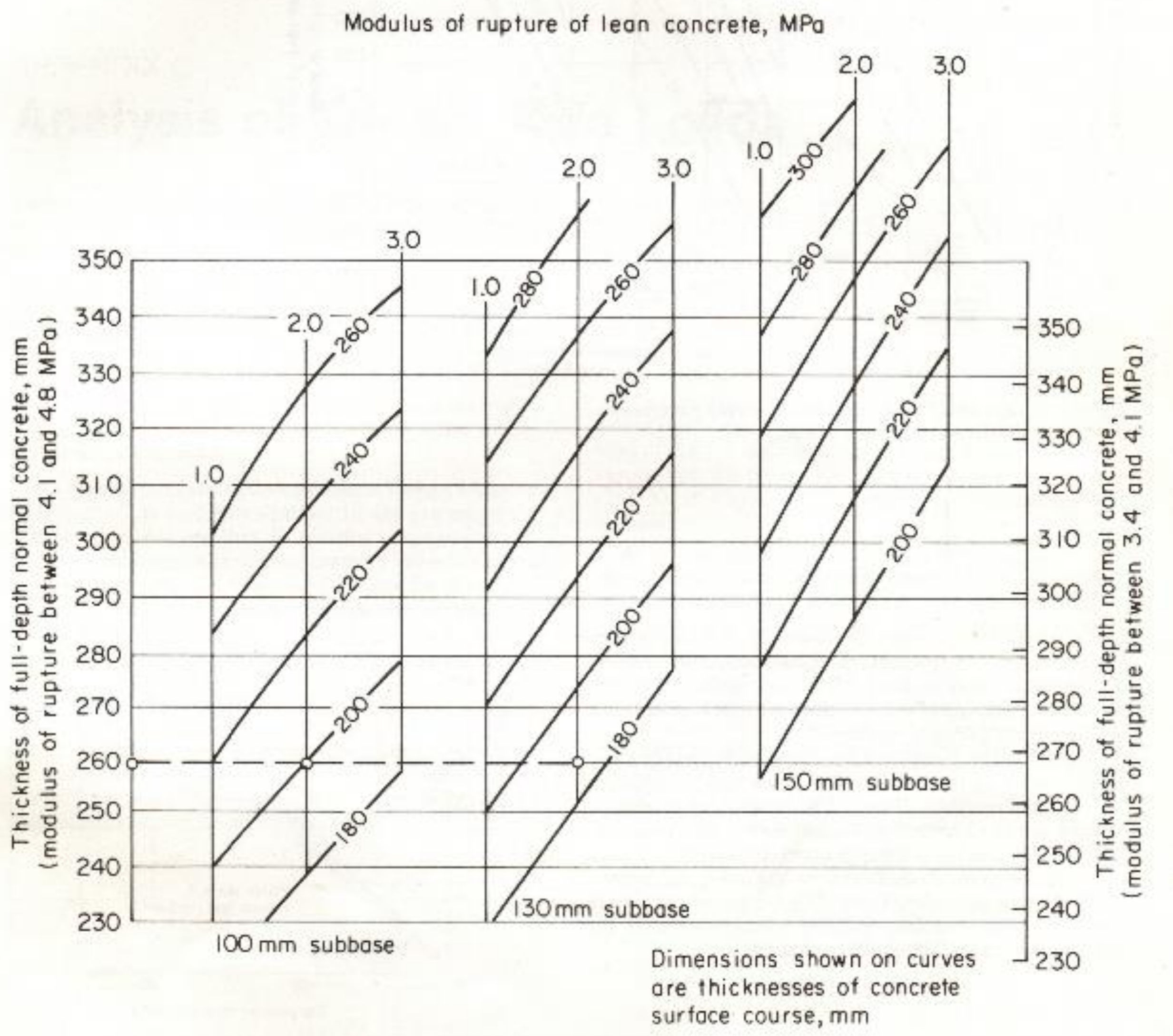


Fig. B1. Design chart for composite concrete pavement (lean concrete subbase).

Chart for unbonded LMC

PCA Engineering Bulletin 1984 – Appendix B
Design of Concrete Pavements with Lean Concrete Lower Course

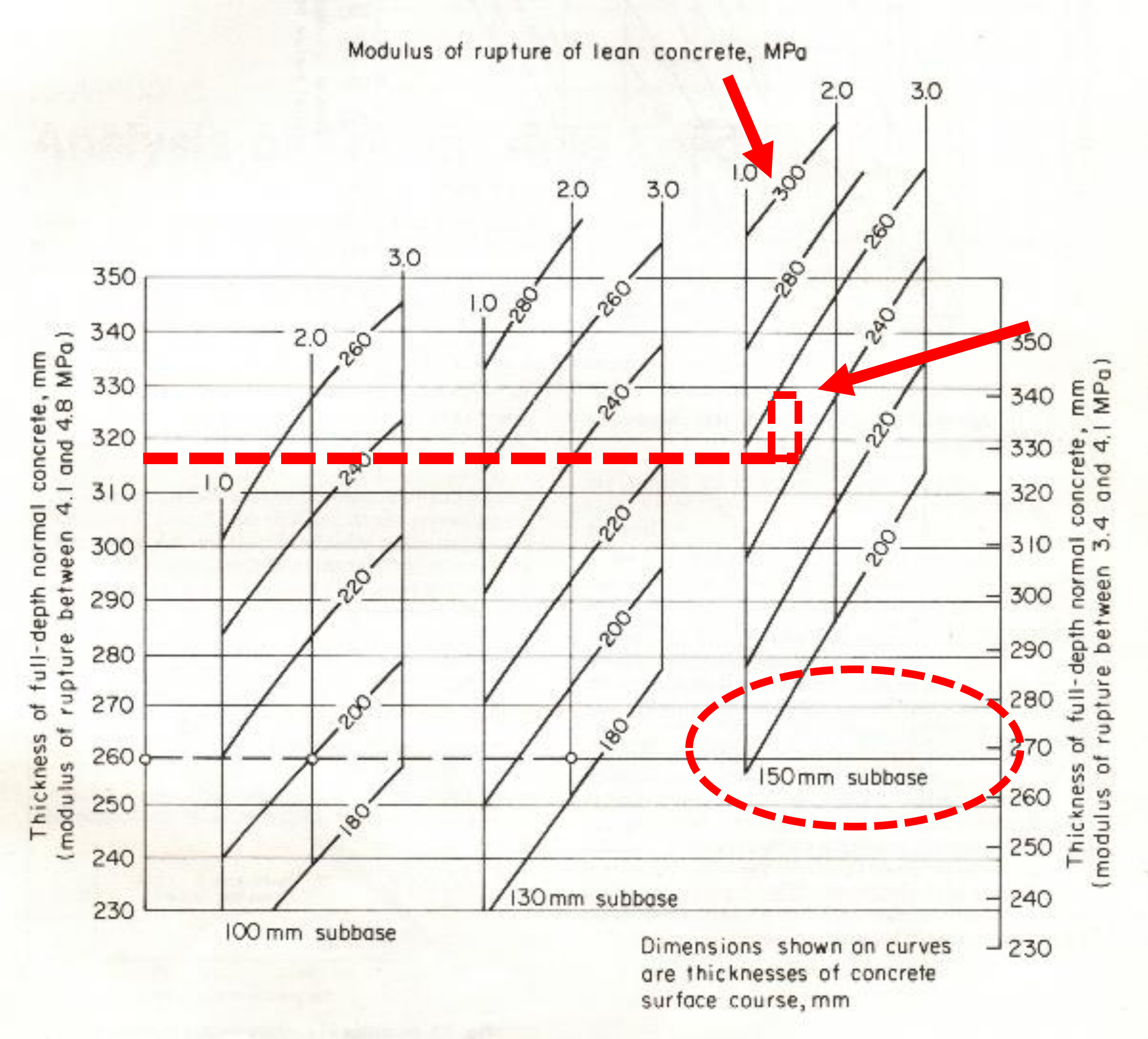
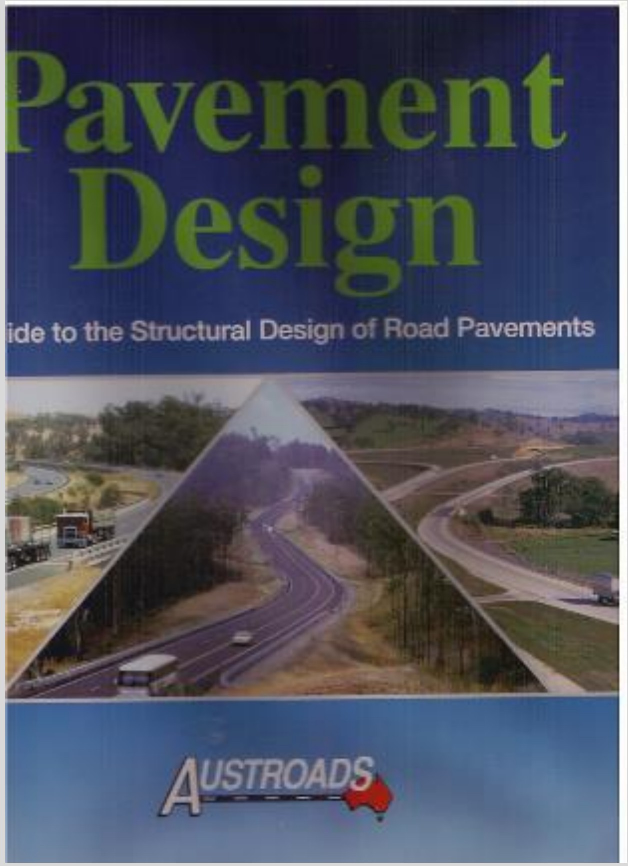


Fig. B1. Design chart for composite concrete pavement (lean concrete subbase).

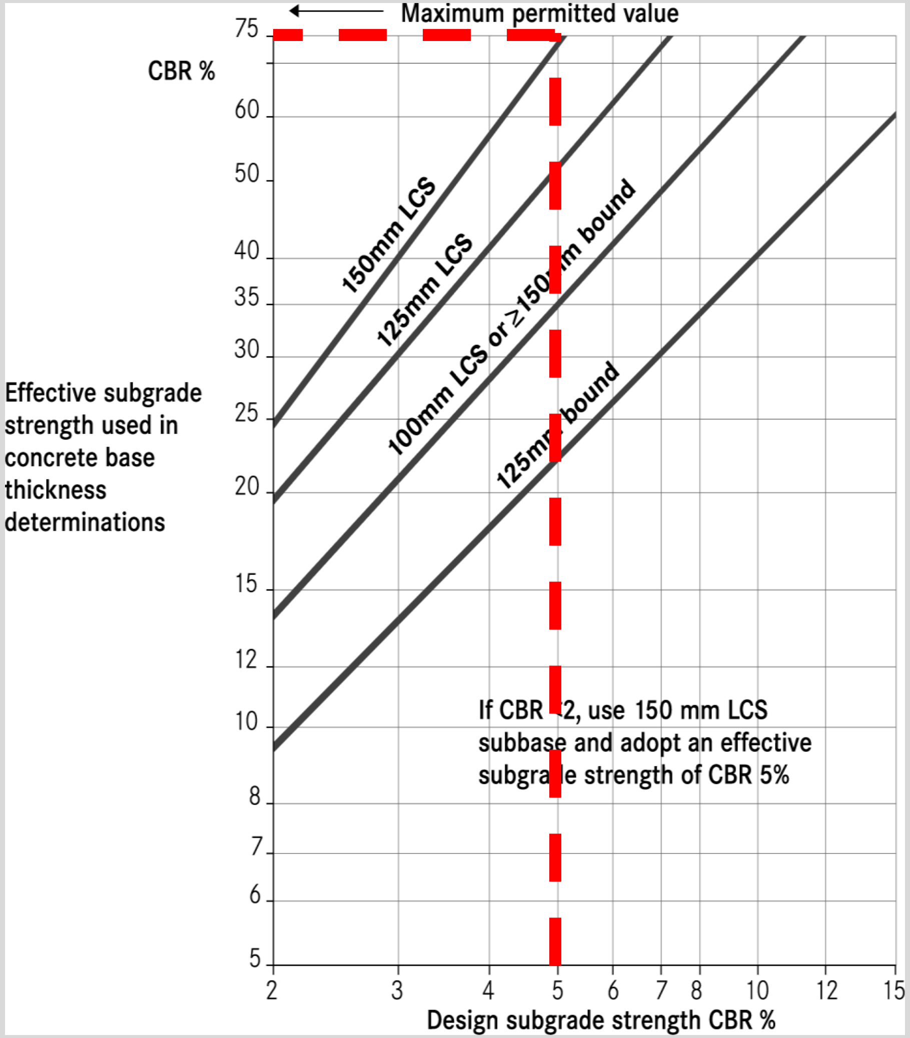
- Equivalent pavement to 315mm without 150mm LMC subbase
- Using indicative LMC flexural strength
- ~250mm base and 150mm LMC subbase

However when Austroads APRG convened 1989-1991 to develop Austroads Guide



- NSW RTA was already committed to LMC subbases
- Austroads influenced by NSW RTA
- So LMC included “ upfront”
- Greatly improved effective subgrade strength (CBR%) but the formal procedure is still followed

Austroads Figure 9.1 – Effective Subgrade Strength (CBR %)



Eldon Yoder

“bound subbase”

(Late) Ed Haber - Local modification
LMC better than “bound”

CBR Test (soaked) – How many have seen one being conducted?

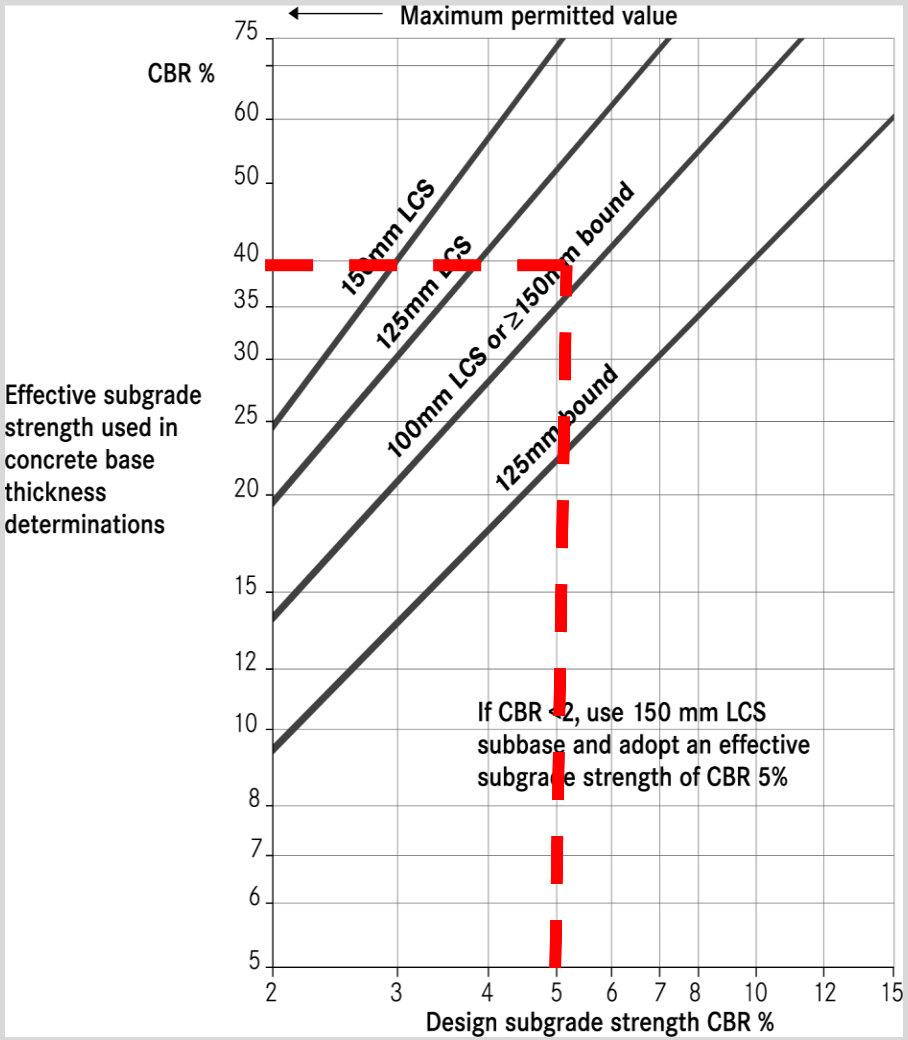
Laboratory test

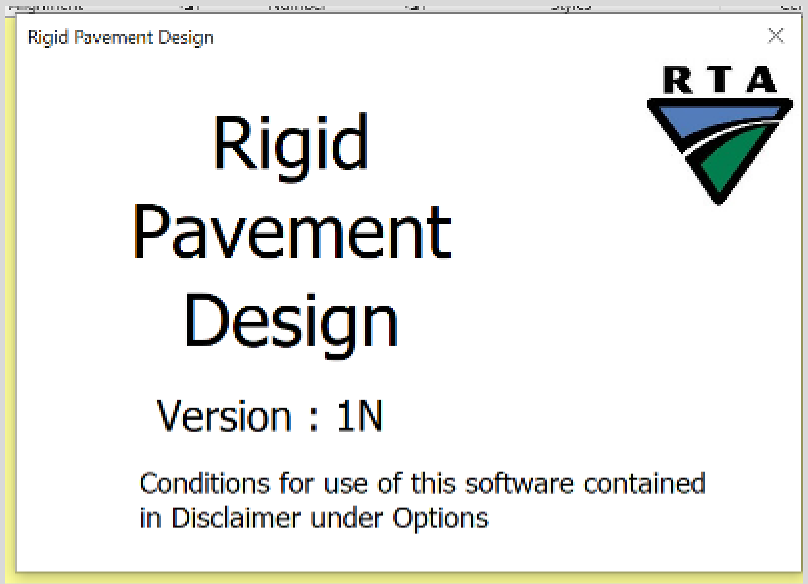
Field test - DCP

Once you get a CBR value above 30-40% in my opinion it becomes meaningless.

So I usually do not assign an effective subgrade strength above 40%

But that is “another story”





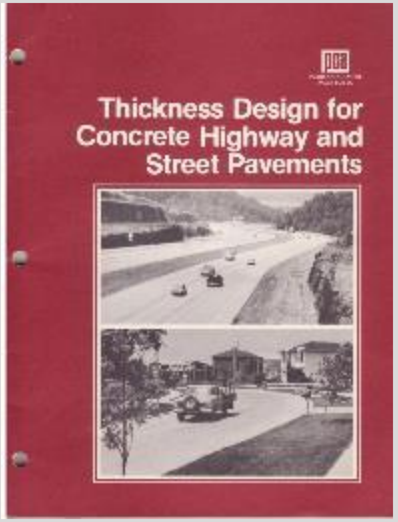
So

With same inputs as before but with an effective subgrade strength of 40%

You get a base thickness around 250mm

In this presentation I am not going to argue about +/- 5mm in discussing the erosion analysis, that is for “boffins”.

Comparison PCA/Austroads for highway loading



Thickness without LMC
About 315mm

Appendix B
150mm LMC
Base about 250mm

Insert 150mm LMC “upfront”

Effective subgrade strength
40% (JH opinion)

Base about 250mm

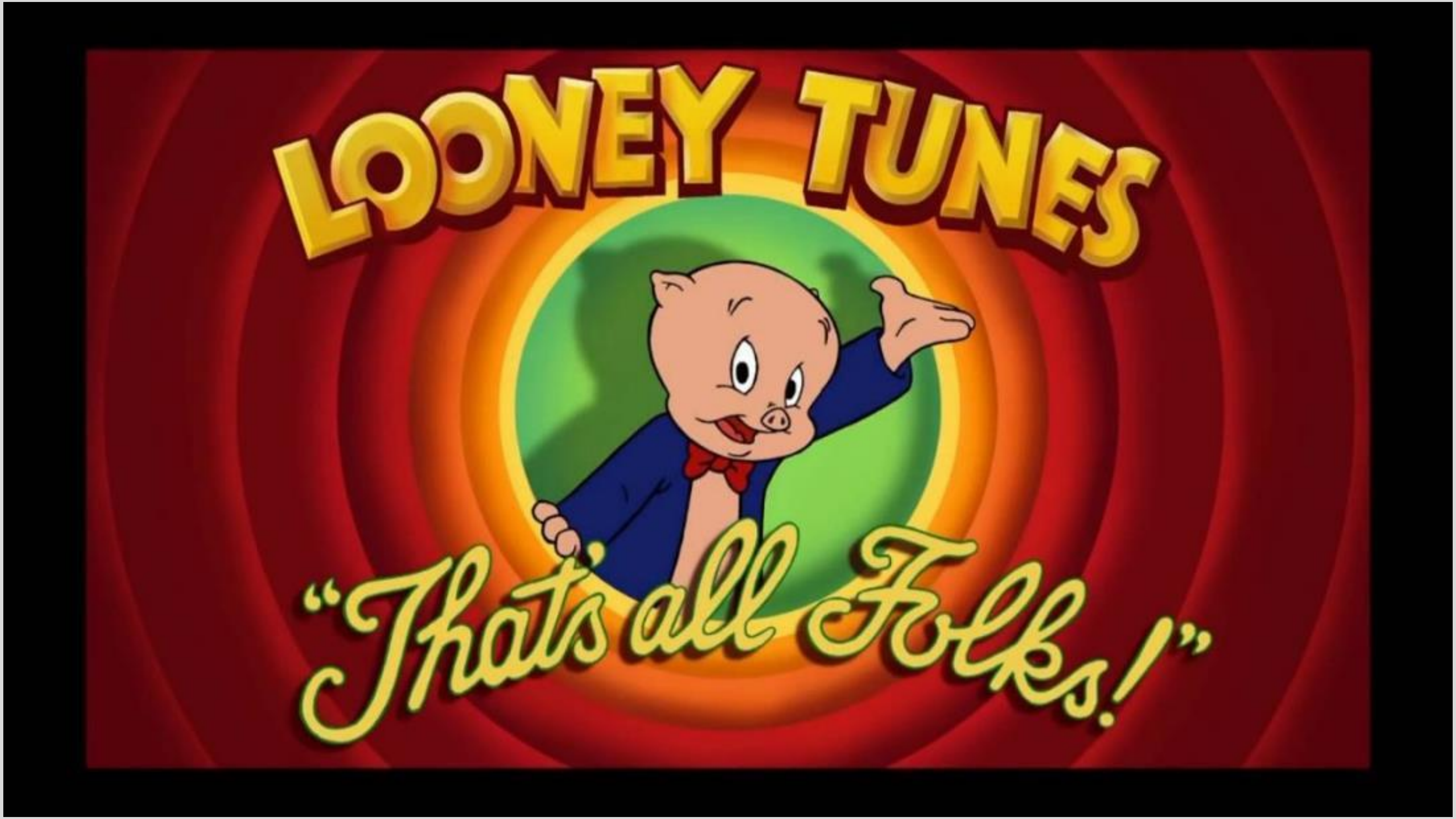
Applying something often absent today - **“engineering judgement”**

The two line up fairly closely

So : Is the Erosion Analysis needed when a LMC subbase is included ?

- You need to read and understand how the source PCA document works, and how Austroads adapted it, but with an “upfront” LMC and related substantially improved effective subgrade strength.
- With erosion analysis, answers are pretty much the same
- Is it necessary?
- The fact is - it **is** an integral element of the design procedure.
- I hear comments - leave out erosion to make base thinner, reduce construction costs
- If you “fiddle” with the design model the integrity of the process is compromised. Q : Is that engineering negligence?

But as I have said, when discussing/explaining this issue on many occasions over the past 35 years or so, nobody has to take any notice of what I say.



LOONEY TUNES
"That's all Folks!"