Use of Perpetual Pavement as a Sustainable Strategy: Bird's Eye View

Dr. Nikhil Saboo
Associate Professor
Department of Civil Engineering
IIT Roorkee-247667

6th Webinar on New Age and Perpetual Pavement for Performance and Economy
IRF-India Chapter
September 19, 2024

Contents

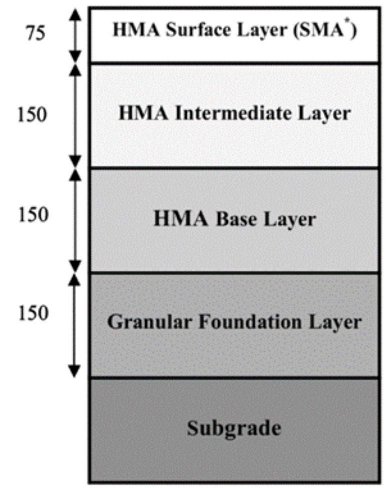
- **Perpetual Pavement-** Definition and International Practices
- Important Points Related to the Structure of 'Conventional' Perpetual Pavement
- Use of Cement Treated Bases/Sub-bases in Perpetual Pavement
- Important Points Related to Perpetual Pavement with Cement Treated Bases
- Example
- Recent Failures: Is the technology questionable?
- Summary

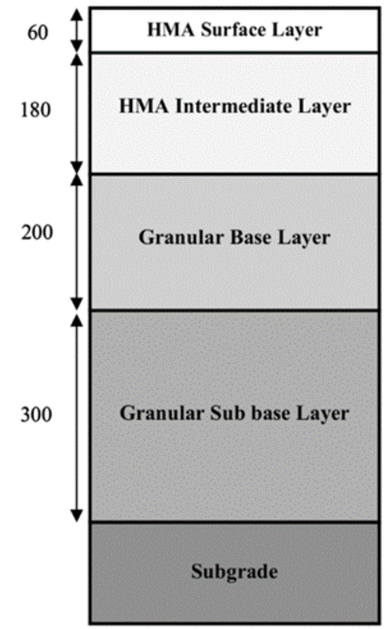
Perpetual Pavement- Definition and International Practices

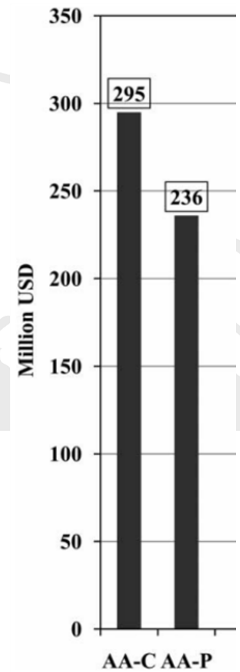
- Pavements, having a service life of more than 50 years, are called "**Perpetual Pavement**".

- A report by Nunn et. al., 1997 indicate that full-depth (asphalt courses used for all layers above subgrade) and deep-strength (asphalt surface and asphalt base over a minimal aggregate base above subgrade) pavements were originally designed for 20-year life expectancies. Later it was found that these pavements exceeded the expectation and performed beyond its design life with requirement of little maintenance.

- A perpetual pavement has a wear-resistant and renewable top layer, a rut-resistant intermediate layer, and a fatigue-resistant base layer.

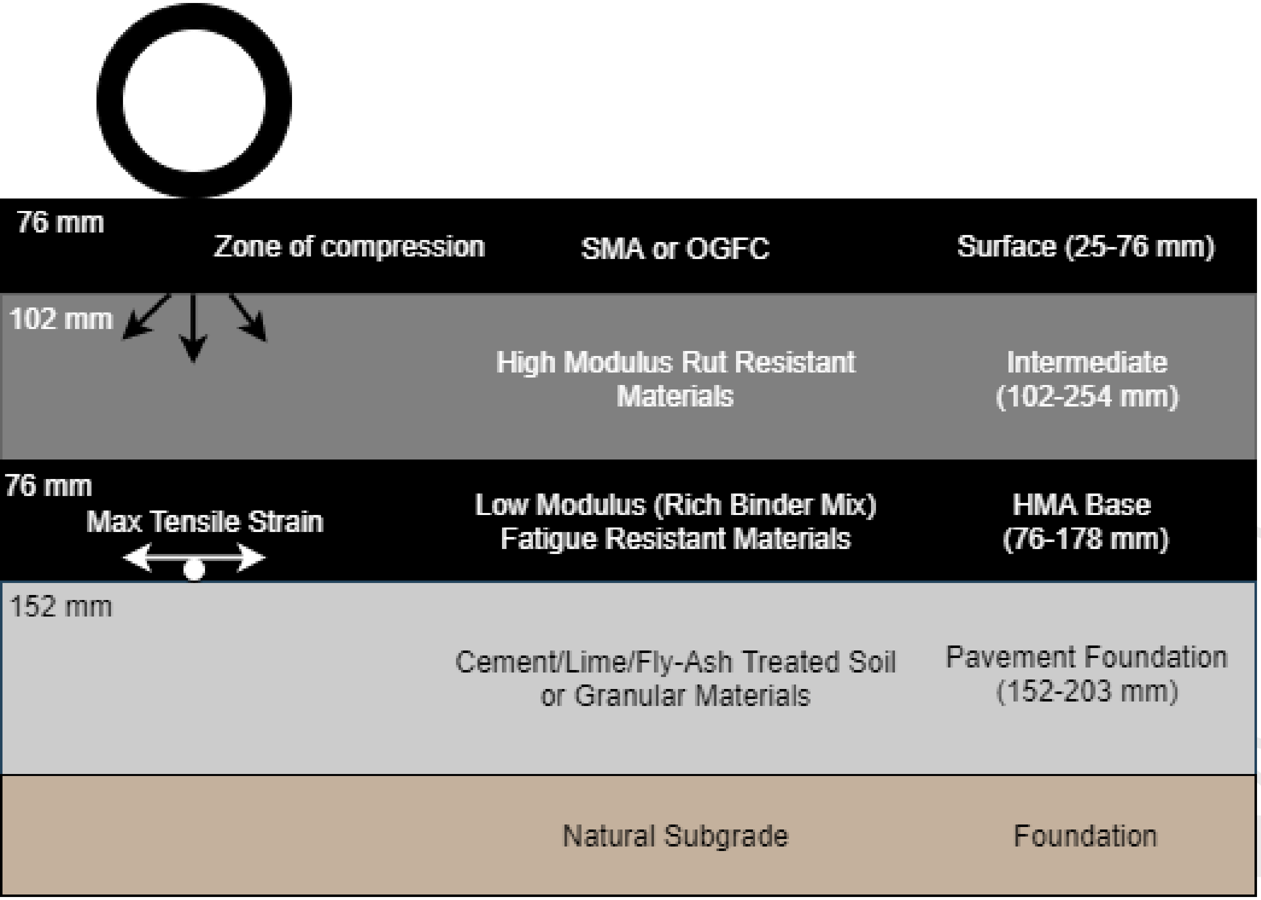






From Amini et al. 2011

Life cycle cost of PP are lower than Conventional. This assumes lower maintenance cycles for PP.



- **Binder:** PMB commonly used in surface and binder course
- **Endurance limit:** 70 $\mu\varepsilon$ more commonly used (Proposed by Monismith and Mclean, 1972)
- **Average thickness of bituminous layer:** 355 mm (250 mm to 500 mm)
- **Average thickness of granular base:** 175 mm
- Stabilized subgrade recommended for a firm working platform: 150 mm-200 mm.
- **Average Traffic:** 7500 commercial vehicles per day

Important Points Related to the Structure of 'Conventional' Perpetual Pavement

- The main structural element is the bituminous layer.
- **'Endurance' limit** defined for the bituminous layer/subgrade confirms fatigue/rutting resistance of the entire 'structure'.
- We have two equations in our design for such structure. Let us look at them.

$$N_f = 0.5161 \times C \times 10^{-4} \times \left(\frac{1}{\varepsilon_t}\right)^{3.89} \times \left(\frac{1}{E}\right)^{0.854} \qquad N_r = 1.41 \times 10^{-8} \times \left(\frac{1}{\varepsilon_v}\right)^{4.5337}$$

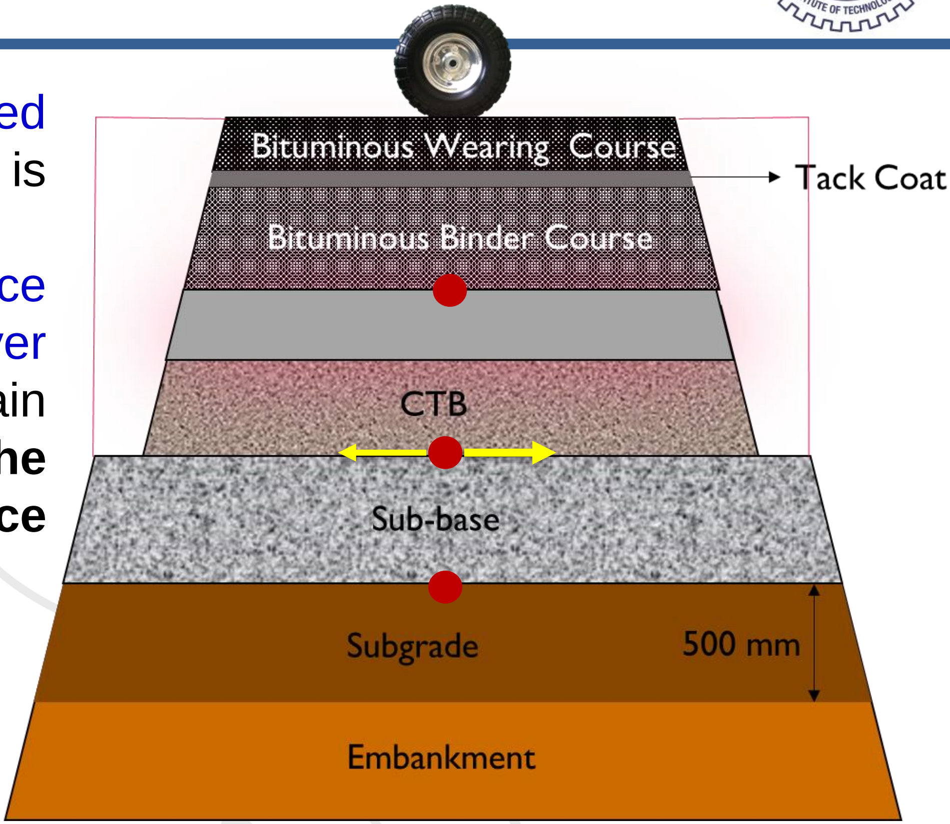
- Endurance limit validated, experimented, and found successful.
- **Will this pavement never fail?** What can be the typical failures?
  - Rutting in the top 50-100 mm. Shear failure and top-down cracking is more critical than fatigue cracking.
  - Moisture infiltration: Trapped moisture in lower bituminous layer
  - Debonding between different bituminous layers

Note:

- Shear failure of bituminous mix not accounted for in our design: But the same can happen!!
- Top-down cracking in the bituminous layer not accounted for in our design: But the same can happen!!
- Moisture related failure within one/more layers not accounted for in design. But the same can happen!!
- Construction related failure not accounted for in design. But the same can happen!!

Use of Cement Treated Bases/Sub-bases in Perpetual Pavement

- Pavement with a stiff layer sandwiched between two relatively less stiff layers is called "**inverted"** pavement.
- The aim of such design is ideally to reduce the strain at the bottom of bituminous layer and thus reduce the accumulation of strain below the bituminous layer. **No doubt, the strain will be lower than the endurance limit of 70 $\mu\varepsilon$.**



- The **'endurance limit'** of such composite structure are not validated/experimented.
- Bituminous layer is **NOT** the main load carrying component in the structure
- Use of axle load spectrum for prediction of traffic at the end of 50 years may be misleading.
- Construction of CTB require high quality control: for example, curing, amount of cement added, etc.

Important Points Related to Perpetual Pavement with Cement Treated Bases

- What are the equations available for design of such structure. Let's look at them.

$$N_f = 0.5161 \times C \times 10^{-4} \times (\frac{1}{\varepsilon_t})^{3.89} \times (\frac{1}{E})^{0.854}$$

$$N_r = 1.41 \times 10^{-8} \times (\frac{1}{\varepsilon_v})^{4.5337}$$

$$N = RF\left[\frac{\left(\frac{113000}{E^{0.804}} + 191\right)}{\varepsilon_t}\right]^{12}$$

$$log_{10} N_{fi} = \frac{0.972 - \left({\sigma_t}/{M_{Rup}}\right)}{0.0825}$$

- In the **third equation** we make a check related to the tensile strain at the bottom of CTB. This is NOT the endurance limit!! So, the consideration of 'infinite' fatigue life of the 'pavement structure' is NOT applicable and thus cannot be designed as 'perpetual'.

- So, early failure in a pavement designed with cemented bases is due to the cement layers???? **May be Yes, may be No.** Depends how the earlier failure has occurred. A thorough forensic investigation is desired.

Example

This example has been taken from a report (details excluded) shared recently. Here, the objective was to design a perpetual pavement with a design traffic of 300 msa. The designer opted for the following combination

- Bituminous layer: 175 mm (3000 MPa, 0.35)
- Aggregate Inter-layer: 100 mm (450 MPa, 0.35)
- CTB: 200 mm (5000 MPa, 0.25)
- CTSB: 200 mm (600 MPa, 0.25)
- Subgrade: 12% effective CBR (86.34 MPa, 0.35)

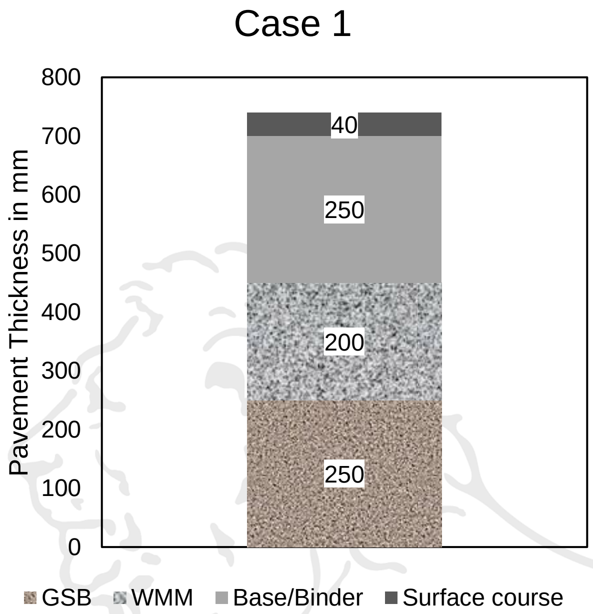
The following checks were made:

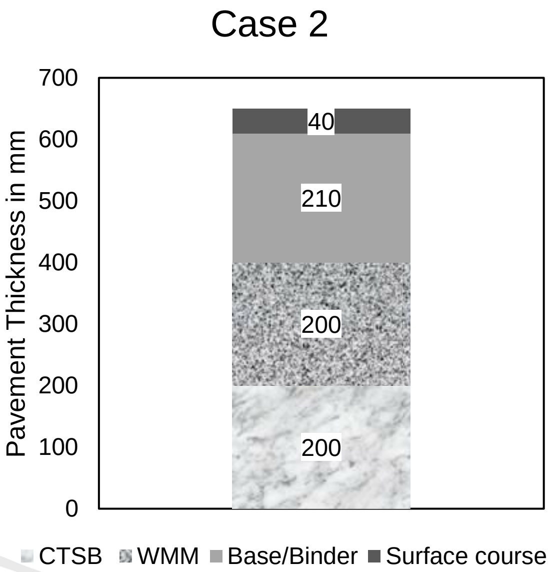
a. Horizontal tensile strain below bituminous to be limited to **80 $\mu\varepsilon$**
b. Vertical compressive strain at the top of subgrade to be limited to **200 $\mu\varepsilon$**
c. Horizontal tensile strain at the bottom of CTB to be limited to **60 $\mu\varepsilon$**
d. CFD to be **less than 1** for the given axle load spectrum.

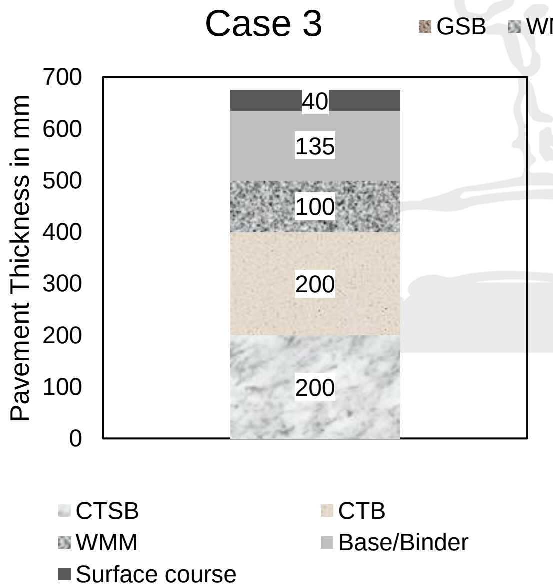
All these checks were satisfied, and the crust was considered as a perpetual pavement. As per IRC 37-2018, there is no discrepancy, and the design is 'correct'.

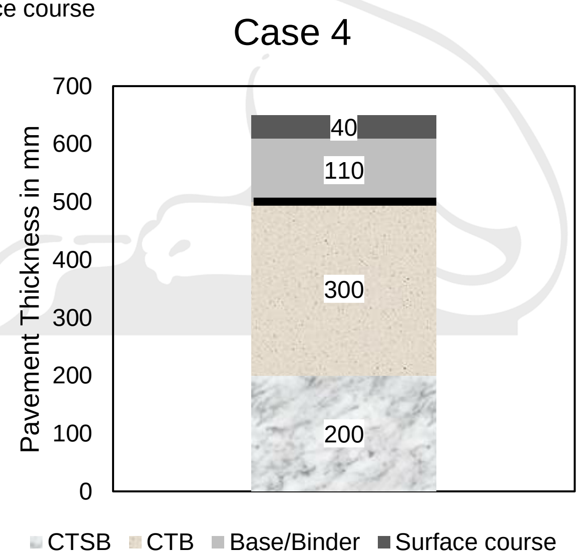
Example

Other options??









Recent Failures: Is the Technology Questionable?




Recent Failures: Is the Technology Questionable?

Recent Failures: Is the Technology Questionable?

Recent Failures: Is the Technology Questionable?

- **Failure in SMA:** Aggregate quality, quality of lime, mixing and compaction temperatures, compaction procedure.
- **Target density:** higher voids allows water to penetrate and weaken the interface. Can fail without the movement of significant traffic.
- **Interlayer** between asphalt layers: inadequate use of tack coat, quality of tack coat.
- **Interlayer** between CTB and asphalt: different thermodynamic behaviour, smoothness in CTB, quality of interlayer material.
- **High embankment construction:** post consolidation of subgrade.

Summary

- Perpetual pavement is a relatively new concept in India. Let us use the available experience.
- Let us monitor constructed pavements with time, including pavement constructed using cemented bases/sub-bases. **Performance data will help in further decision making.**
- Since the endurance limit of long-life flexible pavement with cemented bases/subbases is not known, the same shouldnot be used for >300 msa traffic in the name of 'perpetual' pavement.
- There should be a criteria of minimum depth of bituminous layer for the design of perpetual pavement.
- Construction process and use of appropriate interlayer bonding is crucial.
- Perpetual pavement can be sustainable ONLY when designed and constructed with high quality control.

Thanks!!

nikhil.saboo@ce.iitr.ac.in
+91 7579048967