BASIC GEOTECHNICAL CRITERIA TO INCREASE PAVEMENT STRUCTURAL LIFE

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ABSTRACT

The behavior of most engineering works (e.g., a pavement) is highly dependent on the soundness of their foundations. This is indeed the case of the *pavement* **sub-base course** constructed with RCC (rolled compacted concrete). It may be thought as a *continuous footing capable of carrying* the traffic loads and transmit them uniformly to the underlying material layers.

In order to avoid upward propagation of cracks associated with RCC shrinkage, sound gravel (railroad-ballast type) should be used to build the **base course.** Further more, the granular material would reduce traffic noise and inhibit the upward movement of capillary water that, consequently, would increase the pavement structural capacity. This structural setup results in a significant increase in pavement economic life.

The base course (gravel layer) must be overlaid by an asphalt concrete layer (**surface course**), in order to provide comfort and safety to all vehicles.

In Mexico, there are several cases of pavements built with these basic geotechnical criteria. In all of them, an FWD (Falling Weight Deflectometer) has been used for nondestructive structural evaluation.

Some examples of this pavement type are described in this paper.

This particular type of structural pavement cross section was named “inverted section” (PIS) by Romo and Orozco (1978, 1990), so as to reflect the fact that its structural capacity increases with depth, as opposed to traditional pavement structures (PTS). In figure 1 a sketch of the PIS-type of section is shown.

1. FUNDAMENTAL CONCEPTS

The worst nightmare of flexible pavement designers is the cracking of the asphaltic layer with time, due to:

a) bad mix design,
b) uncontrolled reflection cracks, and
c) deficient structural section

Resorting to geomechanical principles, Orozco (2005) concluded that the best pavement foundation is achieved building a continuous slab of CCR (Compacted Concrete Rolled, with Portland cement). Slab contraction cracking will develop similarly as in hydraulic concrete.

To prevent the reflection of slab cracks to the asphalt concrete layer, a transition between the surface course layer and the slab a granular layer is necessary. As mentioned previously, the material used to build this layer is similar to ballast of railroad: very coarse gravel without sand nor fines. As an alternative, smelting slag could be used. The sounder and harder the gravel is the friction angle (∅) will be higher in that layer. It should be stressed the fact that prevention of crack-reflection from the CCR slab to the asphalt concrete surface course is, according to the author's experience, the most significant beneficial contribution of the gravel layer.

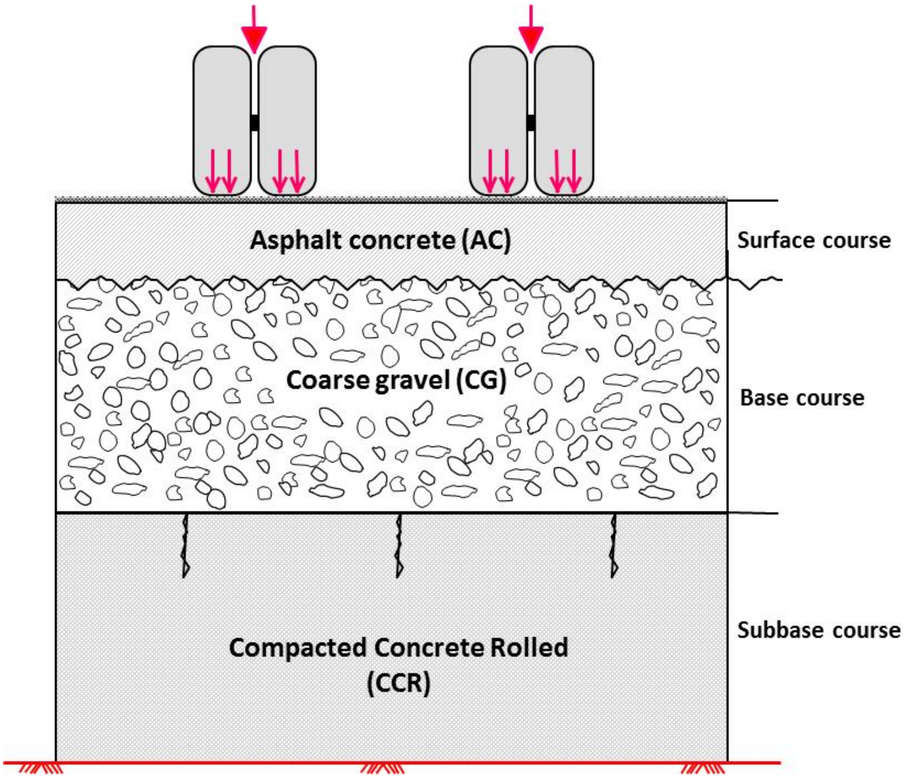

Figure 1 - Pavement “inverted section” (PIS)

2. COMPARISON BETWEEN “INVERTED” AND TRADITIONAL SECTIONS

To the behavior of the “inverted section” in comparison with the traditional one, simulations with mechanistic methods are (Ayala, 2010), as it is illustrated en figure 2, according with next traffic characteristics:

- Average Daily Traffic (ADT) of 10,000 vehicles
- Composition traffic of cars: 10 %; buses 60% and Trucks 30%
- Rate of annual growth: 6%

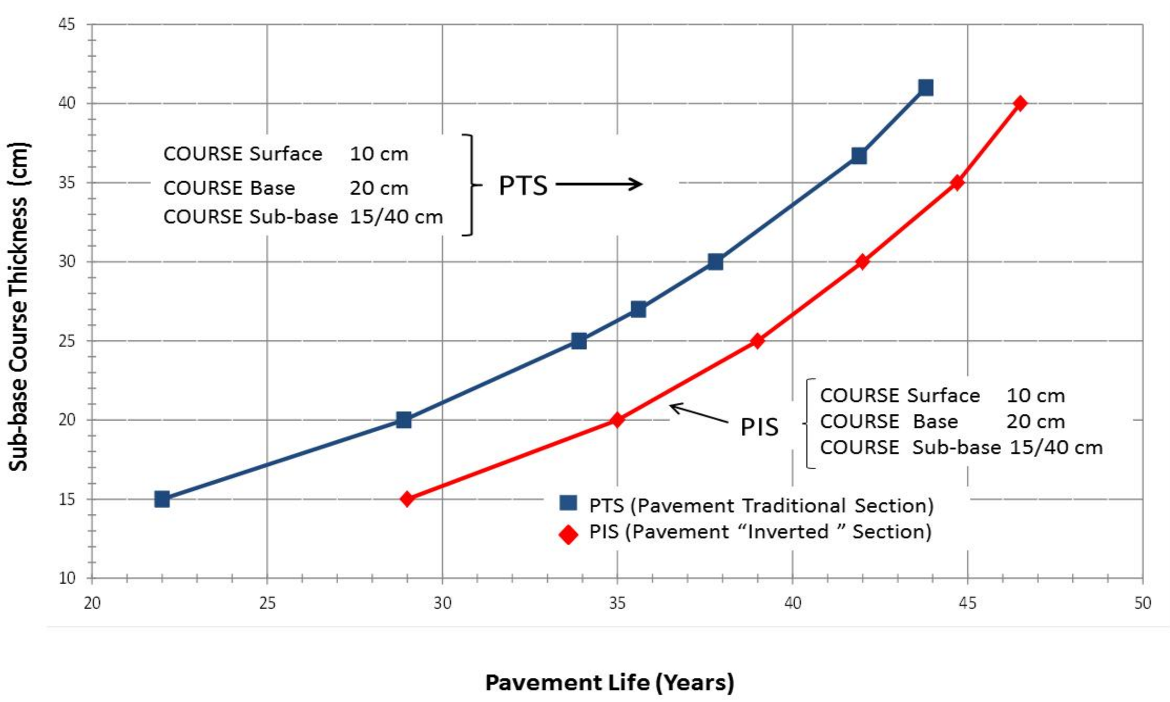

Figure 2 - Economic life of "inverted" versus traditional flexible pavements

From figure 2, it is possible to conclude that the pavement economic life of the inverted section (PIS) increases notably over the conventional one (PTS) when the sub-base course is built with CCR.

3. APPLICATION CASES

A real case where PIS was used is illustrated in figure 3. The data was obtained from FWD (KUAB) field tests. It is evident the relevant deflection reduction in the 4 sensor near to weight application. On the basis of these results, it may be argued that if the deflection is reduced to *half*, then, roughly, the PIS's life would be as longer as twice the PTS' economic life.

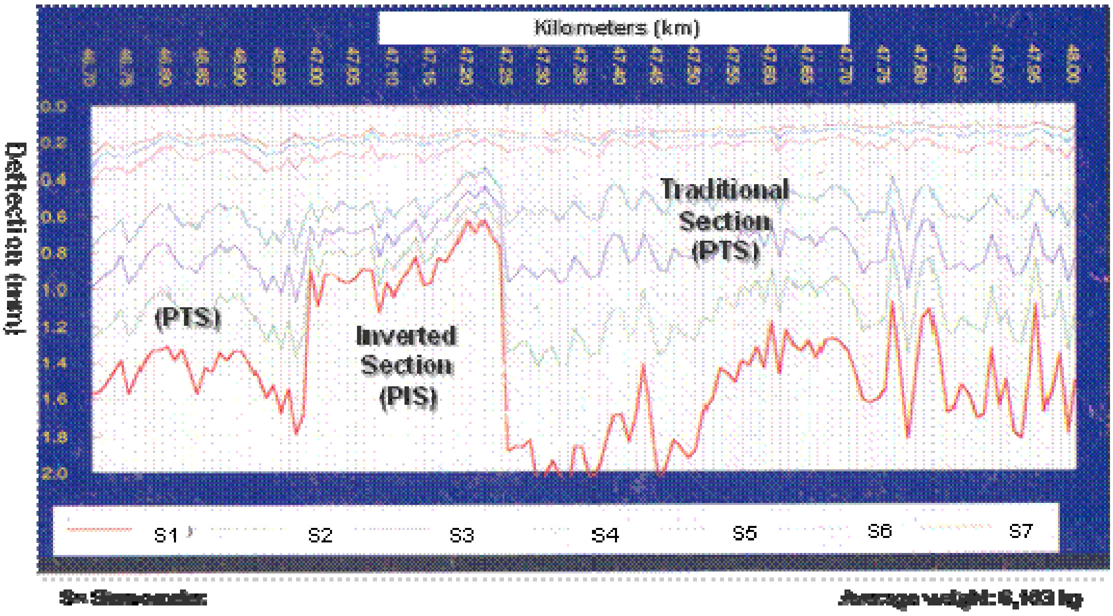

Figure 3 - Deflections with FWD (KUAB) in "inverted" and traditional sections

The information provided in figure 3 was obtained from FWD's field tests carried out in the Guadalajara-Colima highway. The courses were constructed meeting strict specifications to achieve the maximum *compacity* of the layers. The corresponding elasticity modulus were obtained by back calculations (inverted problem solution).

The *compacity* term is synonymous of *solids concentration*, *e.g.,* solid volume/total volume of material. For instance, a reinforcement bar has 100% of compacity (maximum solids concentration); on the other hand, the air has 0% of compacity (minimum solids concentration); the compacted gravel and the concrete (of Portland cement or asphalt), have compacities of 75 to 95% or more.

There are several cases in Mexico where PIS have performed nicely. Course thicknesses were around 10 cm (course surface), 20 cm (base course) and 30 cm (sub-base course). Some illustrations of PIS construction steps are presented in 4 to 14 figures.

- Tepic city – Aguamilpa hydroelectric system road, Nayarit state
- Mexico city – Cuernavaca highway (new lanes)
- Cuautla Intersection to Mexico-Cuernavaca highway
- Mexico city (Entronque Santa Martha) – Puebla highway
- Avenida 20 de noviembre, Xalapa, Veracruz
- Mexico city – Querétaro – Irapuato highway
- Operations platform Durango Airport
- Guadalajara – Colima highway
- Puebla-Orizaba highway

4. ASPHALTIC CONCRETE COURSE

Performance of asphaltic concrete layer improves according the *criteria*:

a) Hard, sound and clean aggregates with good adherence to asphalt and excellent petrographic properties, must be used

b) Asphalt volume/voids volume in the mix (saturation degree) must be sure between 75 and 85 %

c) Solids volume/total volume (compacity or solids concentration) is necessary to make sure that a Marshall Modulus (M_M) of 700 to 1,000 kg/cm^2 be obtained

d) Asphalt weight /solids weight is necessary to achieve, in combination with compacity and M_M of 700 to 1,000 kg/cm^2

The M_M values (Orozco-Santoyo, RV y Torres Verdín, V, 1986) can be computed with the next equation:

$$M_M = \frac{S}{f \cdot t} \qquad (1)$$

Where:

M_M = Marshall modulus
S = Stability
f = Flow of specimen
t = Thickness of specimen

5. RECOMENDATION

When it is necessary to rehabilitate a traditional pavement to increase its structural capacity, it is recommended the next procedure, as an example:

a) Cut the deteriorated pavement (25 cm, minimum), pulverized and mix it *in situ*

b) Add Portland cement and water, and blend them with the material homogenized as said before (a)

c) Compact all material previously mixed (b) and apply water to cure the new layer; and

d) Construct the conventional surface course (asphaltic concrete)

It is important to make sure the conventional quality control of pavement construction is fulfilled at all time in order to accept the geometry, materials, construction procedure, elastic modulus, friction coefficients, IRI, and so for.

6. ILLUSTRATIONS

Figure 4 - “Inverted section pavement Durango airport. Surface course: 15 cm; base course: 40 cm; sub-base course: 30 cm.

Figure 5 - Deflection measurements with FWD in Durango Airport. “Inverted section” pavement

Figure 6 - Solids elements of CCR in sub-base course. Guadalajara-Colima highway. Portland cement content: 10%; water/cement. ratio: 0.37 ± 0.03; elastic modulus: 7000 MPa. Crushed basaltic gravel

Figure 7 - Solids elements of figure 6 more water. Guadalajara – Colima highway

Figure 8 - Mixing CCR elements of figure 7. Guadalajara - Colima highway

Figure 9 - Mixing and compaction of sub-base (25 cm) and base courses (20 cm). Crushed gravel. Puebla - Orizaba highway

Figure 10 - Surface course of asphaltic concrete (10 cm). Guadalajara - Colima highway

Figure 11 - Mixing and compaction of sub-base (25 cm) and base courses (20 cm). Crushed gravel. Puebla - Orizaba highway

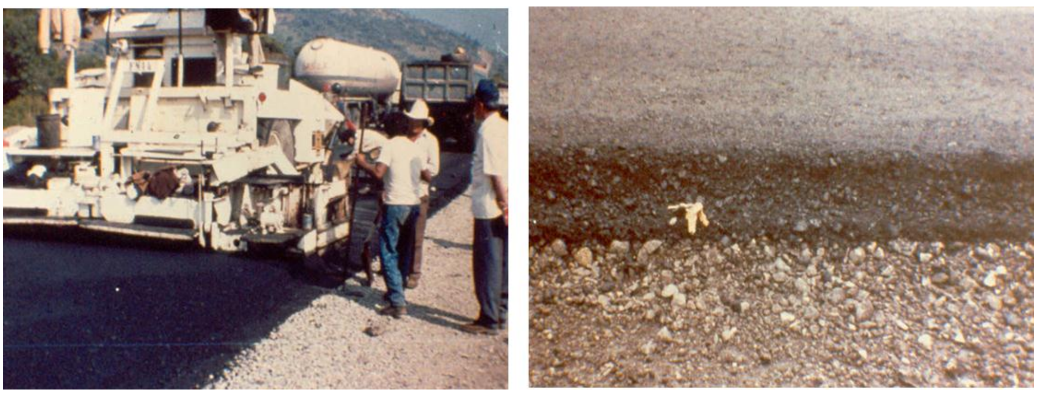

Figure 12 - Compaction of asphaltic concrete (10 cm) and view of complete “Inverted section” pavement. Puebla – Orizaba highway

Figure 13 - Completed “Inverted section” pavement. Mexico – Puebla highway

Figure 14 - CCR compaction (sub-base course) of “inverted section” pavement. Tepic – Aguamilpa highway.
Portland cement content: 10%; thickness: 25 cm. Alluvium gravel.

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