A LONG-LIFE CONTINUOUSLY REINFORCED CONCRETE PAVEMENT IN SERVICE SINCE 1976 IN SPAIN. WIDENING AND FUTURE.

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ABSTRACT

A 43 km long continuously reinforced concrete pavement was opened to traffic 34 years ago connecting three important cities in an industrial region in the North of Spain. Each carriageway has two lanes 3.75 m wide, an outer shoulder 3.00 m wide and an inner shoulder 1.50 m wide. A length of 5.14 km was widened with an additional climbing lane in 1990. Pavement layers are, from bottom to top, 20 cm of selected granular soil, 16 cm of cement treated base and a continuously reinforced concrete pavement, 22 cm thick. Longitudinal reinforcement consists of Ø18 mm steel bars, 14 cm apart, in the pavement built in 1976 and Ø 16 mm, 11 cm apart, in the additional climbing lane built later. Transverse reinforcement is placed with Ø 12 mm steel bars separated 70 cm. Concrete had a modulus of rupture of 6,0 MPa at 28 days. Currently, a new widening is been studied. This paper summarizes the good performance and reduced maintenance operations of this pavement.

KEY WORDS

LONG-LIFE PAVEMENT, DESIGN, PERFORMANCE, WIDENING

1. GENERAL CHARACTERISTICS

The motorway A-66 is better known as the "Y de Asturias" due to its geometry connecting the three main cities of this community located in the North of Spain (Oviedo, Gijón and Avilés). This continuously reinforced concrete pavement was opened to traffic in February 1976.

It is a 43 km long and the average daily traffic is 66,900 vehicles/day, between 8.9 to 10.3% of them are commercial vehicles (data of year 2008). So it is classified as one of the most heavy traffic category according to Spanish specifications (T0, with average daily truck traffic per way > 2,000). It should be mentioned that the maximum single axle load permitted in Spain is 13 tons.



Photos 1 and 2 - Perspective of "Y de Asturias" concrete pavement

Each carriageway has a width of 12.00 m, with two lanes 3.75 m wide each, an outer shoulder 3.00 m wide and an inner shoulder 1.50 m wide. A length of 5.14 km was widened with an additional climbing lane in 1990, with the aim of improving the service level of one of the most congested sections. It has a 4% slope. Currently due to the high traffic volume, specially at peak hours, it is being planned to widen both carriageways with an additional lane located in the existing central reserve between them. These lanes should be restricted to commercial vehicles or high occupancy cars, or allowed to be used by all types of vehicles, depending on the needs.

Pavement layers are, from bottom to top, 20 cm of selected granular soil with a CBR index more than 50, 16 cm of grave cement and a continuously reinforced concrete pavement, 22 cm thick (figure 1). A 4% cement and crushed siliceous aggregate were used in the cement treated base. The compressive strength was 9.3 MPa after 28 days obtained on cylindrical specimen Ø 15 x 18 cm. This was placed by compaction obtaining 100% of the modified Proctor maximum density.



Photos 3 and 4 - Concrete pavement images taken from the air

A minimum flexural strength of 4.5 MPa after 28 days was required in the concrete of the pavement. Longitudinal reinforcement consisted of \emptyset 18 mm steel bars, 14 cm apart, in the main pavement built in 1976 and \emptyset 16 mm steel bar, 11 cm apart, in the additional climbing lane built in 1990 (\emptyset 18 mm bars were no produced then). Transverse reinforcement was placed with \emptyset 12 mm steel bars separated 70 cm and located with an angle of 60° with the longitudinal ones. Stands separators (\emptyset 12 mm) hold the bars 7 cm under the surface level of pavement.



Figure 1 – Pavement section

The concrete pavement was produced in a 180 m³/h output ready-mix concrete plant. Cement amounts of 350 kg/m³ of Portland cement P-350 (currently EN 197-1 Portland cement CEM I 32,5 N) mixed with slags were dosed. Crushed siliceous was used as coarse aggregate with a maximum size of 25 mm. It was distributed into three sizes 0-5, 5-12 and 12-25 mm. Water-cement ratio applied was 0.47 and fluidizer agent was added in order to get a slump measured with the Abrahms cone of 4±1 cm.

A flexural strength of 5.1 MPa and 6.8 MPa were obtained after 7 and 28 days respectively. Prismatic specimens $15 \times 15 \times 60$ cm were used. Compressive strength was obtained on cylindrical specimen Ø 15 cm x 30 cm as contrast control. Strength values are shown in Figure 2.



Figure 2 – Concrete compressive strength (MPa)

Test sections were built by the contractor to test the whole process before starting with construction.

The pavement was built with a CMI slip form paver. Previously, another machine spread the concrete that was transported with trucks that drove along the shoulder. A third team sprayed the curing liquid and made the transverse texture with a mechanic steel brush.



Photos 5, 6 and 7 - Pavement was built with slip form paver during 1974-75

Only a longitudinal join between lanes was cut $50 \times 4 \text{ mm}$ (length x width), widened up, cleaned and filled up with a $15 \times 7 \text{ mm}$ neoprene profile. No expansion joints were used. Transverse anchorage sections were built on both sides of each bridge to avoid the stresses due to horizontal forces derived from thermal movements of the concrete pavement.

In spite of being noisier, transverse texture was selected to finish the concrete surface. Asturias, the community where it is located, is a very rainy region and security reasons were predominates.

The concrete placed in the in the additional climbing lane built in 1990 (figure 3), was made in a ready-mix plant. Cement amounts of 380 kg/m³ of special road cement, produced with approximately 50% of fly ash, and the same siliceous aggregates were used. Water-cement ratio applied was 0.44 and 0.3% plasticizer agent was added in order to get a slump measured with the Abrahms cone of 8 cm in the plant and 4 cm on site. Asphalt top layer was laid on the bridge slabs as in the first pavement.



Figure 3 – Cross section of the additional climbing lane

Strength values of this concrete are included in Figure 4. Prismatic specimen $15 \times 15 \times 60$ cm and cylindrical specimen Ø 15×30 cm are used in flexural and compressive strength respectively.



Figure 4 – Strength values of concrete used in the widened lane

Ratios of flexural strength at different ages are shown in figure 5.



Figure 5 – Ratios of flexural strength at different ages

One of the lanes was closed to traffic and it was used to transport and to spread the concrete. This was placed with a CMI TR-225 and CMI SF-250 slip form paver. The surface treatment was similar to the old pavement, continuing with the transverse texture.

Longitudinal join between lanes was cut 80 mm deep, widened up 12 mm (30 mm deep) and filled up with hot bituminous joint sealing material under the surface level of the concrete pavement.

2. DESIGN OF THE PAVEMENT

This motorway is the first reinforced concrete pavement built on a large scale in Spain. In addition to the advantages of building a concrete pavement, as its reduced maintenance costs, the decision to design a continuously reinforced concrete pavement was made by several fundamental reasons:

- Increasing load capacity support with maintenance costs even lower.
- The removal of the transverse joints that implies:
 - Avoiding any transmission efforts failure between slabs,
 - Avoiding the possibility of water coming through the joints, especially in this rainy region, Asturias,
 - Avoiding potential settlements between slabs or the difficulty of putting dowel bars in that year 1974.
- Cracking is distributed in a fairly uniform way.

Slab thickness was designed in the same way that a conventional concrete pavement but considering the reduction effect that the reinforce bars cause in the deflection curvature radius.

The idea of concrete breaks when steel reaches the 75% of its elastic limit was considered for the calculation of the longitudinal reinforcement.

Amount of 0.847% was used to design the steel section considering the concrete - steel adherence and the base – slab friction. A test section, which was lowered to 0.73%, was made (values higher than those required in present Spanish specifications).



Photos 8 and 9 - Pavement construction and reinforced bars detail

Longitudinal reinforcement was calculated to bear the thermal movements and shrinkage effects. Transverse anchorage sections were built on both sides of each structure to avoid the stresses due to these actions without transmitting horizontal forces to the bridges. Six armed beams, anchored to the ground, were built in each section. The beams are 0.65 m wide and 0.90 m deep and they are separated 4.80 m.

Despite the higher level of road noise, it was decided to finish the pavement with the texture applied in transversal direction for security reasons, due to the high number of rainy days per year in Asturias.

A texture 1.5 mm deep (measured in sand patch test) with streaks separated 25-30 mm was decided to be made after several test textures. Due to the use of good quality siliceous sand, the texture remains in quite good shape after 34 years without any treatment.



Photos 10 and 11 – State of the texture in 1975 and 2010

The same pavement was designed in the additional climbing lane built 14 years later, even if Spanish specifications required a higher thickness section and a smaller reinforcement ratio. As Ø 18 mm steel bars were not produced, Ø 16 mm bars separated 11 cm (instead every 14 cm) were placed as longitudinal reinforcement. The transverse reinforcement was also replaced by Ø 10 mm steel bars (instead Ø12 mm) separated 80 cm forming an angle of 60 degrees with longitudinal ones.

Tie bars Ø12 mm (80 cm long) was placed every 1 m between lanes to anchor the additional lane to the old one. Previously, holes were drilled in the middle of the concrete layer thickness and mortar without shrinkage was introduced in them to glue the bars.



Photos 12 and 13 – The motorway was widened with an additional climbing lane in 1990

It should be mentioned that it is very important to anticipate to traffic interference and to plan a detailed study of signalling, where all appropriate safety road measures have to be included, whenever a widening is projected.

3. PERFORMANCE

More that 510 millions of vehicles have circulated on the pavement since it was opened to traffic in 1976. More than 75 million are commercial vehicles. In spite of this heavy traffic, its performance to date can be classified as exceptional, with hardly any maintenance works and with a minimum cost for them.

No maintenance operations in the pavement were performed during the first eleven years. Five local distressed slabs and punch-outs were detected in 1987, when more than 21 millions of commercial vehicles had circulated on each carriageway. All distresses have been located in the right lane.

The outer shoulder has been built with 18 cm of slag – treated granular material and 4 cm of bituminous mixture. The joint between the pavement and the outer shoulder had widened in some places and water had come into. That is why distresses had appeared in some points due to an insufficient support of the slabs. The pavement-outer shoulder joint was cleaned and sealed with a bituminous product and the broken slabs were repaired.

Three maintenance operations in the pavement have been made lately. Some distressed slabs and punch-outs have been repaired with fast-track concrete. Traffic is allowed after 3 or 24 hours once compressive strength exceeds 15 MPa depending on the type of concrete selected. All of them are small localized failures appeared in recent years.



Photos 14 and 15 – Maintenance operations in the pavement have been very scarce

A long-lasting texture has been ensured thanks to the use of good quality siliceous sand in construction. While the texture decreased 17% the first year (1.59 ± 0.23 mm depth in sand patch test), later it has remained in very good condition, especially the macro-texture.

The join cut between lanes has not received any treatment during these 34 years although the neoprene profile must be replaced in some sections to prevent water from coming in.

The cracks distance varied from 1.19 to 2.60 m with an average distant of 2.03 m and an average crack open of 0.311 mm at the beginning. There were not differences between the two reinforced ratios used (0.847% and 0.73%). Cracking tends to stabilize after four years except in sections where water accumulation or overload can happen.

4. FUTURE PLANNING

Nowadays the possibility of widening both carriageways with an additional lane each is being considered in order to improve the service level. The lanes would be located in the existing central reserve between the carriageways. These lanes should be restricted to commercial vehicles or high occupancy cars, or allowed to be used by all types of vehicles, depending on the needs.

Since the central reserve width is 6.00 m, it is necessary to reduce the present lanes width (3.75 m) to 3.50 m and the inner shoulder (1.50 m) to 1.00 m wide. In this way, there would be enough space to accommodate two separate 3.50 m wide lanes and a rigid separation barrier. The difficulties could appear during the process of bridge widening.



Photos 16 and 17 - Concrete pavement images taken from the air

One of the possible problems that might appear during the construction of this two new lanes could be the join between the widened lane and the present one because it would be under vehicles track. The most logical solution technically will be the construction of continuously reinforced concrete lanes although the final decision has not been taken into account yet.

The wearing course could be a discontinuous bituminous mixture or more probably a concrete layer with exposed aggregate. In this case, a reinforcement of the present pavement would be made with a thin concrete layer.

5. SUMMARY

A continuously reinforced concrete pavement was opened to traffic in the North of Spain 34 years ago. All the characteristics, the concrete properties and the construction details has been summarized. Despite the fact that more than 320 million of vehicles have circulated on the pavement since 1976, the performance is exceptional. Maintenance operations in the pavement have been very scarce. The transverse texture has remained in quite good shape thanks to the use of siliceous sand.

Nowadays the widening of both carriageways with an additional lane each is being considered. The present lanes width will have to be reduced to 3.50 m. Although, more probably a thin concrete layer with exposed aggregate would be placed in the new lanes and to reinforce the present ones, the final decision has not been taken into account yet.



Photos 18 and 19 - Perspective of the 34 years old concrete pavement

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