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A start for stops?

São Paulo on crusade to improve pavement at bus stops

Last June, protests in Brazil originated from the low quality and prices of public transportation, with special concerns for buses in the main capitals of Brazil.

In addition to concerns over the travel fees and operational and infrastructure quality, residents also wanted to see pollution control, which has been addressed through the use of ethanol and hybrid diesel-electric vehicles.

São Paulo has almost 10.5 million inhabitants, and 6 million passengers are served daily by the motorized bus transport within the city, demanding around 15,000 vehicles and 1,300 routes. More than 240 million people board every month. The number for bus corridors in the most important city in Latin America is also impressive: 10 long-range exclusive corridors for urban buses, 28 urban terminals and 19,000 bus stops, performing a limited extension of 155 km and representing less than 1% of the street system in the city.

The current mayor of the city wanted to build up more than 150 km of bus corridors by 2016. Recent press reports announced federal government support for the mobility of public transportation in São Paulo at an investment level of $1.9 billion for 129 bus corridors, including new bridges and tunnels.

Not very pleasant

Conventionally, asphalt has been used by the São Paulo Transit Authority for paving the bus corridors. Over the last decade most of the corridors were built by transforming one left lane of the main avenue to an exclusive bus lane. Pavement solutions mostly consisted of overlaying the existing asphalt pavement and, more recently, by replacing the old pavement with a new plain jointed concrete pavement (PJCP). The PJCP solution of pavement reconstruction is more expensive but it might perform better. However, São Paulo's history with PJCP has not been a pleasant one, as many have lasted no more than 10 years before extensive maintenance was required. Technical evaluations and reports revealed poor construction practices were to blame (lack of control over dry shrinkage, misconception of dowel systems at transverse joints, poor drainage and poor sealing between the concrete and asphalt lane).

Most of the bus corridors cross natural thalwegs and commonly have poor foundation soils under the resilient point of view. A typical problem at those bus corridors is the development of distresses like rutting and shoving, especially close to bus-stop areas and street intersections and crossings. Potholes also are a nuisance. The decision was made to come up with a long-term pavement solution, and the University of São Paulo was chosen as a test site. Over the last 20 years, the campus has been used for several heavy-traffic pavement experiments, including ultrathin whitetopping for bus stops and conventional PJCP.

Short order

The first continuously reinforced concrete pavement (CRCP) in Brazil was built at the University of São Paulo during the winter of 2010 (July to September). It was originally intended to verify, for tropical conditions, the occurrence of transverse cracks and its comparison to other crack patterns in other climates. The idea of a seamless concrete pavement was enticing, since most of the concrete pavement distresses verified over the decades in Brazil were related to contraction joints and dowels and tie bars, especially on bus corridors in large cities of the country. Poor construction control of such critical elements in PJCP leads to several possible distresses like faulting, pumping, spalling, corner breaks, etc., and led officials to believe CRCP could take the place of PJCP in bus-stop areas treated as a reinforced pavement with longitudinal and transverse bars without requiring saw-cut or transverse joint dowels for one-lane traffic. Therefore, four short lanes (50 m each) of CRCP were built. The use of short slabs, lacking anchors at section ends, allowed researchers to check the opening of shrinkage cracks within the system. The traditional CRCP behavior in the matter of dry shrinkage is well known and understood. Short CRCP slab cracking should be evaluated because crack spacing is crucial in establishing design parameters.

The entire four-lane, 200-m length is composed of 240 mm of portland cement concrete (MR > 4.5 MPa), a hot-mix asphalt (HMA) base of 60 mm and 200 mm of dry macadam as a sub-base over a clay subgrade. HMA was used as a base course to aid diminishing thermal gradients in concrete slabs, since in tropical conditions the thermal differentials between slab top and bottom reaches 26°C during the summer. The four sections have different percentages of steel (0.4, 0.5, 0.6 and 0.7%). The experimental lanes of CRCP were built manually using lateral wood forms. Each lane section was 50 m long and 5.05 m wide. All of the building steps were carried out manually, from the placing of steel bars to the surface finishing (texturized with brooms).

Monitoring crack development showed that the lack of anchorage made the short CRCP behave differently from conventional CRCP. The daily traffic was composed of around 800 urban buses per day along with dozens of medium trucks and 1,500 cars.

Crack track

During the first year weekly surveying showed cracks did not arise in the slab concrete surfaces (at least to the naked eye). However, this situation changed drastically after October 2011, when the first crack was observed, in Section 3, located on the opposite side of the transverse joint between sections 3 and 4. One might assume that cracks were present within all of the slabs at construction and curing time, but they were not due to two fundamental reasons. First, there was no anchor system at the end edge of the slabs. In addition, the concrete was laid over an HMA base course, creating a strong bond-breaker interface between the slabs and the base compared to cemented bases and rolled-compacted concrete. The combination of no anchoring and slipping freedom helped conceal the shrinkage mechanism, but not avoid it altogether. The strong tying effects of the longitudinal bars prevented the cracks from appearing during the earlier stages.

As of March 2013, the average spacing between the cracks in the short CRCP slabs is twice the value observed on U.S. highways over the last five decades—4.55 m and 6.25 m in sections 3 and 4, respectively. The average crack width in May 2013 was 0.17 mm in Section 2 and 0.55 and 0.33 in sections 3 and 4, respectively, at 16°C. During the summer

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Fact Finder

All of the building steps were carried out manually, from the placing of steel bars to the surface finishing.

(January 2013), the crack widths for the three sections were 0.1 mm, 0.37 mm and 0.26 mm at 27°C. Therefore, it makes sense to consider conventional slab sizes as PJCP for the design of short CRCP sections at bus-stop areas.

What will it be?

The short CRCP sections built on the University of São Paulo campus developed a few transverse cracks since construction in 2010. After one year, the cracking patterns on the short sections of CRCP were quite different from conventional CRCP. The effect of minimal anchorage in the CRCP slabs resulted in a delay of shrinkage cracks on the concrete surface, an unexpected result for CRCP supported by research. Large spacing between the shrinkage cracks has been observed. Deflections also have shown to be a relevant effect of steel percentage in stiffening the short CRCP sections, resulting in a better performance in sections 1 and 2 over the short and medium term.

The dilemma facing the city of São Paulo in the use of CRCP sections in bus corridors in the coming years is this: Do they design them as conventional PJCP slabs in the case of short lanes for bus stops, or do they design in accordance to AASHTO-MEPDG with anchor systems in long CRCP sections over concrete bases? The São Paulo Transportation Authority held a seminar to present and discuss the needs for improved long-lasting pavement systems for the public-transportation corridors. **R&B**

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