Full-Scale Load Testing of Segmental Concrete Paving Slabs and Planks

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Background and Need

In 2015, Applied Research Associates pavement engineering consultants were retained by the ICPI Foundation for Education & Research to conduct computerized finite element modeling (FEM) of various shapes and thicknesses of paving slab and plank units. ICPI Foundation Fact Sheet 11 provides information on this modeling. The units were subjected to modeled truck wheel loads (~8,750 lbs of 40 kN) on three pavement structures; dense-graded aggregate, lean concrete over an aggregate subbase, and concrete over an aggregate subbase. Structural design tables were provided from the FEM with traffic categories and load limits for a range of square and rectangular slabs, as well as planks, with flexural strengths of 650 and 750 psi (4.5 and 5.2 MPa) on aggregate, stabilized, and concrete bases over four soil subgrade strengths.

From applying a single wheel load on each paving assembly, the FEM calculated the resulting stresses in the slabs and base. Structural design tables allowed up to 75,000, 18,000 lb. (80 kN) equivalent single axle loads (ESALs) using stress ratios, i.e., the applied tire stress divided by the paving unit flexural stress. The structural design tables were included in a draft of ICPI Tech Spec 24 *Structural Design of Segmental Concrete Slabs and Plank Systems.*

Test pad with slabs and planks on concrete and aggregate bases subject to tractor-trailer loads.

Objectives

Being a theoretical FEM exercise, limited full-scale load testing of selected slabs and planks was conducted to provide partial model validation. This load testing occurred at an inventory yard of a paver manufacturing facility in Frederick, Maryland, subject to documented tractor-trailer loads. The research objective compared the response of slabs and planks to the design guidance provided from the FEM exercise. Slabs sizes tested were 24 x 24 x 3.125 in. (600 x 600 X 80 mm) and 12 x 12 x 3.125 in. (300 x 300 x 80 mm). Plank sizes tested included 4 x 12 x 4 in. (100 x 300 x 100 mm) and 4 x 16 x 4 in. (100 x 400 x 100 mm) units. Flexural strengths ranged from 530 to 990 psi (3.6 to 6.8 MPa). All units were set on a 1 in. (25 mm) thick sand bedding layer over 12 in. (300 mm) of compacted aggregate base or over 4 in. (100 mm) thick concrete base and 6 in. (150 mm) of compacted aggregate subbase to provide partial validation of the FEM exercise from 2015.

Installed over a subgrade having an average California Bearing Ratio of 4.6%, all pavements were subject to at least 75,000 ESALs over four years.

Outcomes

Of the eight paver/base combinations, five had no cracked units, thereby meeting the 75,000 ESAL limits recommended by the FEM defined by stress ratios. However, the units on the dense-graded aggregate base experienced significant rutting that would likely not be tolerated due to potential ponding and tripping hazards.

The 4 x 16 x 4 in. thick units on a minimum 4 in. concrete base and 6 in. aggregate subbase exhibited cracking past 30,000 ESALs. The 12 x 12 x 3.125 in. thick slab units exhibited adequate performance up to 75,000 ESALs except for severe rutting while supported by an aggregate base. Likewise, the 24 x 24 x 3.125 in. thick slabs on an aggregate base survived 75,000 ESALs without cracking but experienced severe rutting. The three cracked 24 x 24 x 3.125 in. thick slabs on the concrete base were replaced and almost immediately cracked again under truck loading. This is likely due to uneven bedding sand and/or an uneven concrete base, or concentrated loads since the cracked units are located at edges of the test area.

Pavement condition and elevation surveys confirmed that the concrete base materials provided lower rutting levels than the aggregate base. However, the load recommendations were set at 30,000 ESALs due to excessive rutting at 75,000 ESALs that could likely create ponding and tripping hazards even though most slabs and planks did not crack. The 30,000 ESALs load limit for slab and plank designs provided limits on unit dimensions less than those modeled in the FEM exercise. This load limit is significantly lower than UK and Australian limits for paving slabs. However, it agrees with those published for paving slabs on aggregate bases by the German industry association.

The outcome of the study was used to revise ICPI Tech Spec 24 *Structural Design of Segmental Concrete Slabs and Plank Systems* released in April 2022. This technical bulletin provides design guidance for slabs from 2 to 4 in. (50 to 100 mm) thick up to 24 x 24 in. (600 x 600 mm), and square units only. Guidance is also provided on planks which are generally exposed to lower vehicular traffic than slabs, i.e., planks 3 to 4 in. (75 to 100 mm) thick and up to 36 in. (910 mm) in length. Backed with modeling and full-scale load testing, the bulletin provided much needed guidance with conservative design solutions for these increasingly popular segmental concrete paving products.

The final report on the full-scale load testing can be downloaded here. ICPI Tech Spec 24 is available here.