Finite Element Modeling and Design Tables for Segmental Concrete Paving Slabs

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Fact Sheet 11

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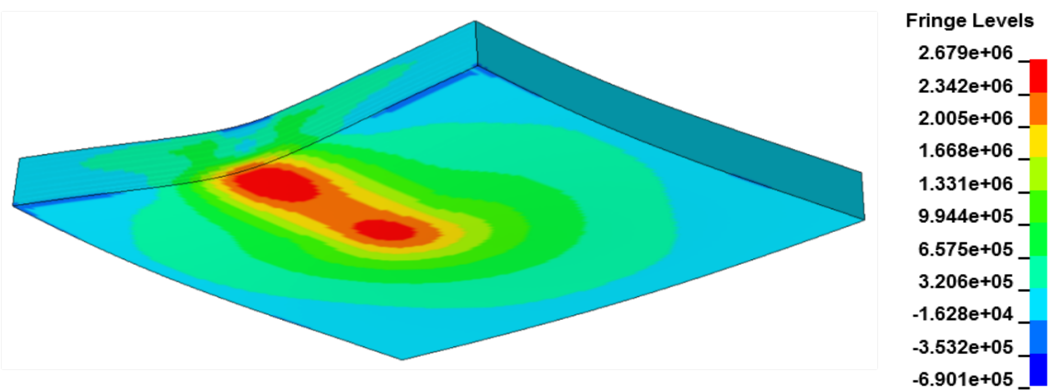
Background and Need

For large concrete paving slabs typically used on highways, structural design includes well-established relationships between the number of standard axle loads and slab cracking to failure assuming a range of soil subgrade and base characteristics, concrete strengths and reinforcing. No such relationships exist for much smaller segmental concrete paving slabs defined in ASTM C1782 Standard Specification for Segmental Concrete Paving Slabs and CSA A231.1 Precast Concrete Paving Slabs. While such paving units can withstand only a fraction of the axle loads compared to interlocking concrete pavement, this research project used finite element modeling to characterize the permissible number axle loads for a range of paving slab and plank lengths, widths and thicknesses over aggregate base, lean concrete and concrete bases.



Objectives

Outcomes

Finite element modeling illustrates the principal stresses in megapascals (MPa) on the bottom surface of 48 x 48 x 4-inch thick paving slab subject to a dual truck wheel load. (To convert MPa to psi, multiply by 145.)

Objectives

ARA reviewed industry design guidelines for paving slabs from the United Kingdom, Australia, and Germany. While informative, all overseas design methods were empirically derived without published relationships among slab size, strength, base, load repitítions and cracking (i.e., failure) derived from modeling or full-scale load testing. This project conducted finite element modeling that examined the reaction from a range of sand-set paving slab and plank dimensions over aggregate, lean concrete and concrete bases. The model used was LS-DYNA program that modeled the behavior of paving slabs when repeatedly loaded with a dual wheel truck tire consisting of 9,000 lbs.

Model input variables included the following:
Paving slab dimensions: 12x12, 24x24, 36x36, 48x48, 12x18, 12x24, 16x24, 20x30, 24x 36, 24x48,

36x48
Plank dimensions: 12x3, 24x4, 36x6; 12, 18, 24, 30, 36 and 48-inch lengths by 3, 4, 5 and 6 inch widths
Thicknesses: 2, 3, 4, or 5 inches
Thin tile pavers: 4x8 inches by ¾ (20 mm), 1¼ (30 mm), and 1 5/8 in. (40 mm) thick

Slab material properties: flexural strength of 650, 700, and 750 psi as determined per ASTM C1782. Flexural strengths are measured with spacing of rollers at 8 in. for units having a maximum length of 12 in.; 10 in. spacing for units having a length between 12 in. and 20 in.; and 12 in. roller spacing for units having a length of greater than 20 in.
Bedding type: 1-inch thick sand
Base materials: aggregate at 100% CBR; cement-treated, lean concrete at 1500 psi; concrete at 4,000 psi
Subgrade support: k-values of 50, 80, 100, 140, 200, or 300 psi/in and/or approximate correlated California Bearing Ratio of 3%, 5%, 7% and 10% using the correlation between resilient modulus (M_r) and CBR in the *Mechanistic Empirical Pavement Design Guide,* i.e., M_r (psi) = 2554 x $CBR^{0.64}$.
Loads: Dual truck tire 9,000 lb. (half of an 18,000 lb equivalent single axle load) located the center, edge, or corner depending on slab dimensions.

The output generated for each of the above combinations was the induced tensile stress resulting from the combination of paving material properties, slab dimensions, and base support structures under load repetitions. The tensile stress at the slab or plank bottom was divided by the modulus of rupture (MOR) for the paving slabs. These stress ratios were used to estimate the number of allowable ESALs from a truck tire before fatigue failure (typically cracking) is anticipated. The following table defines the range of stress ratios with the lower ratios used for higher load limits.

Traffic Limits	Stress Ratio	20 yr ESALs*	Equivalent Heavy Vehicles/Day**
Do Not Use	1	0	0
Primarily Pedestrian	0.7	1,000	0.1
Cars	0.5	7.500	0.5
Cars and Light Trucks	0.4	30,000	2.0
Cars and Occasional Heavy Vehicles	0.3	75,000	5.0

* ESALs = 18,000 lb (80 kN) equivalent single axle loads.
** Heavy vehicles/day assumes 2 ESALs per heavy vehicle.

Outcomes

This table was used to develop an extensive list of design options for slabs, planks and thin pavers at three flexural strengths and three California Bearing Ratios for subgrade support. This was issued in 2017 as a draft ICPI Tech Spec 24 *Structural Design of Segmental Concrete Paving Slab and Plank Pavement Systems.* The draft led to a decision by the ICPI Technical Committee on conducting partial validation using full-scale load testing of selected slabs and planks. At this writing, that project is underway in an outdoor yard subject to dump truck and loaded flatbed trucks located behind a concrete paver manufacturing facility in Frederick, Maryland.