

Thin concrete pavement design method and application in Chile

A new design methodology of concrete pavements is being applied in Chile and other countries of South and Central America.

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Figure 1, above left: Load situation in traditional slabs. Figure 2, above right: TCP approach to geometry design of slabs.

The key principle of this new design method is to select the slab size so that not more than one set of wheels is on any given slab at any one time, thereby minimising the critical top tensile stress. By reducing top tensile stresses, concrete slabs have been made thinner, using less concrete. With this optimisation, concrete pavements are competitive against traditional asphalt solutions.

More than 6 million m² of this new technology has been constructed worldwide, in roads, industrial truck yards, parking lots and low-volume roads. This new concrete pavement design has been approved by relevant government departments in Chile, Peru, Guatemala and Costa Rica. It is included in technical manuals in the USA, Chile and Peru and was recognised in 2013 by the National Innovation Awards.

TCP design approach

The typical slab dimensions for a concrete pavement are 3.6m wide × 4.5m long, with slab thicknesses ranging from 150 to 350mm depending on the level of traffic. The required thickness is primarily dependent on the axle weight and number of load repetitions, concrete strength,

slab length, soil type and climate conditions (curling).

As concrete slabs curl with the edges lifted from the ground, the loads of the trucks induce tensile stresses at the top of the slab. These stresses depend on the amount of construction curling, slab geometry, soil support and climate conditions, as seen in Figure 1.

The new TCP design approach is to design the geometry of the slabs so that only one set of wheels load each slab at a time, as shown in Figure 2.

This change in geometry minimises top flexural stress, the bottom stress being the predominant mode of failure. The support of the soil and the use of fibre-reinforced concrete (FRC) have an important impact on the performance of the slabs.

Design software

Design software for traditional jointed plain concrete pavements isn't able to design slabs of less than 3.5m joint spacing. OptiPave2 was developed especially for designing concrete slabs with joint spacing between 1.4 and 2.3m. This program calculates pavement distresses, simulating different load levels and properties of the concrete slab.

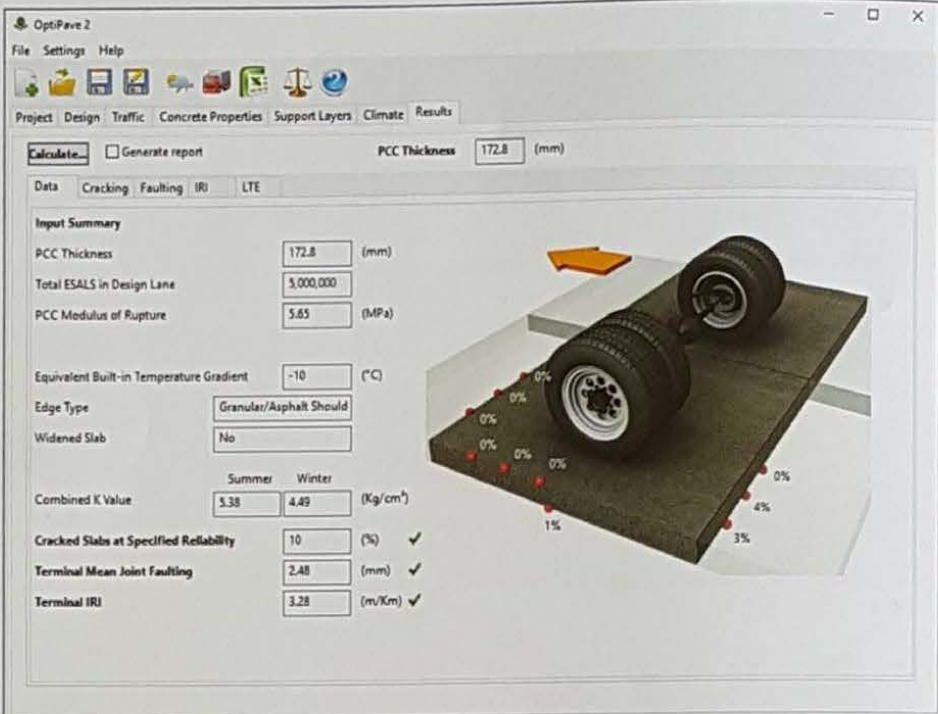


Figure 3, right: General output screenshot of OptiPave 2.

Figure 4, below: Longitudinal cracking calibration curve.

It was developed from a large number of runs in finite elements, using ISLAB2000. For greater speed and accuracy in the calculation of stress and deformation of the slab, neural networks were developed and also the concept of equivalent structure was applied in the development of the software.

The program has the following features:

- calculates the percentage of cracked slabs in time,

according to three failure mechanisms – transverse, longitudinal and corner cracking

- calculates International Roughness Index (IRI) and mean joint faulting using a differential energy model
- adds the possibility to design FRC pavements
- multi-language and allows international and imperial unit systems.

Calibration

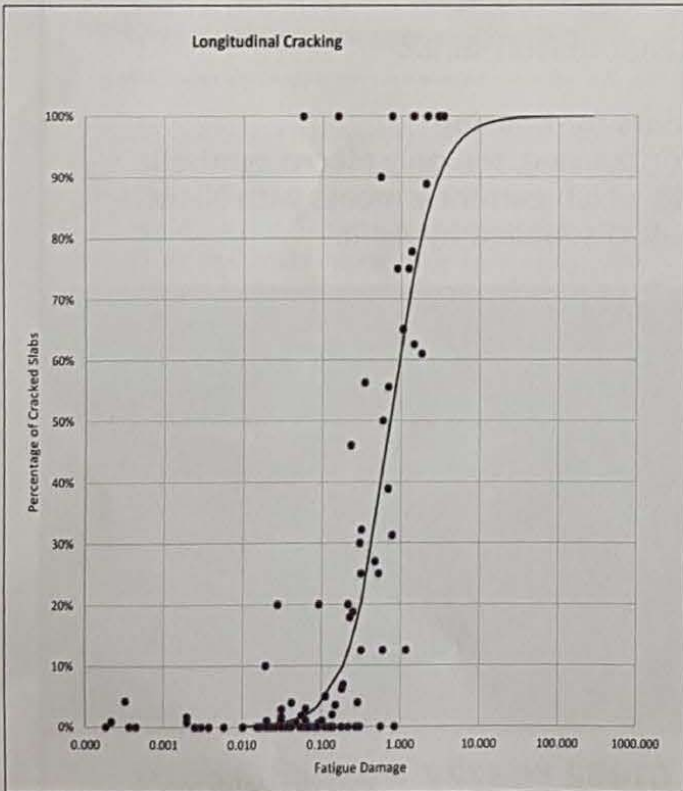
In order to provide accuracy in performance calculation, the software was calibrated using data collected from accelerated test sections conducted at the University of Illinois and local test sections performed in several locations in Chile.

Transverse, longitudinal and corner cracking were calibrated, which provided accuracy to the design software. The program also was calibrated with ultra-thin pavement sections. It can be used to design concrete pavements up to 60mm thick. In Figure 4, the longitudinal cracking-fatigue damage curve and the red dots are the results from each test section using the TCP system.

High traffic projects

Route 60-Ch, La Polvora Highway, Chile

This project was constructed and opened to traffic in 2008. It is the route to one of the biggest shipping ports of Chile, with more than 5000 trucks travelling the road every day. This project was constructed with asphalt and showed high levels of distress on the surface in some sectors. Now it is being rehabilitated, with a TCP unbonded concrete overlay placed directly over the existing asphalt. The road is 12km long with two lanes in each direction, 7m width plus 200mm of lane widening. The structure used 230mm-thick concrete FRC slabs.



Route M-50 Cauquenes-Chanco, Chile

This project was constructed in 2012 located in a forest area, where heavy trucks laden with timber use the road. The design is for 10 million 18,000lb (8200kg) standard axles for a ten-year design life. The pavement is 170mm thick.

After four years of service, it is performing according to the design, with no major distress. An adjoining section of this road its being fitted with the same technology.

TCP in truck yards and parking

TCP has also been designed, engineered and specified for parking lots, distribution centres and warehouses due to its good performance and savings in construction costs. Typical thicknesses range from 110 to 160mm, depending on traffic level and soil characteristics. Over 1 million m² has been built so far in Chile.

U-TCP solution

This is a variant of the TCP technology for low-volume roads. This design consists in a short jointed FRC pavement, with thicknesses ranging from 80 to 120mm, placed directly over the existing granular way, without a sub-base.

The key principle is to use the high degree of compaction over time of the existing granular road and pave directly over this. This allows building of concrete pavements at a very low initial cost. The Ministry of Public Works of Chile has carried out four contracts so far.

In 2012, the first U-TCP project was built in the IX Region, in the vicinity of Temuco, 700km south of Santiago. The slabs are 90mm thick, 1.5m wide and 1.4m long. Three years after construction, the pavement shows no fatigue cracking or differential settlement. ■

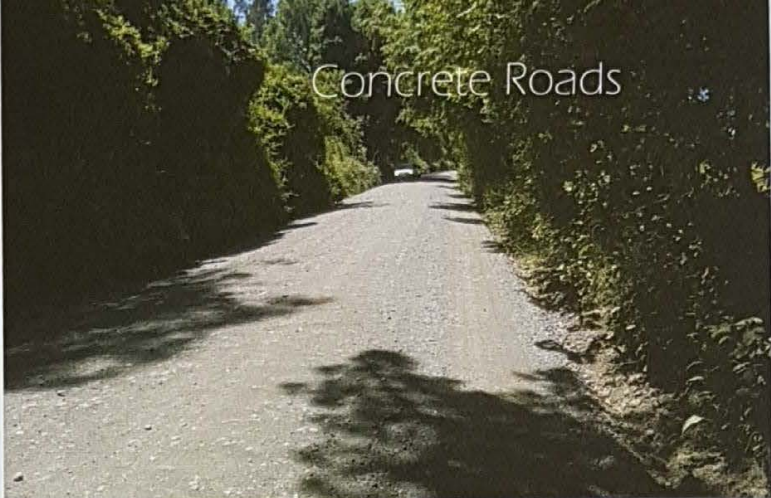


Figure 5, previous pages, top left: Cauquenes-Chanco Road after three years. Figure 6, below left: Walmart Lo Aguirre distribution centre, Santiago, Chile. Figure 7, above: Mahuidanche – Mision Inglesa pre-paved and after two years.



A second U-TCP project was constructed in 2013. This is a 5.2km project, divided into 4.7km of double treatment and 0.5km of a 100mm U-TCP. The cost per kilometre of the concrete solution was similar to that for the asphalt, as reported by the constructor. After two and a half years, the concrete subsection has performed better.

Two more projects have been built to date: the first is the paving of an existing granular road with a slope of more than 20°, with an 80mm-thick FRC; the second project is 4.4km long near Coyhaique using a 100mm FRC.