Calls for tenders should on all accounts specify technical data for the tack coat.

The quantity of the required bituminous emulsion depends on the roughness of the substrate (table 9).

Substrate	**Quantity of tack coat S&P emulsion G**
Asphalt pavement without cut milling	~ 300 - 400 g/m² emulsion
Cut-milled asphalt pavement	~ 400 - 500 g/m² emulsion

Table 9: Quantity of tack coat S&P bituminous emulsion G

If the grid interlayer is applied to shaded areas or on **cool autumn days**, the problem of tack coat softening does not arise. Under these conditions a good quality adhesive is an expedient alternative.

7. Research at EMPA Dübendorf CH "Impact of different pavement layers“

7.1 Load test at the four-point bending beam

At the EMPA CH research centre, bituminous pavement layers with different types of reinforcement were examined, using the four-point bending beam. This showed two typical break patterns.

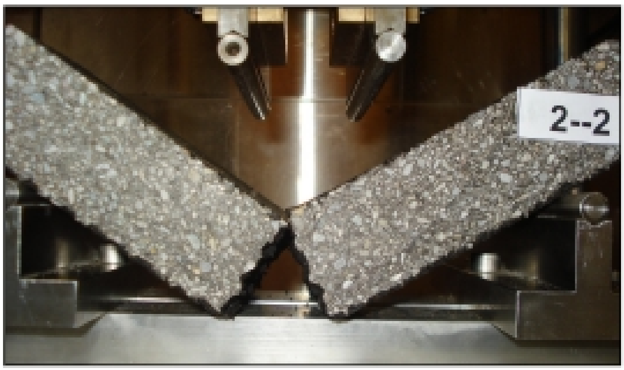
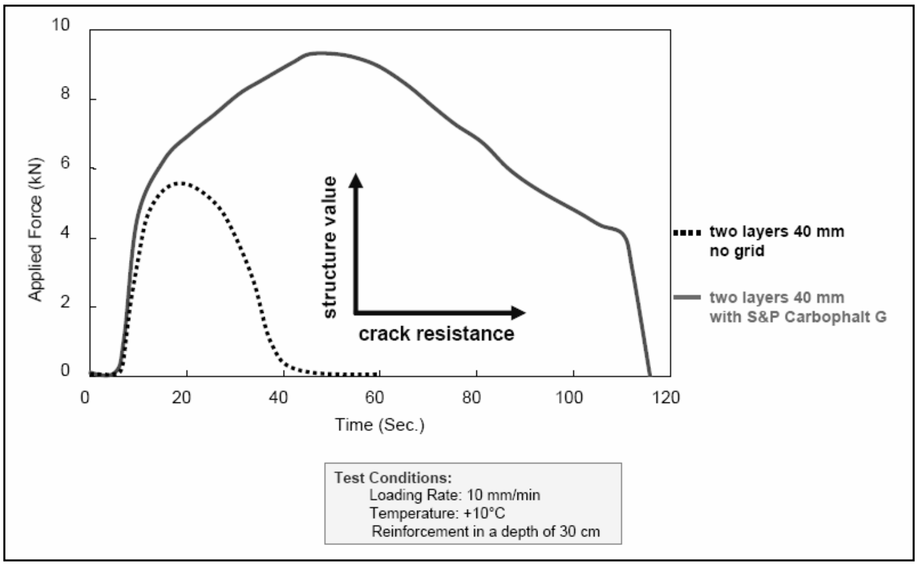


Image 2: Reference sample without grid

Image 3: Sample with S&P Carbophalt G 200 kN as interlayer

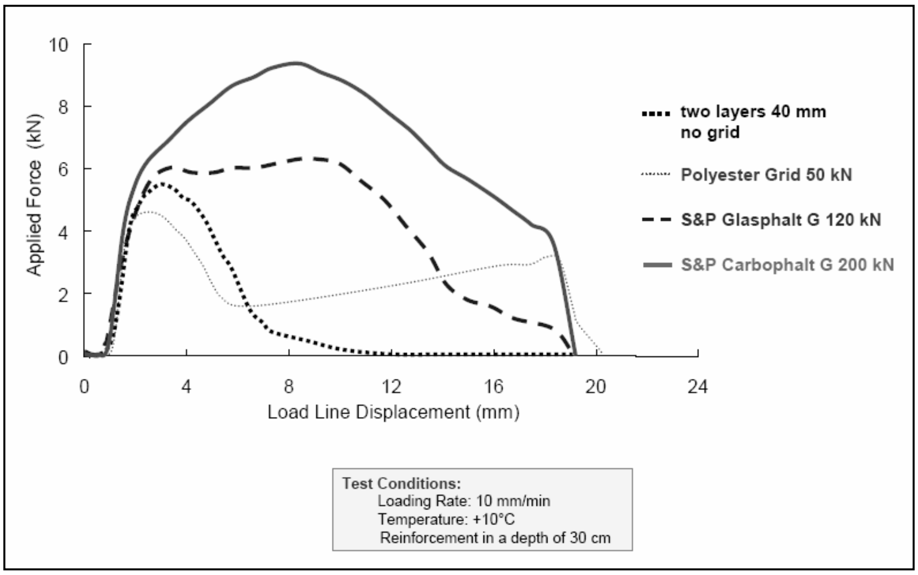
Whereas in the asphalt layer without grid *(Image 2)* a crack developed in the middle of the reference sample, leading to a break, the C-fibre reinforced asphalt layer *(Image 3)* showed optimal stress redistribution and crack distribution.

The ultimate load (structure value) as well as the crack resistance of the reinforced pavement layer is significantly increased through the carbon fibre grid (Graphic 5).



Graphic 5: Impact of the carbon fibre grid

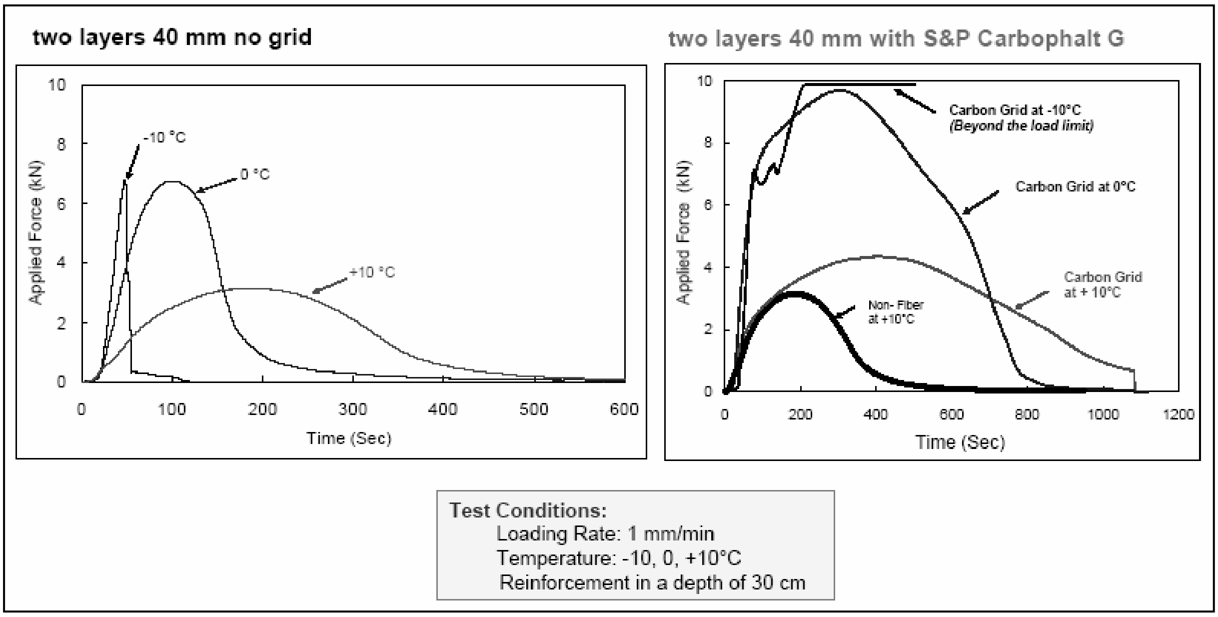
In graphic 6 a polyester grid was compared with the pre-bituminised S&P glass and carbon fibre grid. The polyester grid with a tensile elasticity modulus of ~15 kN/mm² bends during the test under the load and is thus not capable of absorbing tensile forces acting on the asphalt pavement. The pre-bituminised glass grid “S&P Glasphalt G“ with a tensile elasticity modulus of ~ 70 kN/mm² absorbs tensile forces in the asphalt layer and is thus suitable for reducing cracks in the asphalt pavement. The ultimate load can be increased further with the carbon fibre grid “S&P Carbophalt G“. The carbon fibre grid with a tensile elasticity modulus of ~ 240 kN/mm^2 increases the structure value of the reinforced asphalt layer and substantially improves the resistance to cracks.



Graphic 6: Carbon fibre grid in comparison with other intermediate layers

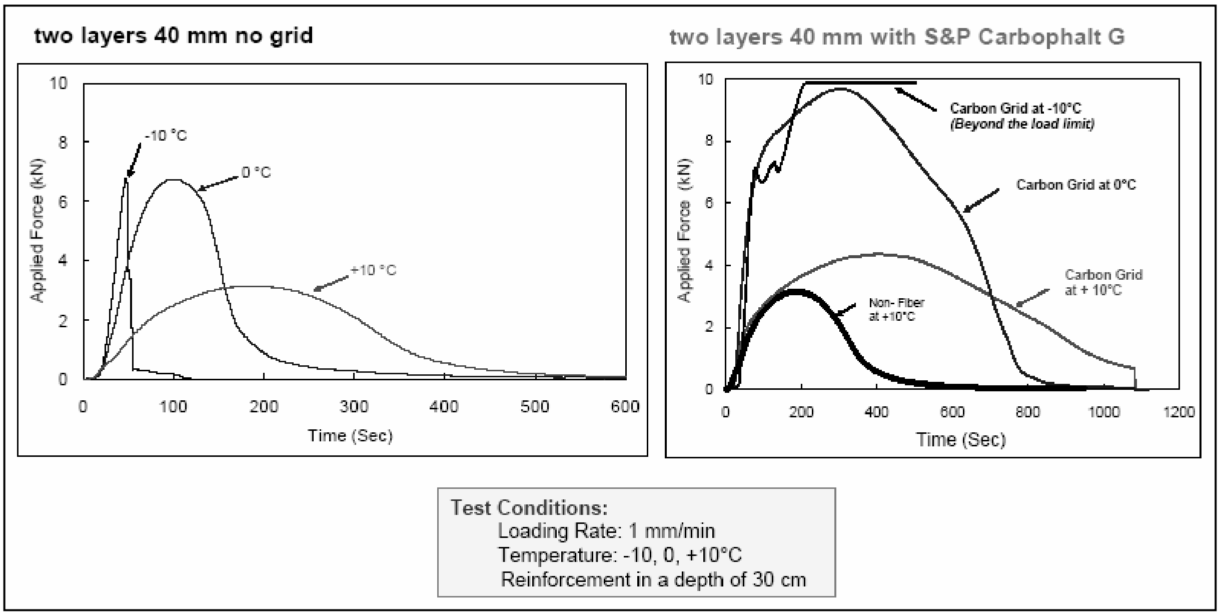
A further test compared the influence of the temperature at -10°, 0° as well as at +10°C, on a non-reinforced layer and on a carbon-fibre reinforced asphalt layer.

Graphic 7/8 shows that the carbon fibre grid “S&P Carbophalt G“ considerably increases crack resistance as well as the ultimate load in all temperature ranges, at -10º, 0° as well as at + 10º C.



Graphic 7/8: Influence of temperature

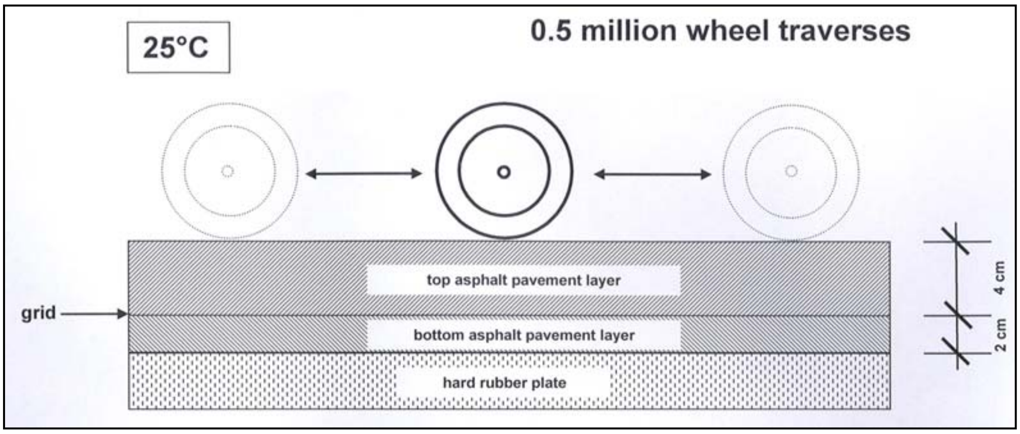
A further test compared the influence of the load 1mm/min, 5 mm/min as well as 10 mm/min on a non-reinforced asphalt layer and on a carbon-fibre reinforced asphalt pavement layer.
Graphic 9/10 shows that the carbon fibre grid “S&P Carbophalt G” considerably increases the ultimate load and crack resistance in all load ranges, 1 mm/min, 5 mm/min as well as 10 mm/min.



Graphic 9/10: Influence of the load

7.2 Dynamic loading under effective wheel

At the EMPA CH research centre two-layer carbon-fibre reinforced and non-reinforced pavements were compared under cyclic loading *(Graphic 11 / Table 10).* To simulate the deflection of the foundation the test specimens were applied to a rubber base and subjected to rolling over by 0.5 million wheel motions at a temperature of 25° C.



Graphic 11: Test arrangement dynamic cyclic load

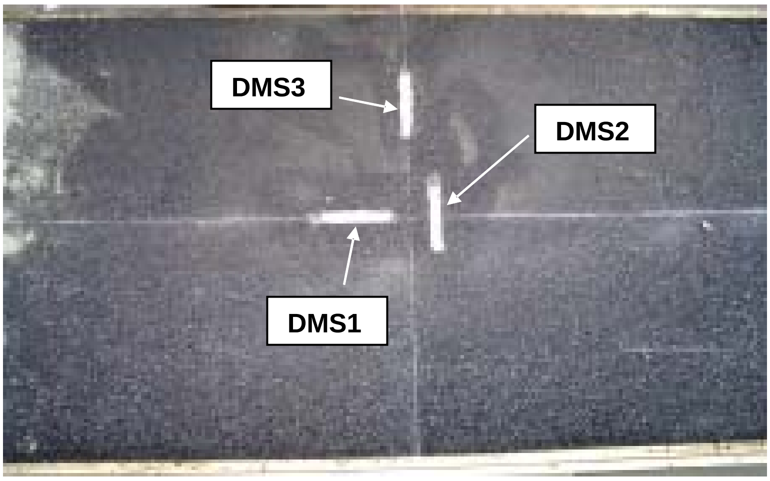


Image 4: Arrangement of strain gauges

Test Specimen K1:	Two-layer pavement without asphalt grid
Test Specimen K5:	Two-layer pavement S&P Carbophalt placed at a depth of 4 cm(cut-milled sub-base)

Table 10: Overview Test Specimen

The test specimens (Table 10) were fitted with strain gauges on the bottom in longitudinal and transverse directions (Image 4). The results of the experimental tests were modelled by the EMPA CH using a finite element calculation. Modelling and experimental tests showed comparable results.

The expansion transverse to the wheel load on the bottom of the asphalt layer was reduced by 25-45 % (depending on the asphalt mix) as a result of the carbon fibre grid "S&P Carbophalt G".

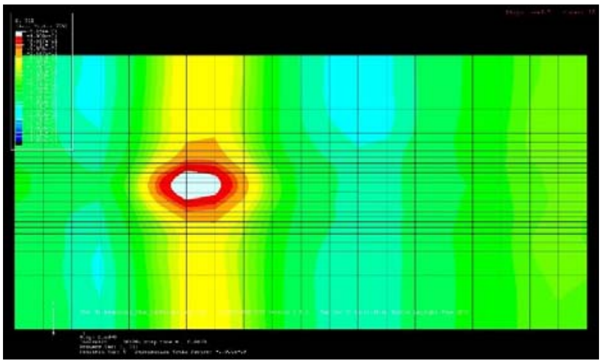


Image 5: without carbon fibre reinforcement

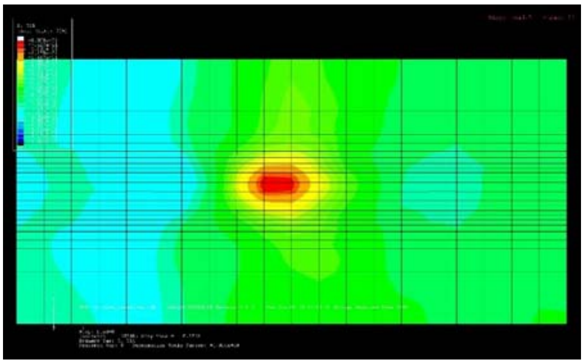


Image 6: with carbon fibre reinforcement

Image 5 and 6 show the compressive stress in front of and behind the wheel load, when being rolled over, as well as the tensile forces under the wheel load. In the carbon-fibre pavement specimen the forces are fed into the grid and absorbed by it. The asphalt layer thus experiences reduced stress.

8. Design concept for C-fibre reinforced asphalt pavements

The design software BISAR 3.0 gives a possible design concept for carbon-fibre reinforced asphalt pavement layers. In a first stage, a binder course measuring 12 cm in thickness and a wearing course of 4 cm in thickness were placed on an existing old base. The expansion is determined using the software under standard load conditions.

Asphalt layer	Thickness (cm)	Elasticity modulus (MPa)	Layer designation	Load number	Vertical load (kN)	Vertical stress (MPa)
1	4 cm	3000	New wearing course	1	20	0.577
2	12 cm	4000	New binder course	2	20	0.577
3	Old, existing base	1500	Existing base			

Expansion beneath wearing course (µ): **(Result of BISAR 3.0 software)**	**XX = 58.3** **YY = 33.9** **ZZ = 59.3**

Table 11: Design with BISAR 3.0 "without S&P Carbophalt grid"