Durable asphalt surfaces with high crack resistance

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For several years now pre-bituminised grids have been successfully used for increasing the durability of asphalt surfaces. The grids reduce fatigue cracks as well as thermal cracking in the bituminous pavement and, as a result, also minimise maintenance costs.

Carbon fibre grids additionally increase the structure value of the reinforced pavement layer. The carbon fibre grid has a structure value equal to that of an asphalt layer measuring 3 – 4 cm in thickness. This provides interesting rehabilitation options for inner-city areas. For example, an existing old pavement can be cut-milled to a depth of 3 cm and repaired with the carbon fibre grid as well as a new pavement layer of 3 cm. The structure value of the reinforced pavement layer corresponds to a 6 – 7 cm thick layer of non-reinforced asphalt. When milling to a depth of 3 cm the kerb and edge areas are not affected. Because the existing, old level is maintained after the repair job, shafts do not have to be raised to the new level. This makes the carbon fibre grid an interesting option with regard to costs. Moreover, the construction period is reduced and resources saved. At the materials research centre EMPA Dübendorf/CH, conventional grids were compared with the pre-bituminised S&P grids. The results of these comparisons are presented in this article.

Layer bonding of old and new pavement layer

In various European directives and road construction standards a layer bonding > 15kN (Leutner Ø 150 mm test-core) is required between the old and new pavement layers, a criterion which also applies to reinforced asphalt pavements. This value cannot be reached using the traditional non-woven intermediate layers. Conventional grids partially meet this criterion when laid in combination with a SAMI surface dressing (2 – 3 kg bitumen with 12 – 15 l hard chippings).

Bonding tests carried out on work performed demonstrate an interlayer shear bond of > 15 kN for pavement layers reinforced with S&P grids. EMPA/CH tests as well as many reference projects in practice show that with pre-bituminised S&P grids an additional SAMI surface dressing as intermediate layer is not required. S&P grids are stabilised to grid structures through the bitumen pre-coating for transport to the construction site. When unrolling the grid and during the laying of a new hot asphalt mixture the grid structure dissolves as a result of the high temperatures. The carbon- or glass fibre strands are movable in length and cross direction. Large particles of the asphalt mixture penetrate through the dissolved grid structure. During compacting of the new asphalt mix, the particles will make an intensive interlock with the old existing asphalt layer through the displacement of the fibre strands. The fibre strands that are also displaceable in lengthwise direction adjust to the uneven existing pavement layer. Thanks to the S&P technology “opening of junctions under the impact of heat“ the required layer bonding of the reinforced asphalt layer is attained.

Research at EMPA/CH at the four-point bending beam

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

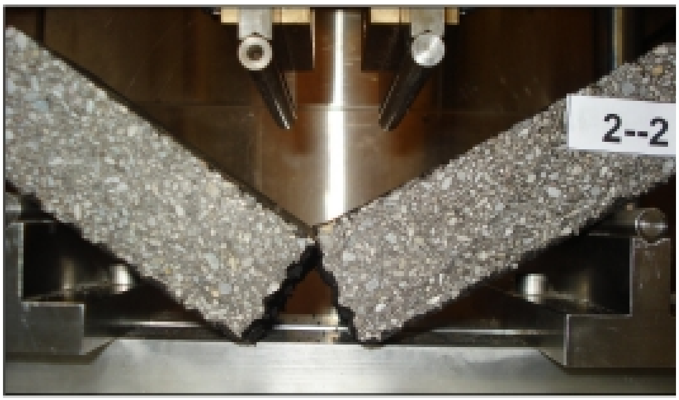

Photo 1: Reference sample without grid

Photo 2: Sample with S&P Carbophalt G 200 kN

Whereas in the asphalt layer without grid *(Photo 1)* a crack developed in the middle of the reference sample leading to a break, the C-fibre reinforced asphalt layer *(Photo 2)* showed optimal stress redistribution and crack distribution.

Impact of the carbon fibre grid

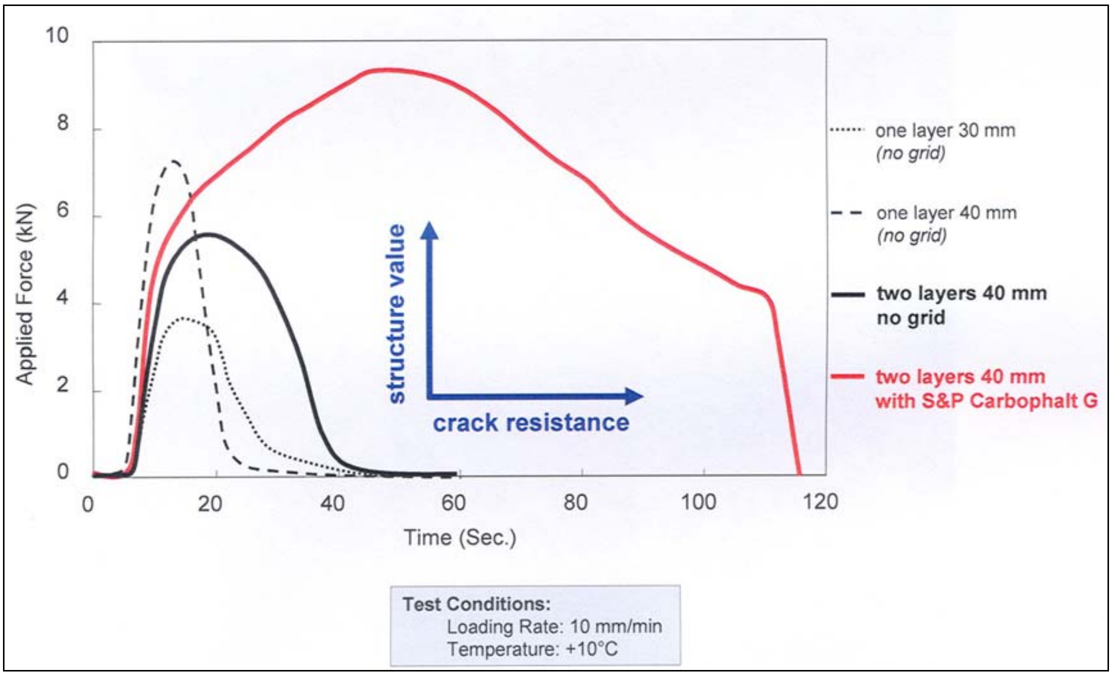

Chart 1

The rupture (structure value) as well as the crack resistance of the reinforced pavement layer is significantly increased through the carbon fibre grid *(Chart 1).*

Carbon fibre grid in comparison with other intermediate layers

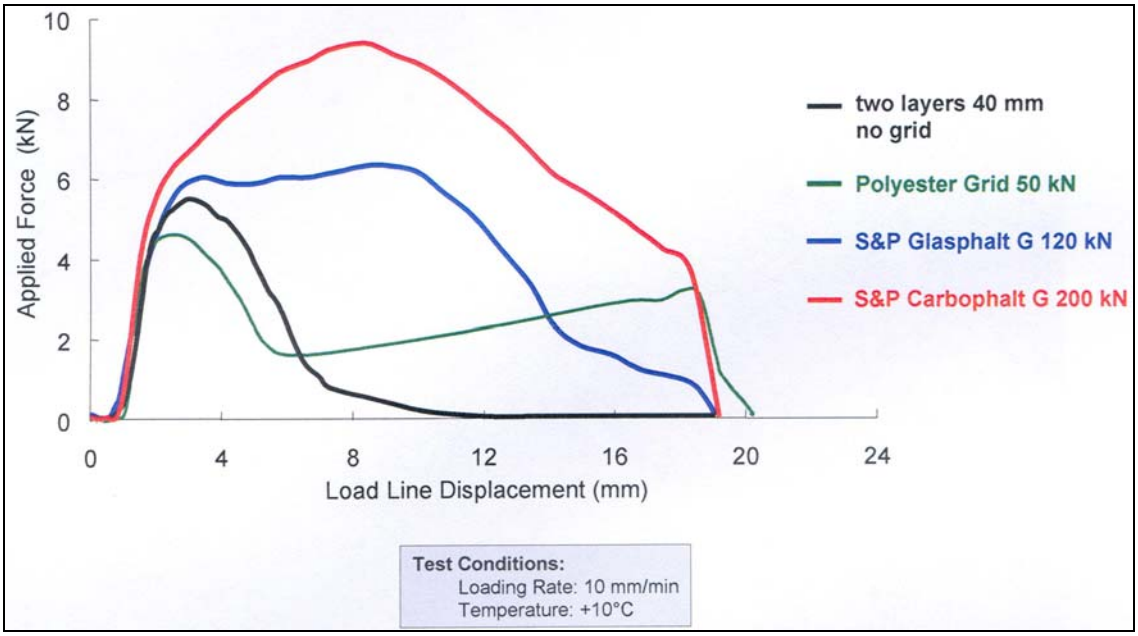

Chart 2

In the test a traditional polyester grid was compared with the pre-bituminised glass and carbon fibre grid.

The polyester grid with a tensile elasticity modulus of ~15 kN/mm² bends 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 layer. 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 *(Chart 2).*

Influence of the temperature (*Chart 3 / 4*)

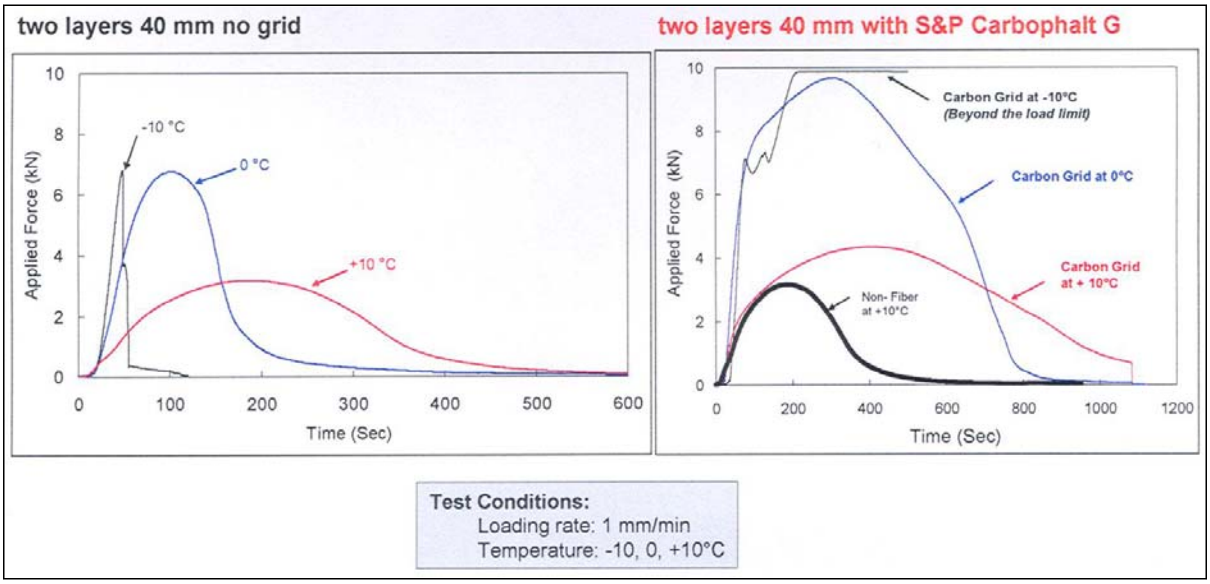

Chart 3 / 4

The test compared the influence of the temperature at -10.0°, 0° as well as at +10°C, on a non-reinforced layer and on a carbon-fibre reinforced asphalt layer.

The carbon fibre grid “S&P Carbophalt G“ increases crack resistance as well as the ultimate load in all temperature ranges, at -10º, 0° as well as at + 10º C *(Chart 3 / 4).*

Influence of the load

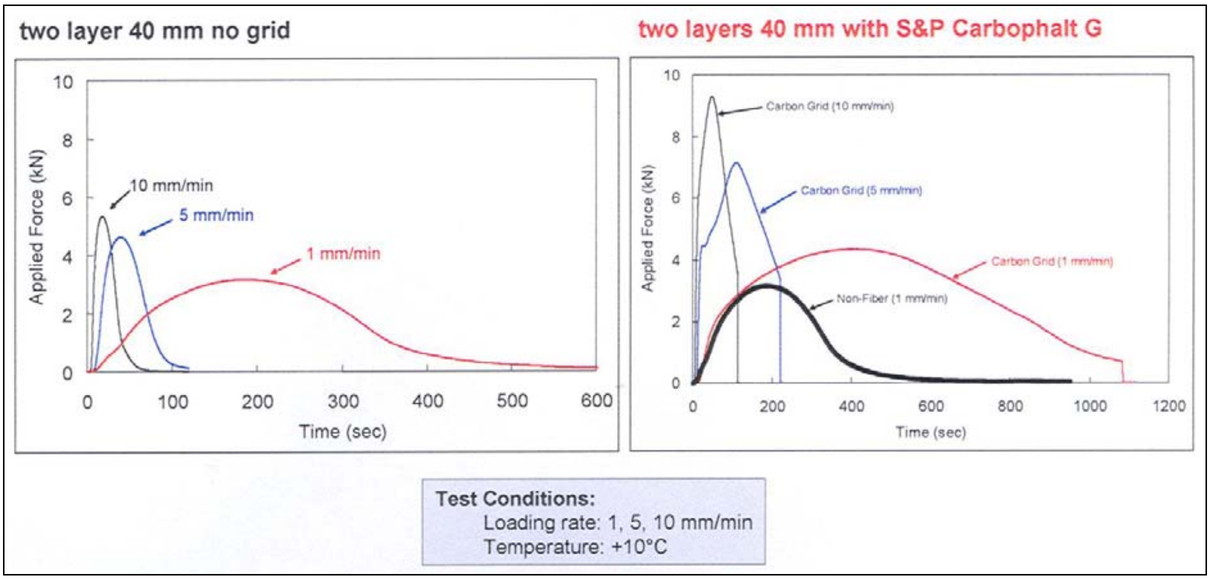

Chart 5 / 6

The test compared the influence of the load 1mm/min, 5 mm/min as well as 10mm/min on a non-reinforced asphalt layer and on a carbon-fibre reinforced asphalt pavement layer.

The carbon fibre grid “S&P Carbophalt G” increases the rupture and crack resistance in all load ranges, 1 mm/min, 5 mm/min as well as 10 mm/min *(Chart 5 / 6).*

Dynamic cyclic load under effective wheel load

At the EMPA/CH research centre two-layer carbon-fibre reinforced and non-reinforced pavements were compared under cyclic loading *(Chart 7).* 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 inside the rutting device.

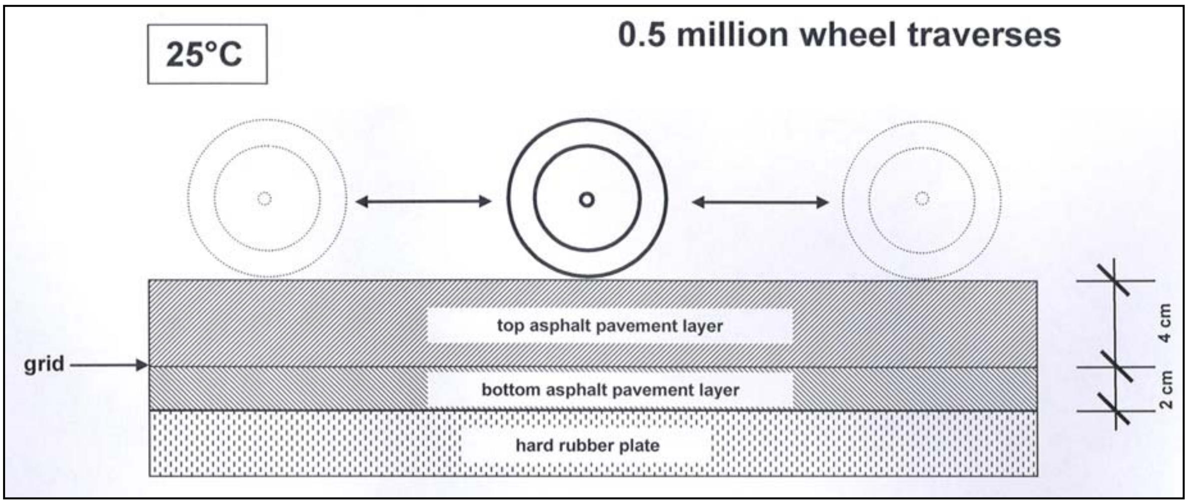

Chart 7

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)

The test specimens were fitted with strain gauges on the bottom in longitudinal and transverse directions. 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 33 % as a result of the carbon fibre grid.

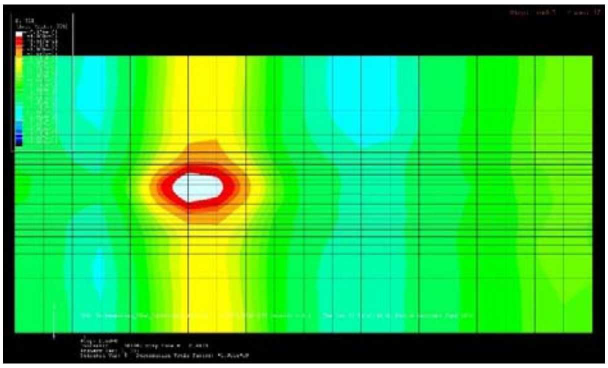

Figure 3: without carbon fibre grid

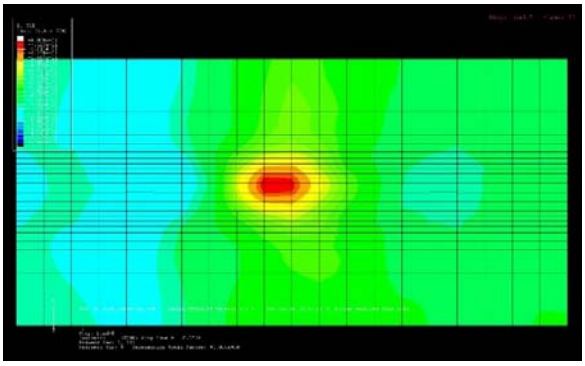

Figure 4: with carbon fibre grid

Fig. 3 and Fig. 4 show the compressive stress (blue areas) in front of and behind the wheel load, when being rolled over, as well as the tensile forces (red, orange and yellow area) 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.

Dimensioning concept

The dimensioning software BISAR 3.0 presents 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 thickness were placed on an existing old base.

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 sub-base	1500	Existing base			

Table 1: Dimensioning with BISAR 3.0 "without S&P Carbophalt grid"

Expansion beneath wearing course (µ): XX = 58,3
(BISAR 3.0) YY = 33,9
ZZ = 59,3

In a second stage the carbon fibre grid was placed underneath the wearing course. Thanks to the carbon fibre grid the strength (modulus of elasticity) of the 4-cm thick upper layer as well as the 4-cm thick bottom layer is increased by approx. 30 %.

Asphalt layer	Thickness (cm)	Elasticity modulus (MPa)	Layer designation	Load number	Vertical load (kN)	Vertical stress (MPa)
1	4 cm	4000 (+ 25 – 30 %)	New wearing course (+ 30 % strength)	1	20	0.577
2	4 cm	5000 (+ 25 – 30 %)	New binder layer (+ 30 % strength)	2	20	0.577
2 a	8 cm	4000 (no influence)	New binder layer (no influence of the asphalt reinforcement)	2	20	0.577
3	Old, existing sub-base	1500	Existing sub-base			

Table 2: Dimensioning with BISAR 3.0 "with S&P Carbophalt grid"

Expansion beneath wearing course (µ): XX = 47,4 (- 19 %)
(BISAR 3.0) YY = 28,1 (- 17 %)
ZZ = 39,5 (- 34%)

The results determined using the BISAR 3.0 software show a reduction in expansion of 19% to 34%. The results verify the tests carried out by EMPA. A simple dimensioning for carbon-fibre reinforced asphalt pavement layers is thus possible using the BISAR 3.0 software.

Summary

The pre-bituminised carbon-fibre reinforcement reduces expansion and thus reduces stress in the asphalt layer by approx. 30 %. Carbon fibre grids as well as glass-fibre grids are used to reduce cracks in the asphalt layer. Both reinforcement grids increase durability. The carbon fibre grid additionally improves the structure value.

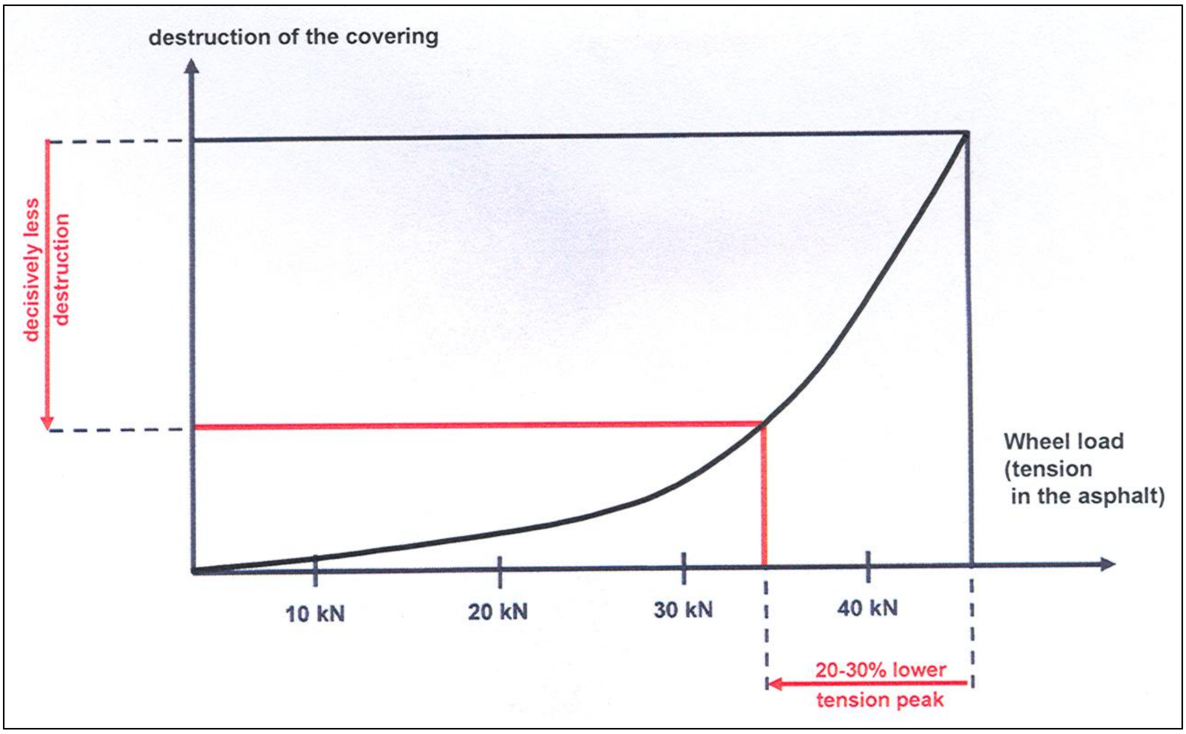

Chart 8: Influence of the wheel load on the destruction of the covering

Chart 8 shows that the destruction of the bituminous pavement layer increases as a function of the wheel load. The carbon fibre grid reduces stress peaks caused by high wheel loads that act on the asphalt pavement layer. The destruction of the pavement is thus substantially reduced. This is expressed in higher durability, prolonged replacement cycles as well as reduced maintenance work. Thanks to less congestion there are also economic benefits. Taking all aspects into account, the cost advantages of reinforced asphalt pavement layers are significant.