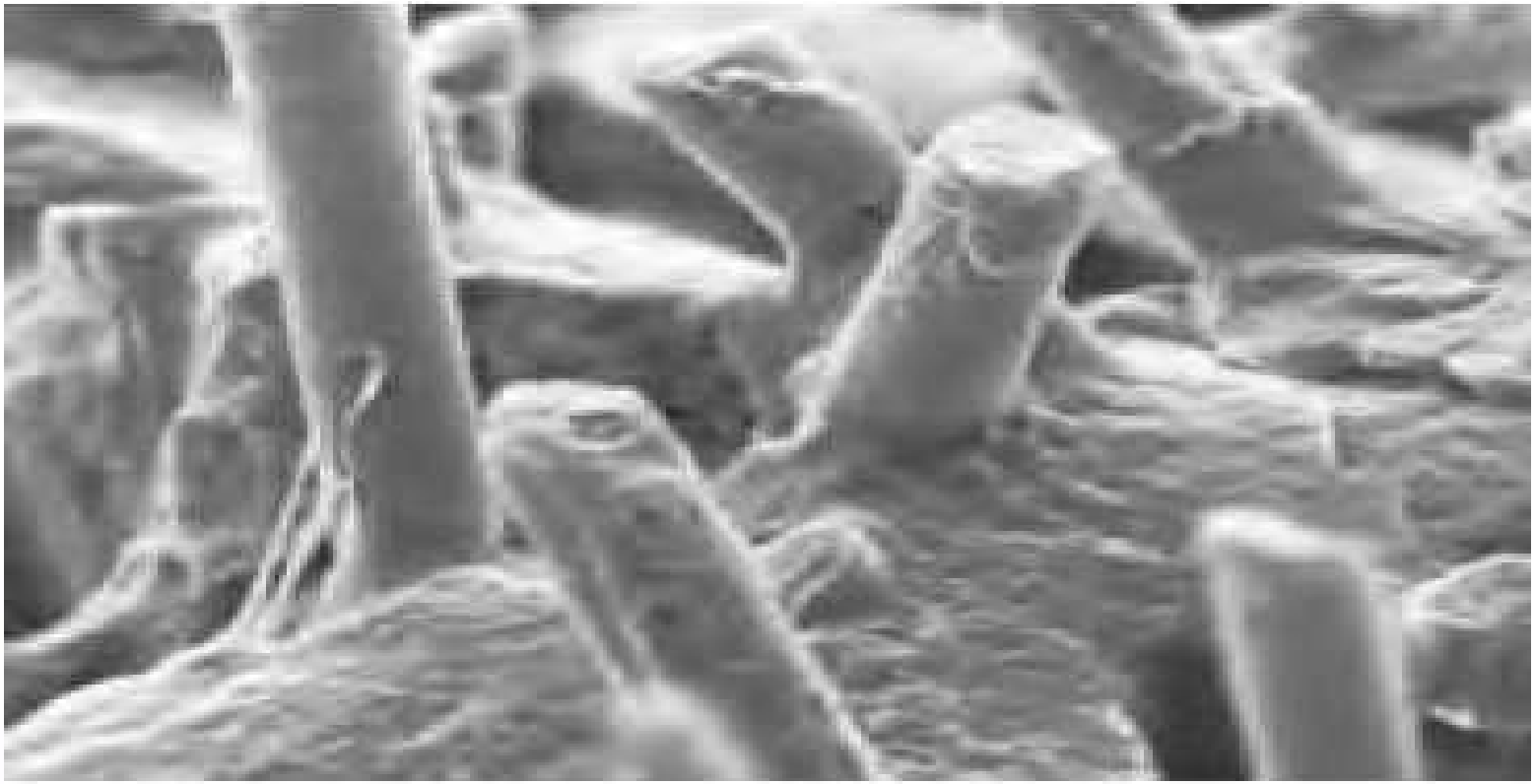
Synergic effect of fibers



Synergy of fibers and matrix

- Models of composites most for simplicity assume that all the fibers in the composite have exactly the same properties.
- To find out what is the influence of scattering properties of individual fibers, it is necessary to considerably challenging statistical calculation.
- Instead, we will only deal with a simplified model case.

Simplified case
Only six fibers – without integration

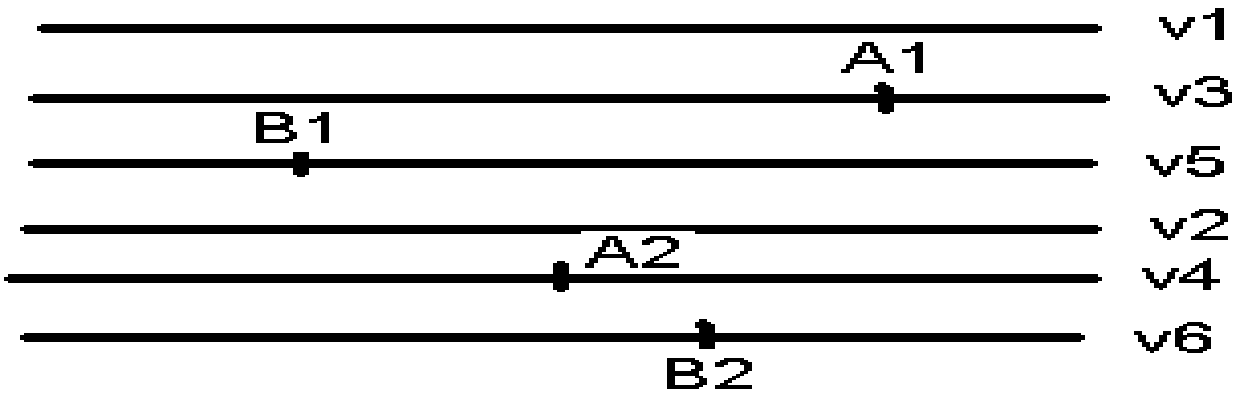
Six parallel, continuous fibers with a cross section S and maximal tensile strength R

Fibers v1 and v2 are the perfect tensile strength R

Fibers v3 and v4 are at A1 or A2 weakened, so there are only 90% of the strength, namely 0.9 R

Fibers v5 and v6 are at B1 or B2 severely weakened, so there are only 60% strength, namely 0,6 R

Possible arrangement of fibers



Points A1, A2, B1, B2 are not below

Individual fibers

If the load is on each individual fiber, it is possible to calculate the average strength

$R_v = (2*R+2*0,9*R+2*0,6*R)/ 6$

$= 0.83*R$

The average tensile strength of individual fibers is 0.83 R

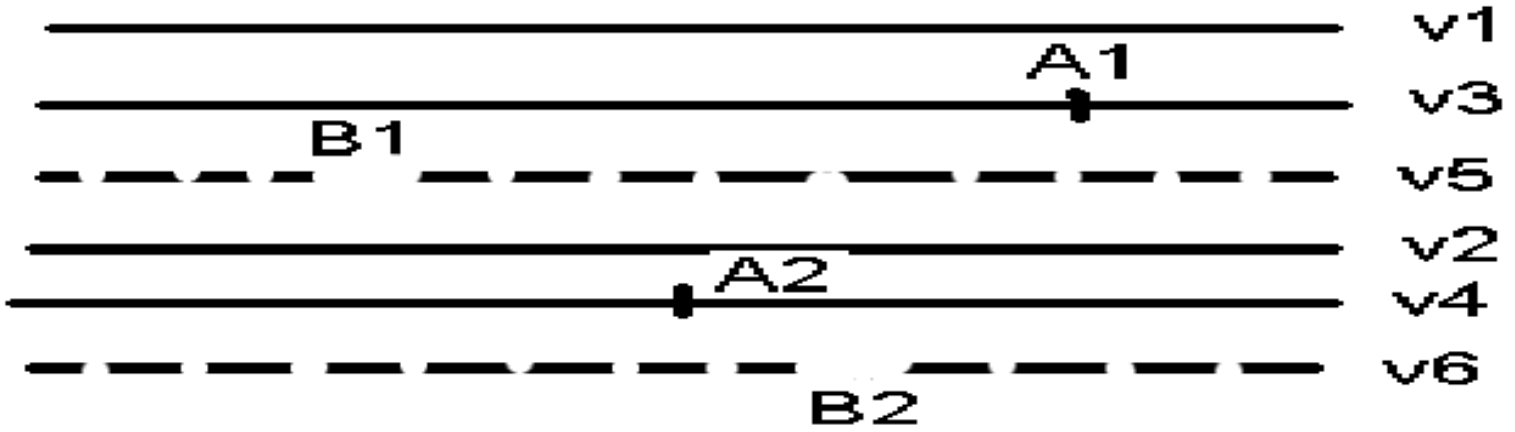
Strength of fiber bundle 1

Assemble the fibers of the bundle (rope)

the total cross-section 6 * S.

By growth load on the beam to 3.6 * S * R will be tension in the fibers of 3.6 * S * R / (6 * S) = 0.6 * R.

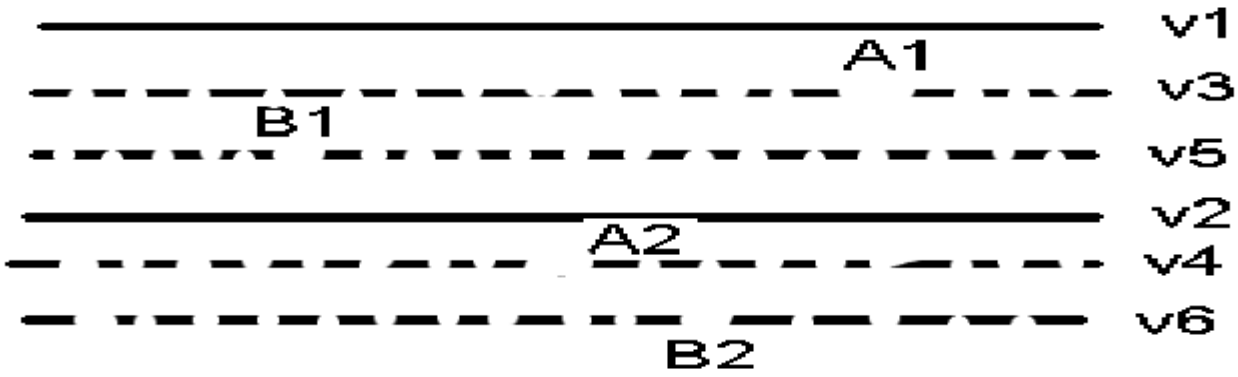
Fibers break in points B1 and B2



The load is redistributed to the remaining four fibers, in them stress will be (3.6 * S * R) / (4 * S) = 0.9 * R.

Strength of fiber bundle 2

Now are two more break points in the fiber A1 and A2



In the remaining two fibers will be stress (3.6 * S * R) / (2 * S) = 1.8 * R

Strength of fiber bundle 3

So now break the remaining fibers and is broken all beam.

Tensile strength of bundle (rope) of these fibers

will therefore be

$$R_l = 0.6 * R$$

- Lower than the average strength of the fibers.

Consequence of damage of the weakest fiber in bundle is damage of the whole bundle

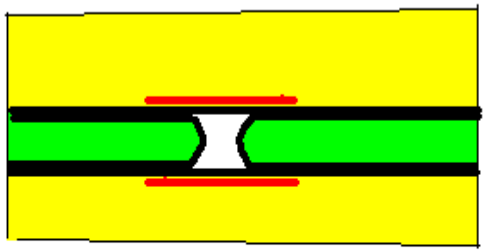
Fiber in composite

Green ...broken fiber

Yellow ... matrix

In place of break of fiber matrix transmits the load from one end of the fiber to the other.

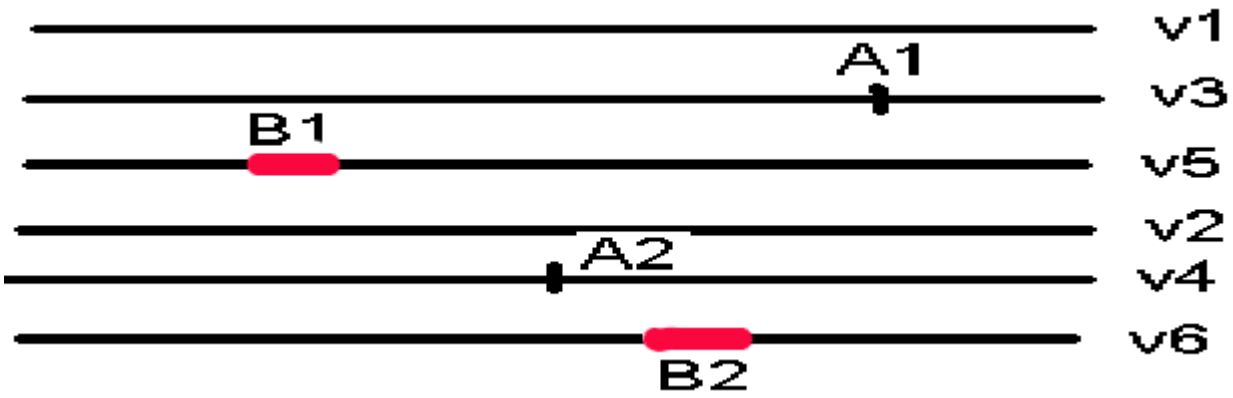
Except red area transmits the broken fiber further load.



Strength of composite 1

With increasing loads on the composite
to 3.6 * R * S is the stress in the fibers 0.6 * R

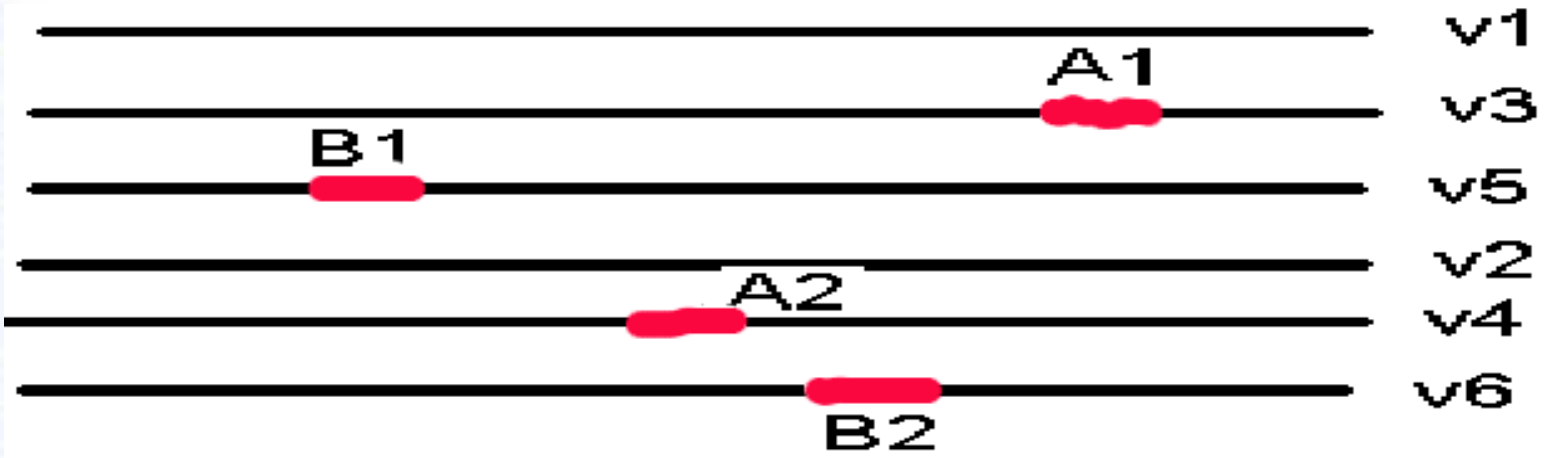
Fibers break in points B1 and B2



In each of the points B1 and B2 transmits load still remaining five fibers, thus there increases tension in the fibers to (3.6 * S * R) / (5 * S), it is 0.72 by R. No fiber thus further cracked

Strength of composite 2

The next increase of load up to 5,4 * S * R will increase tension in the fibers at points A1 and A2 to (5.4 * S * R) / (6 * S) = 0.9 * R and the fibers break at these points.



Strength of composite 3

On the remaining fibers increases in critical areas A1, A2, B1, B2 stress to
(5.4 * S * R) / (5 * S) = 1.08 R
and occurs fibers break in any of these places.

Tensile strength of the composite fibers is thus

$$\mathbf{R_k = (5,4 * S * R) / 6 = 0,9 * R}$$

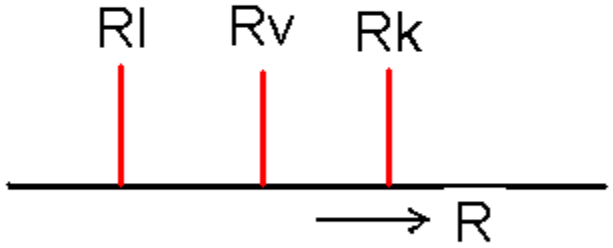
Tensile strength of the composite is therefore larger than the average strength of the individual fibers

Comparison of tensile strength

In the picture is a comparison of tensile strength of fiber, fiber bundle (rope) and composite.

As a result of the synergic effect is always the biggest strength of the composite.

These differences are greater, the greater the dispersion properties of fibers



Numeric calculation of synergic efect by fiber composite

Results of accurate statistical calculation.
Dependence on relative error of fibers tensile strength.

Relative error [%]	20	10	6	1
R_k / R_v	5,9	2,7	1,9	1,1
R_l / R_v	0,56	0,58	0,59	0,72

Overall conclusion

- Use of fiber in the composite is advantageous because the mean tensile strength of the composite is greater than the mean tensile strength of fibers themselves.
- This difference is yet more important, the greater the dispersion of sterngth of individual fibers.
- In the composite is therefore suitable even lower quality fiber with large dispersion characteristics