Ultimate strength of composite

Strength of fiber composites - generally

Basic models are developed for tensile strength of fibre composite (1D fiber composites in the main direction).

Other loading cases required further consideration.

In the plane of isotropy is not very different tensile and compressive strength , in the main direction can differ very strongly.

Perpendicular tensile strength

Is given by the matrix properties and adhesion to the fibers.

General expression

$$R_{ku}^{90} = R_{mu} * (1/S)$$

S is the strength reduction factor,
 S> 1

To determine S using different analytical or empirical relationships.

Theoretical procedure

Using theoretical estimate for the maximum transverse deformation of the composite

$\varepsilon_{ku}^{90} = \varepsilon_{mu} * (1 – (4v_d/\pi)^{1/2} * (1\text{-}E_m/E_d))$

For brittle fracture is valid until break Hooke's law :

$$R_{ku}^{90} = \varepsilon_{ku}^{90} / E_k^{90}$$

Furthermore by break of matrix

$$\varepsilon_{mu} = R_{mu} / E_m$$

The result will be

$$\mathbf{R_{ku}^{90} = R_{mu} *}$$

$$\mathbf{(E_k^{90}/E_m) * (1 – (4v_d/\pi)^{1/2} * \quad (1\text{-}E_m/E_d)}$$

(purple is the coefficient of 1 / S).

Empirical procedure

Using empirical estimate for the maximum transverse deformation of the composite

$$\varepsilon_{ku}^{90} = \varepsilon_{mu} * (1 - v_d^{1/3})$$

For brittle fracture $R_{ku}^{90} = \varepsilon_{ku}^{90} / E_k^{90}$

Furthermore $\varepsilon_{mu} = R_{mu} / E_m$

The result will then be

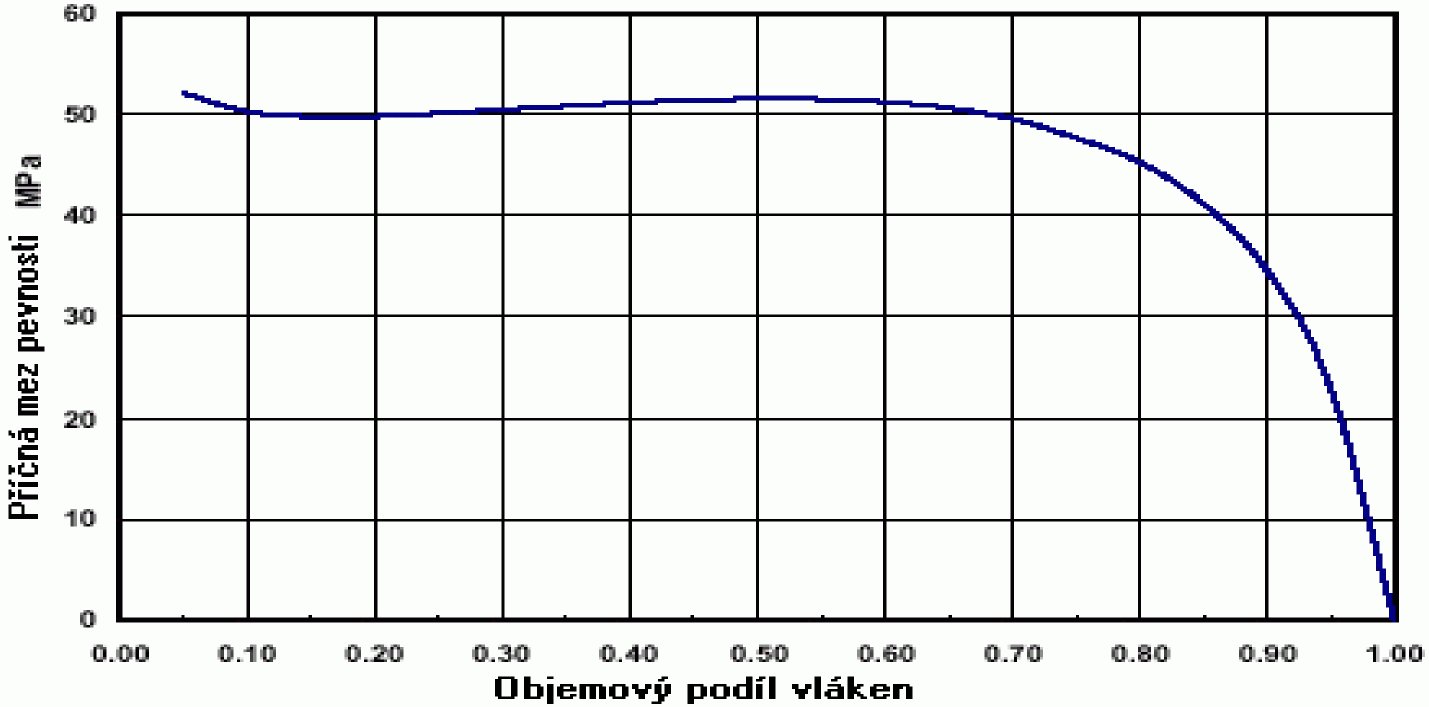
$$\mathbf{R_{ku}^{90} = R_{mu} * (E_k^{90}/E_m) * (1 - v_d^{1/3})}$$

(purple again factor 1 / S)

In both cases it is necessary to calculate E_k^{90} use a transverse model of composite.

This applies in both estimates $1/S \leq \mathbf{E_k^{90}/E_m}$

Sample of dependency on the amount of fiber



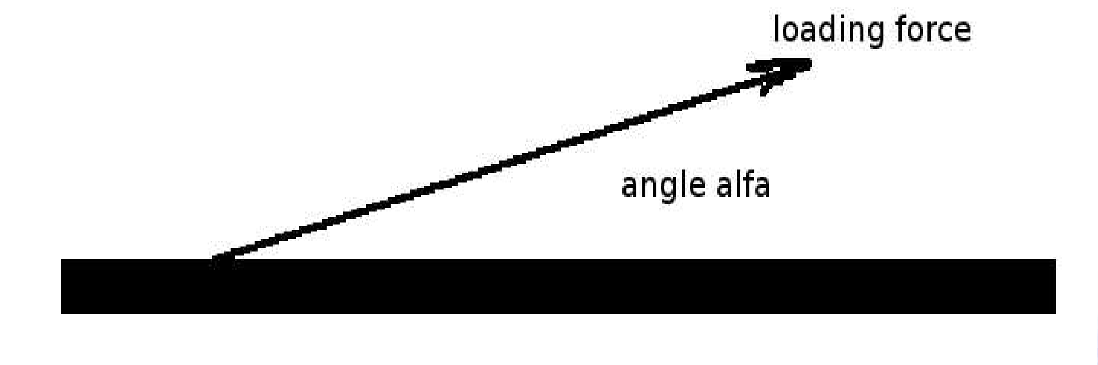
Transversal tensile strength of composite
epoy / glass fiber. Tensile strength of epoxy 80 MPa.

Tensile in a different direction

Denote the angle between the direction of fiber and tension α.

The applied tensile force F can be decomposed into components in the fiber direction $F_v = F * \cos α$ and perpendicular to the fiber direction $F_k = F * \sin α$.

Break of this composite will decide which of these components stress prevails.



Little angle

For small deviations from the direction of the fibers (approximately 4 degrees) occurs due to the longitudinal component loading in the fiber direction - that is, to break the fibers.

Force component in the direction of the fiber

$$F_v = F * \cos \alpha.$$

The fibers are skewed to the direction the applied force, cross-section S, the force which will operate will thus be larger than the perpendicular cross-section fibers S_v , therefore

$$S_v = S / \cos \alpha.$$

Tensile strength

Stress in the fibers

$$F_v / S_v = (F / S) * \cos 2\alpha.$$

In the fibers will thus be less stress than by power exactly in the direction of the fibers and the fibers break later. For the tensile strength of composite

$$R_{ku} = R_{ku0} / \cos 2\alpha$$

R_{ku}, R_{ku0} ... tensile strength in direction with small angle, tensile strength in main direction.

Great angle

For large deviations (above approximately 45 degrees) is a break due to the load component perpendicular to the fiber direction, namely the separation matrix from fibers.

Force component perpendicular to the fibers is

$$F_k = F * \sin \alpha.$$

The fibers are skewed in the opposite direction to the applied force, cross-section S, the force which will operate will thus be larger than the cross section perpendicular S_k,

$$S_k = S / \sin \alpha.$$

Tensile strength

The stress in the matrix will therefore be

$$F_k / S_k = (F / S) * \sin 2\alpha.$$

The matrix will thus be less stress than by the force perpendicular to the fibers and the matrix breaks off later. The tensile strength of composites therefore í

$$\mathbf{R_{ku} = R_{ku}^{90} / \sin^2\alpha}$$

Middle angle

The middle value of the angle between the fibers and the load can not override or tension in the fibers or perpendicular tension in the matrix and shear violation occurs at the interface between fibers and matrix. A similar, but more complex procedure it is possible to derive a relationship

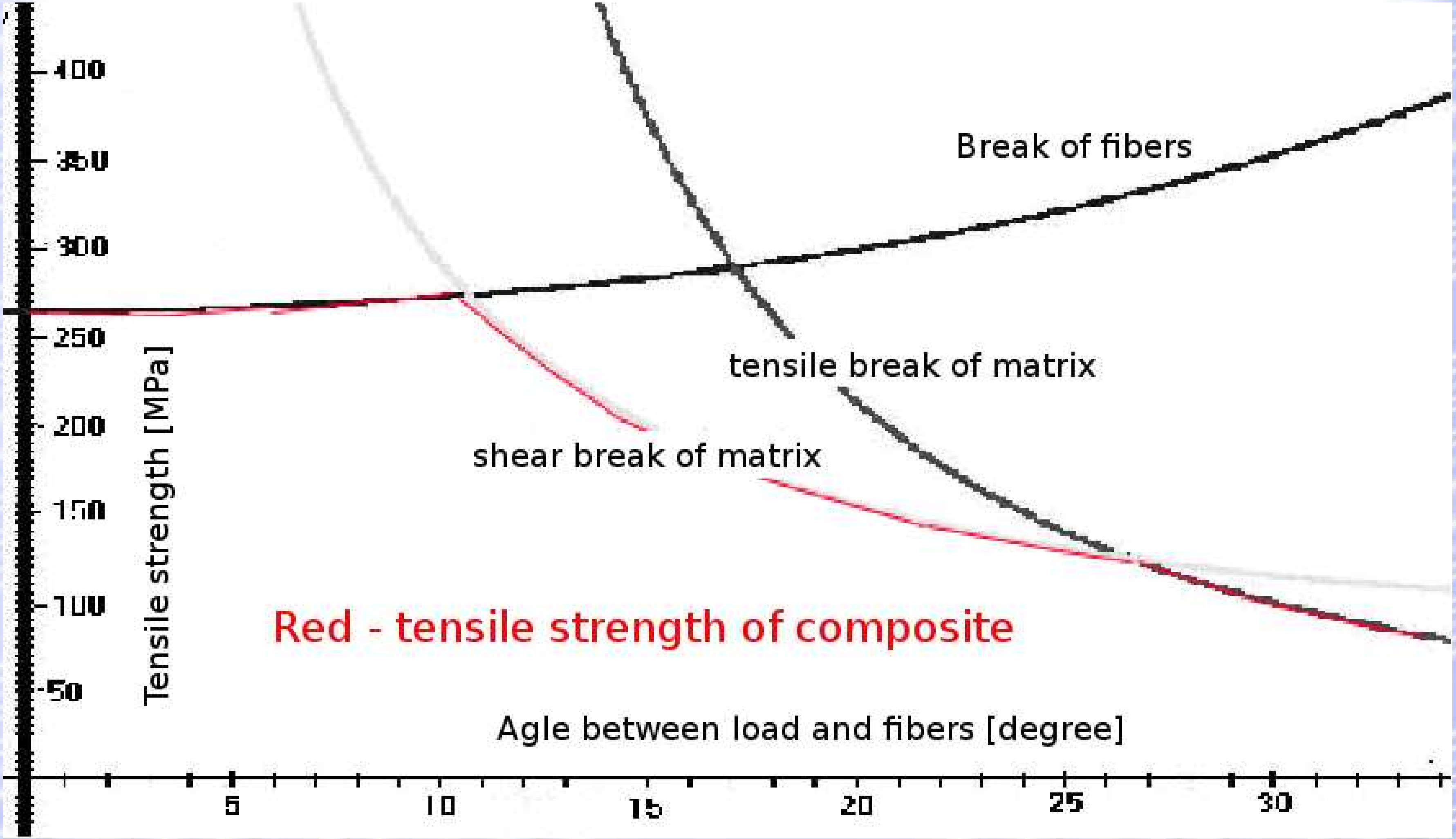
$$\mathbf{R_{ku} = R_{mtu} / \sin 2\alpha}$$

(R_{mtu} is the ultimate shear strength of the matrix)

Actual fracture mechanism

- For the specific case of composite and its load inclined tensile force is necessary to calculate all three possible casest of break of the composite , actual fracture is always the lowest.
- The example shows the following picture. Red in it plotted tensile strength of composites depending on the angle of loading.

Tensile strength (epoxy with kevlar fibers)



Longitudinal compressive load

- As already pointed out, the fibers are characterized by their negligible flexural stiffness, in compression thus have a tendency to warp fibers.
- For pressure load of fiber composite in the direction of fiber compressivee strength is always less than the tensile strength and depends on how accurately the fiber curl.

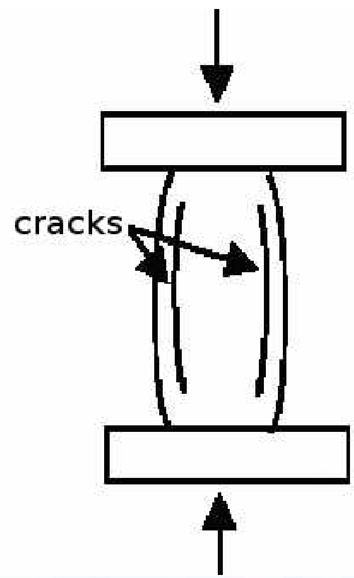
Options of fibre ripple

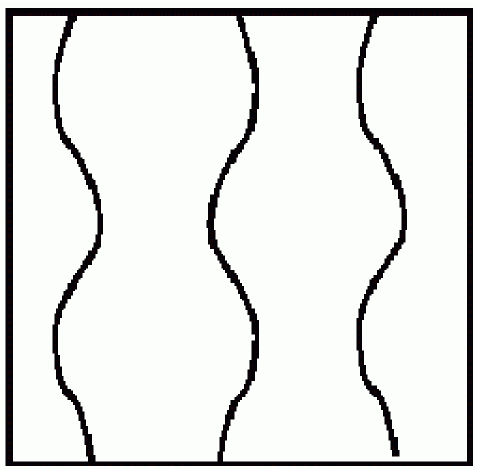
Short samples and a large number of fibers

- Buckling with longitudinal cracks

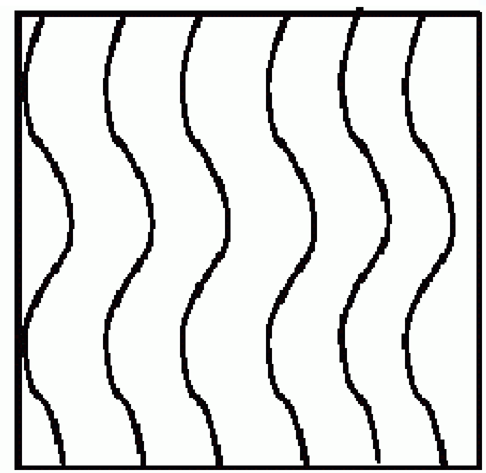
A small number of fibers opposite phase microbuckling

Larger quantities of fibers – same phase microbuckling





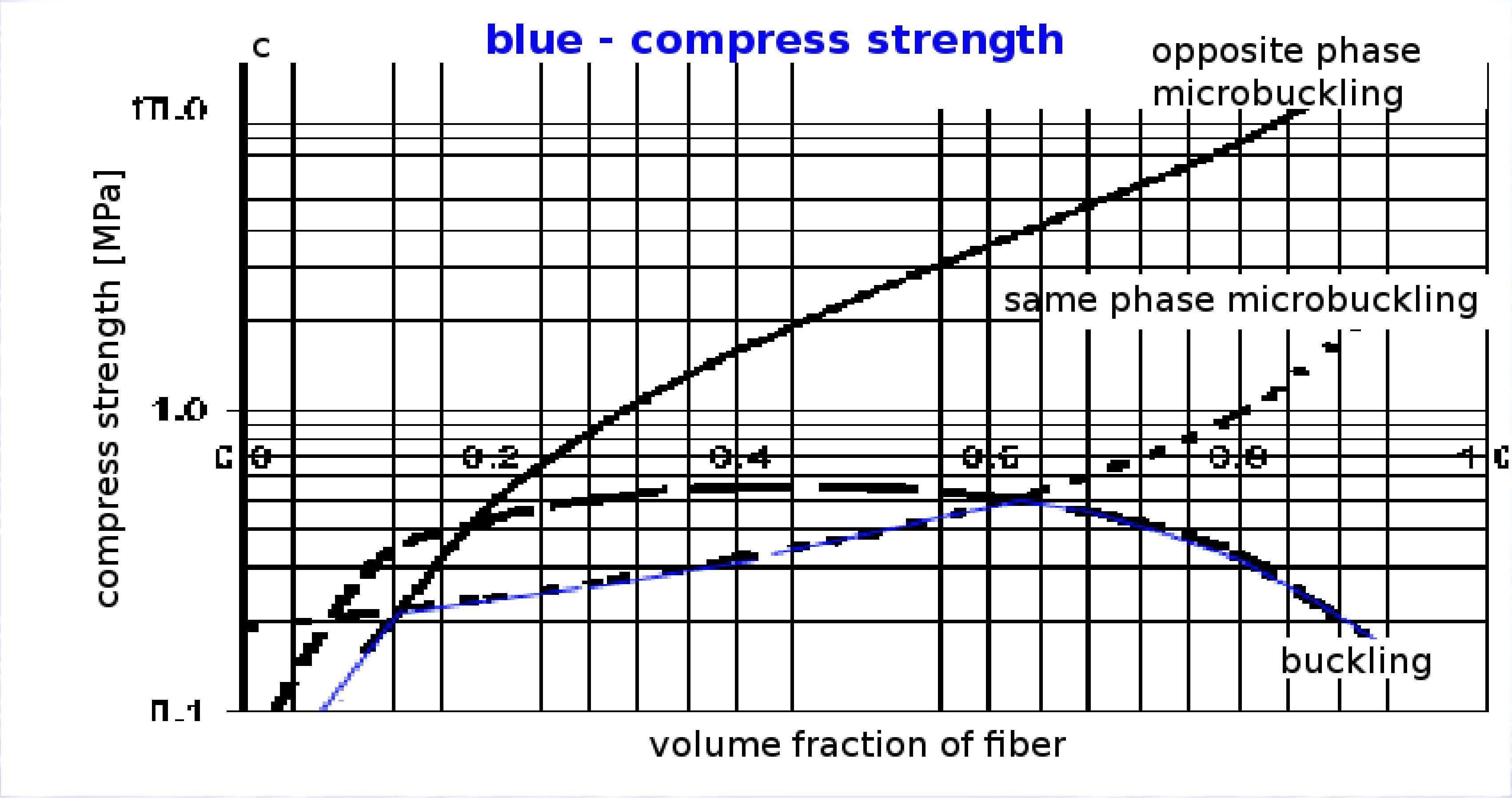
opposite phase microbuckling



same phase microbuckling

Longitudinal compress strength for a typical case

Most often – same phase microbuckling



Same phase microbuckling

In most cases that possibility.

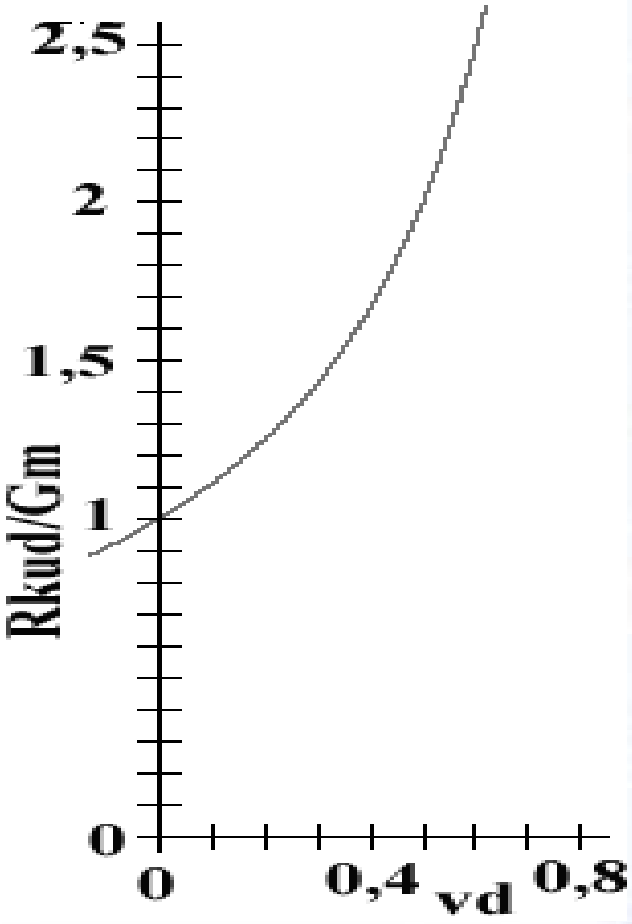
The basic formula for compress strength R_{kud} is determined primarily by the matrix shear modulus G_m and the amount of fiber v_d

$$\mathbf{R_{kud} = G_m / (1 - v_d)}$$

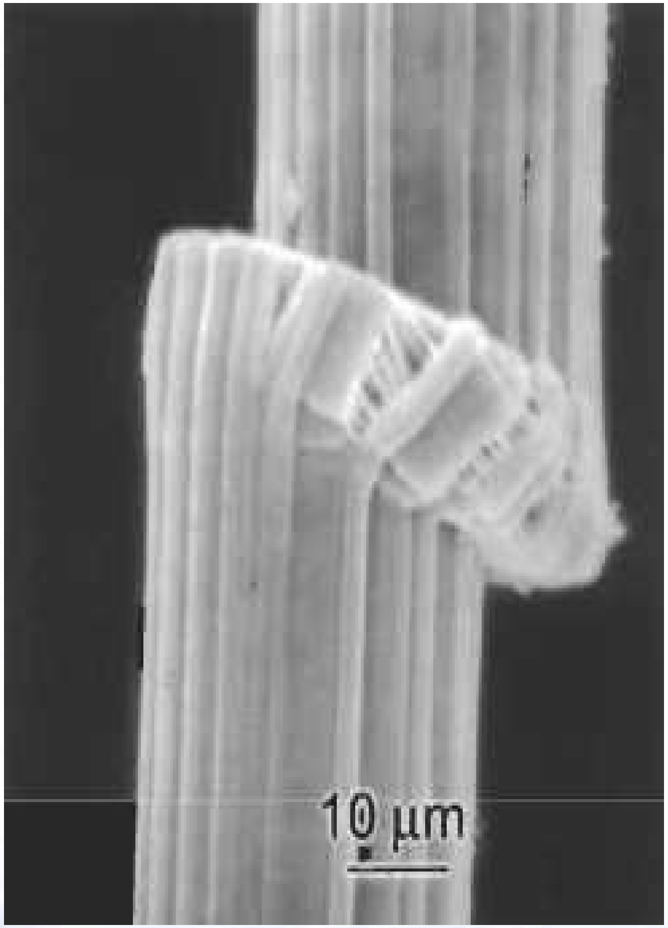
- Can be adjusted to

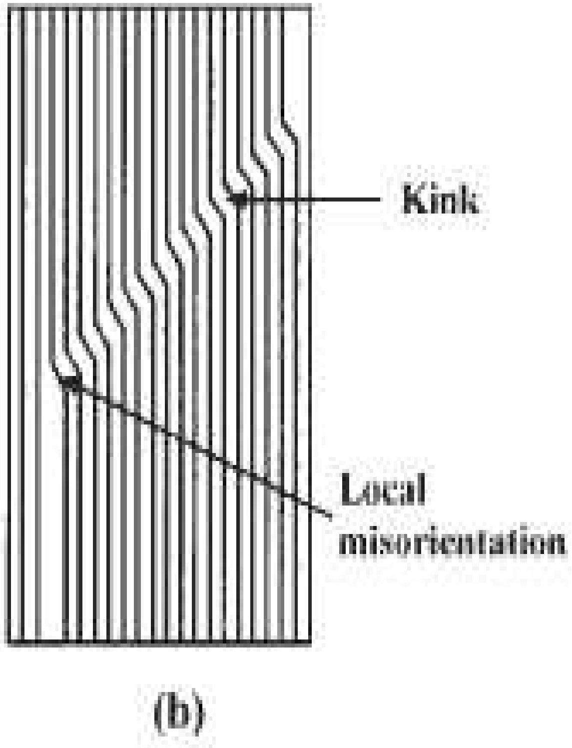
$$\mathbf{R_{kud} / G_m = 1 / (1 - v_d)}$$

- This relationship is on the chart alongside.



Kink of fibres
(by carbon fibres)





Can lower longitunal compress strength

Transversal compress strength

It is approximately equal to the transverse tensile strength - in the transverse direction is a working diagram of the composite symmetrical.

Even Young's modulus in the transverse direction is approximately the same for tension and pressure.