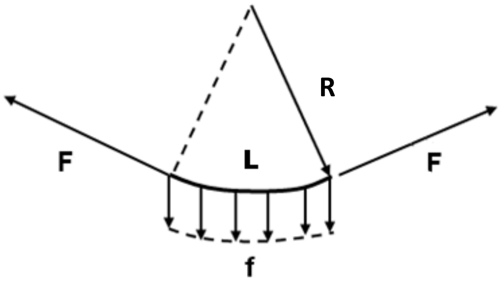
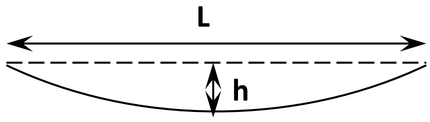
## THE ‘SUSPENSION BRIDGE EFFECT‘

The distributed load **f** of a ‘Suspension Bridge’ (structure + vehicles) is carried by the tension **F** of the curved suspension cables with curvature **K** or radius **R = 1/K**:




**$F = f*R = f/K$**

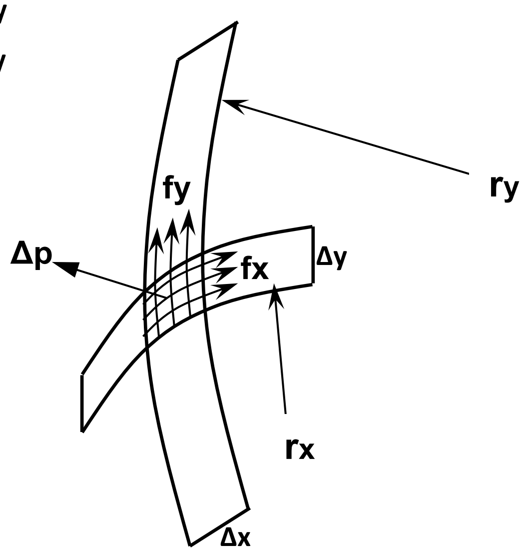


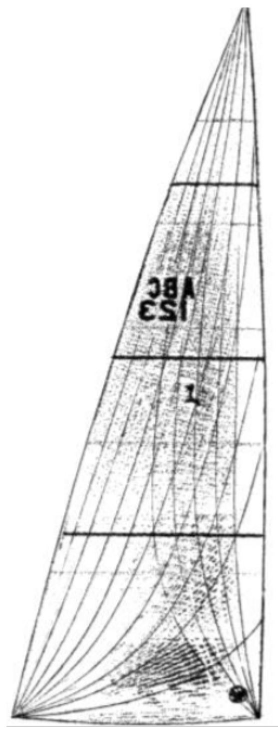

This rather general ‘Suspension Model’ may also be applied to varying loads **f(x)** and varying curvature **K(x).**
And the suspension cable may also be a strip of sail cloth of width **Δy,** carrying a pressure differential **Δp** between the windward and the leeward sides of the sail panel.
The sail pressure differential **Δp** is then carried by the cloth tension **f** and the sail profile curvature **k=1/r:**

$$f = \Delta p * r = \Delta p / k$$

A two-dimensional curvature **kx, ky** and cloth tension **fx, fy** may be accounted for, by a model of two crossing cloth strips in x- and y-direction:

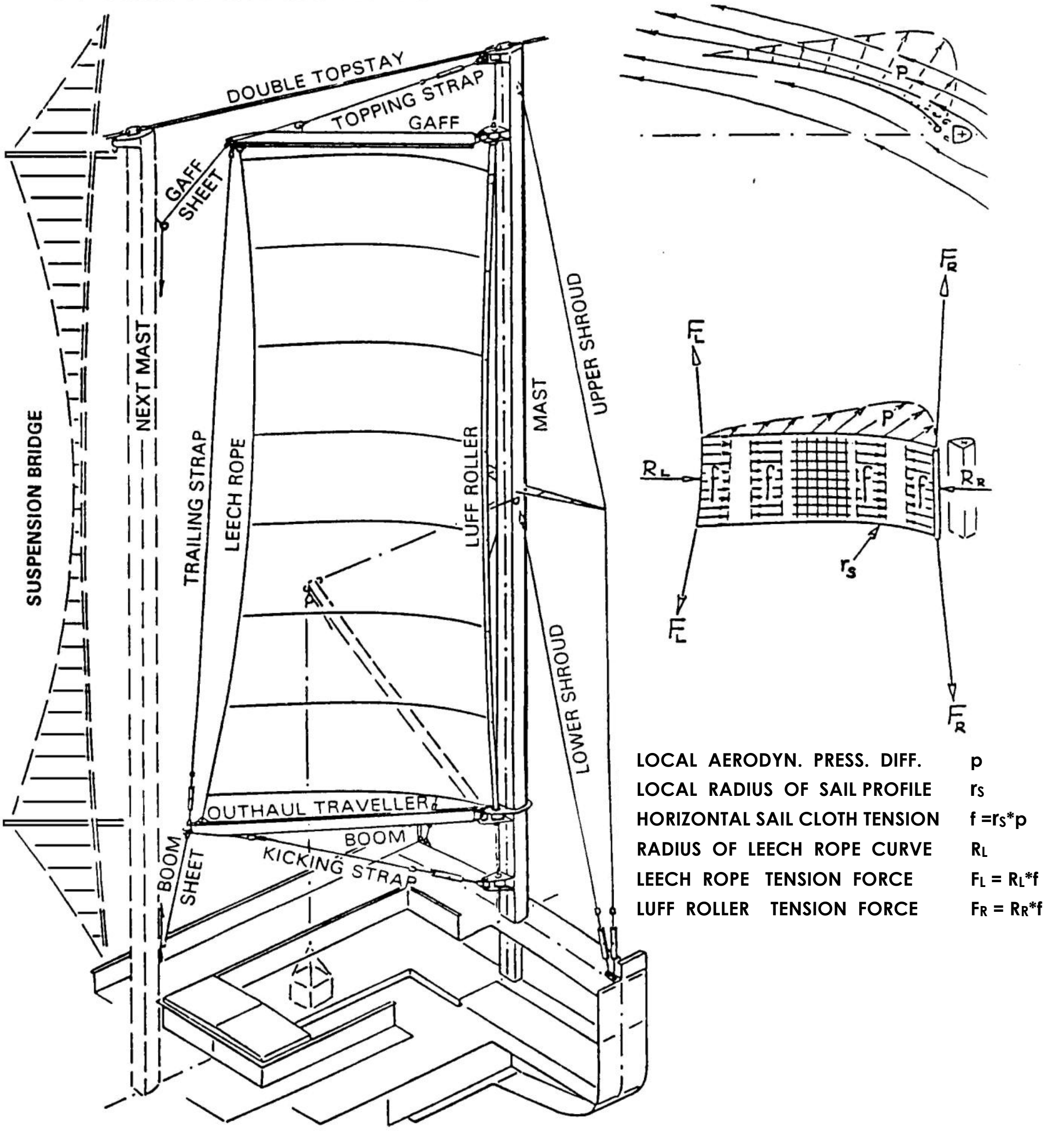
$$\Delta p = fx*kx + fy*ky$$
$$= fx/rx + fy/ry$$



**Conventional Fore-and-Aft Sails**
While the horizontal curvature & tension are controlling the profile of sails, the vertical tension and curvature control the twist of fore&aft sails.
Since twist control is particularly important for fully shaped battened and gaff sails, the necessary vertical control tension can be 5-10 times as high as the horizontal tension for profile control.
As a consequence, such sails require extremely high vertical tensile strength and stiffness of the sail fabric (provided by laminated, taped and composite sail cloth) and the sheeting gear.

INDOSAIL UTILITY SAILING RIG




CONCEPT OF THE "SUSPENSION SAIL"

**‘Suspension Sails’**

By separating the functions of horizontal profile control and vertical twist control, the sail cloth carries only the horizontal tension along the sail profiles, while the huge vertical control forces are carried by strong vertical (luff and) leech ropes.

The leech rope in the hollow-cut roach of the leech seam of the sail cloth carries the horizontal cloth tension by the suspension effect, analogous to the cable of a suspension bridge.

The tensile strength- and stiffness-requirements of the sail cloth (and of the sheeting gear) are thus significantly reduced (to ~20%) by the separation of the control functions.

Consequently, Suspension sails may be made of conventional woven sailcloth.

**Numerical Example**

A single 'Suspension Sail' of the INDOSAIL type

| | | | |
|---|---|---|---|
| Chord length | **$c = 8$ m** | chord camber radius | **$r = c/(8\ h/c) = 8$ m** |
| Chord camber | **$h = 1$ m** | chord camber curvature | **$k = 1/r = 0{,}125$ 1/m** |
| Leech length | **$L = 20$ m** | leech roach radius | **$R = L/(8H/L) = 62{,}5$ m** |
| Leech roach | **$H = 0{,}8$m** | leech roach curvature | **$K = 1/R = 0{,}016$ 1/m** |
| Sail area | **$As = L*c = 160$ m²** | | |

Apparent wind velocity **$Ua = 8$ m/s (~Bft 4)** sail pressure coefficient **$Cp = 1{,}5$**

Sail pressure differential **$\Delta p = \frac{1}{2}\ \rho\ Ua^2\ Cp = 60\ N/m^2$**

Starting from the average sail pressure differential **$\Delta p$** (between pressure- and suction-side) we can calculate a cascade of structural loadings of the rig:

Horizontal sail cloth tension:

$$\mathbf{f = \Delta p*r = \Delta p*c/(8\ h/c)} = \Delta p*8m/(8*\ 1/8) = 60\ N/m^2\ *8m = \mathbf{480\ N/m}$$

Vertical leech rope tension:

$$\mathbf{F = f\ *R = f\ *L/(8\ H/L) = \Delta p*c*L\ /(8\ h/\ c\ *8\ H/L) = \Delta p*As\ /(64\ *h/c\ *H/L)}$$

$$= 480\ N/m\ *20m\ /(8\ *0{,}8/20) = 30\ 000\ N = \mathbf{30\ kN}$$