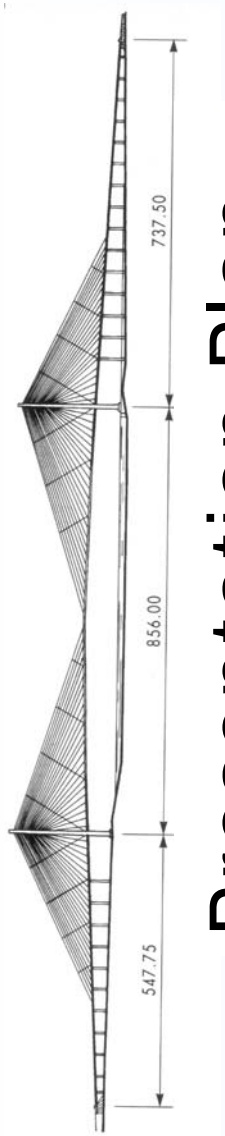
Various surface processing of cables against RWIV

Olivier FLAMAND – CSTB – Nantes - FRANCE



Presentation Plan

1 Introduction

prevention against RWIV + drag reduction

2 Surface indentation : the Japanese way

how the surface indented cables for the Tatara bridge were designed

3 Spiraled wires

how the helical rib sheath for the Normandie bridge was designed

4 Following studies

how the helical rib sheath was improved for bigger diameter

5 Recent development

what should we do now

6 Conclusion

Cable stayed bridges : Ever longer spans

1986 :

1995 :

1999 :

2007 :

2008 : Sutong 1088 m

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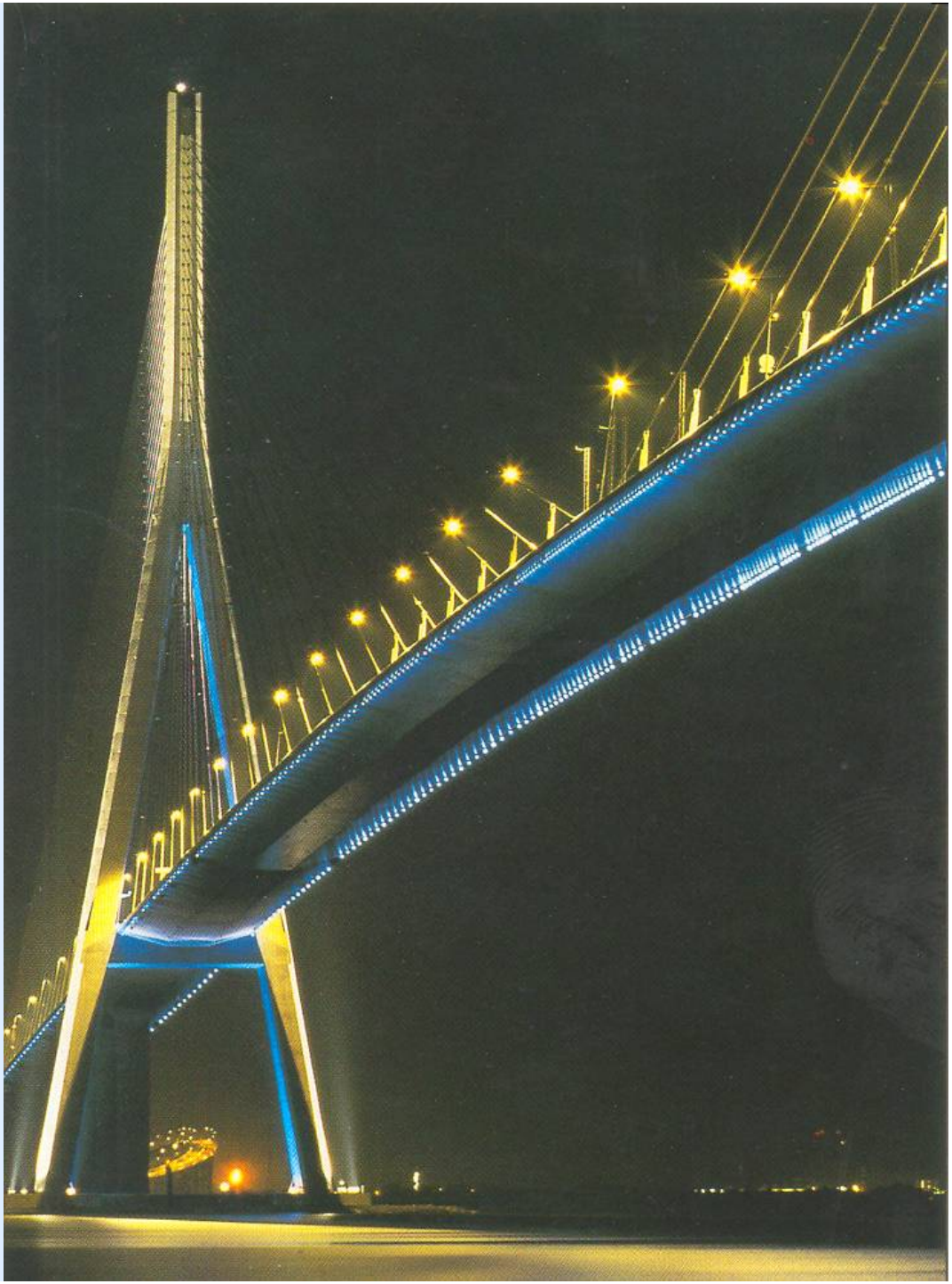
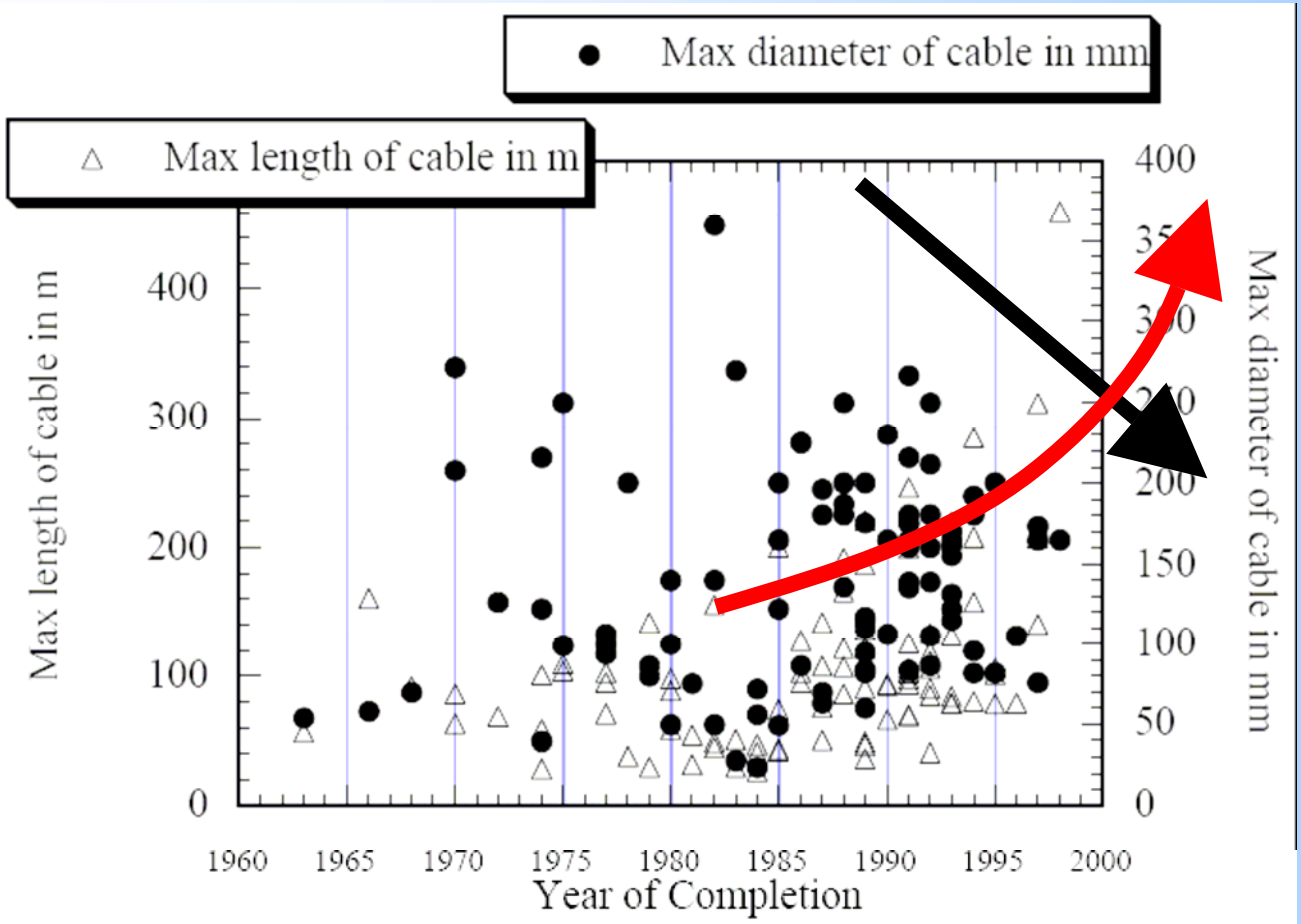
Even if these bridges are « cable stayed »

The stays are generally not highlighted

Low technical content ?



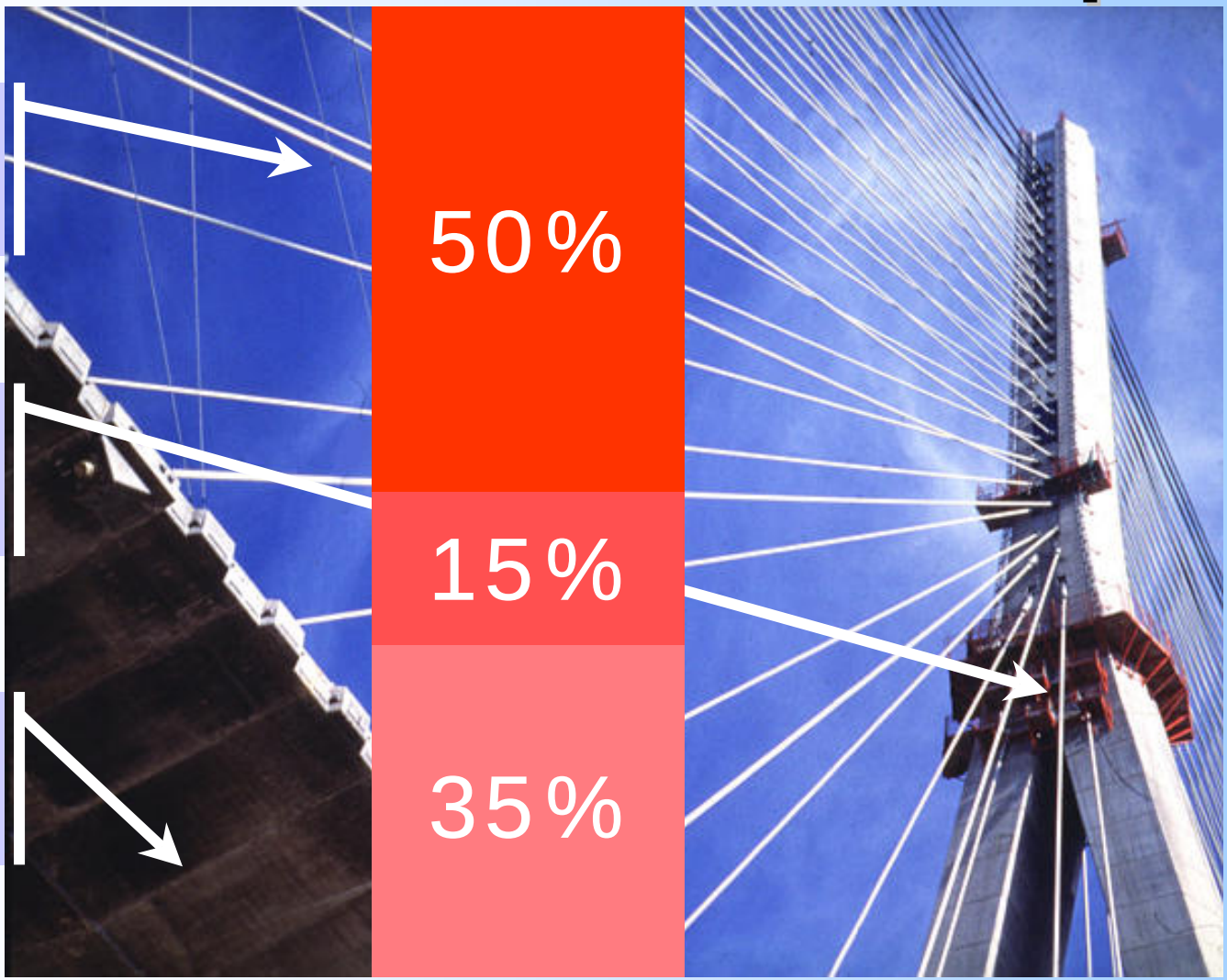
When length of cables increases, their excitability increases too.



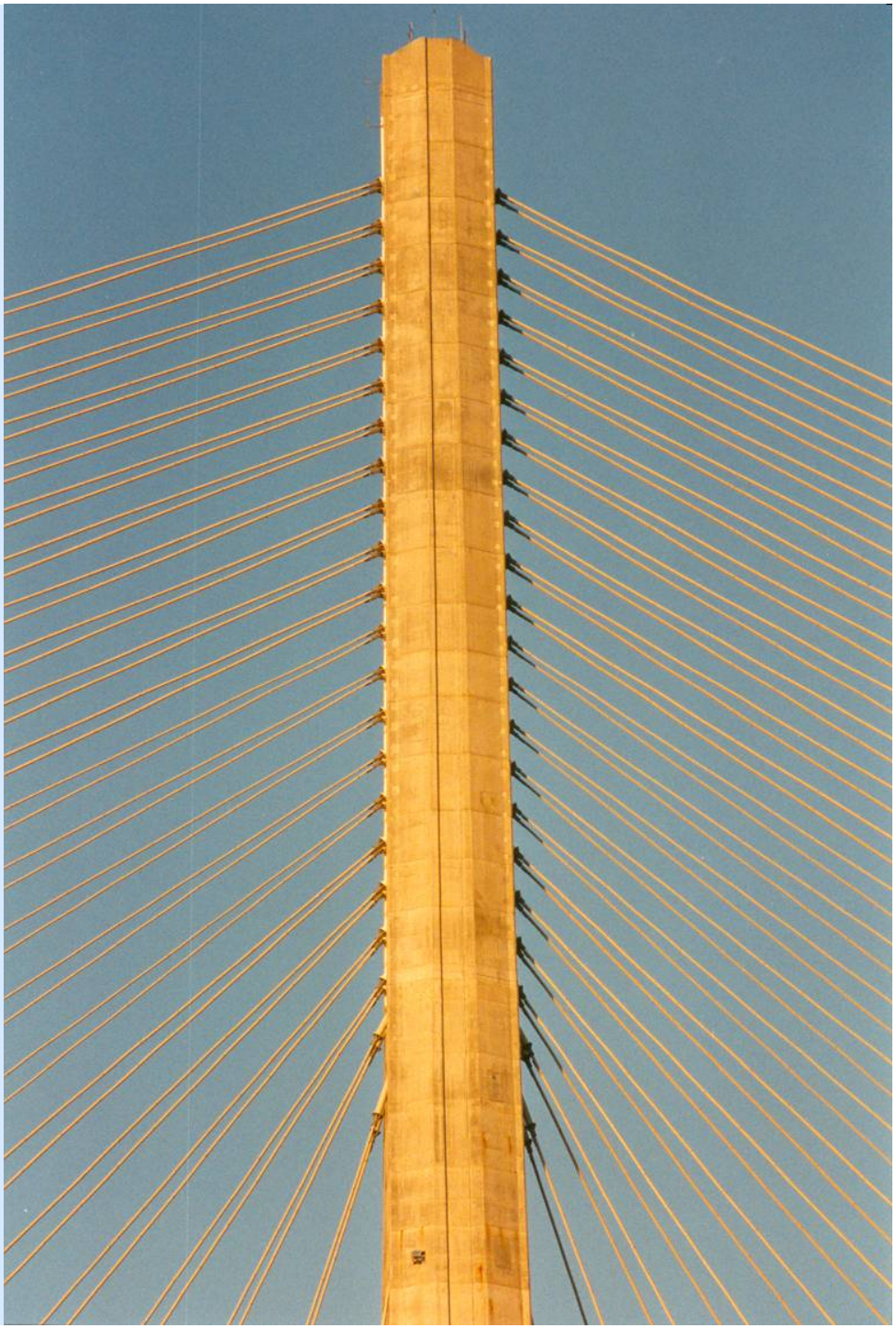
Because frequencies and damping are lower

A survey on japanese bridges, after Yamada

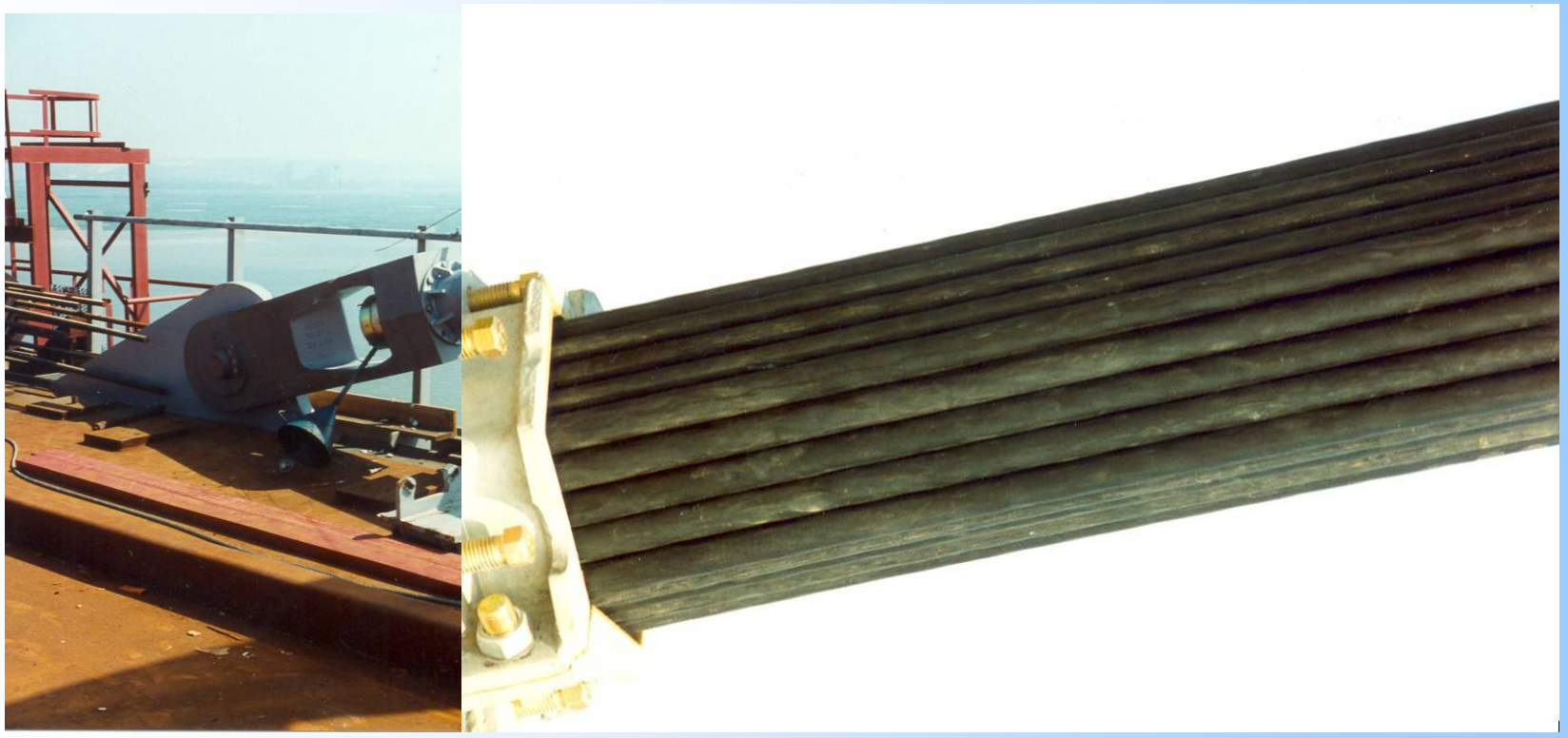
The balance of drag force for a 900m span



Therefore reducing the drag on stays becomes one major concern for very large cable stayed bridges



When designing the cable system, one can act on size and shape



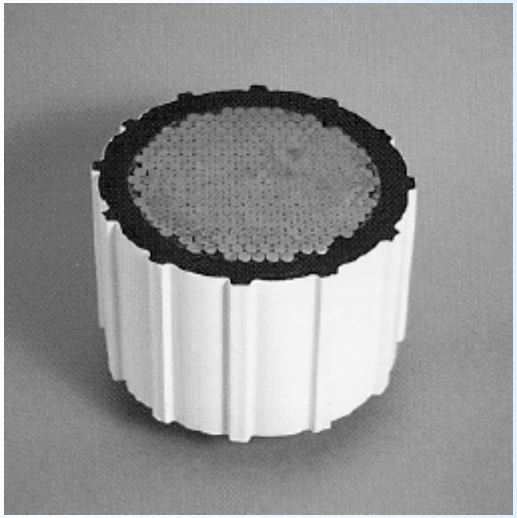
Why does the best shape, from the aerodynamic point of view, usually be the circular cylinder ?

Because it is symmetrical :

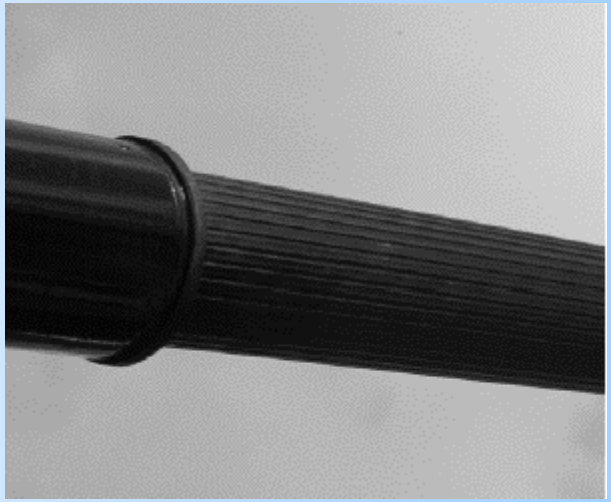
Smaller risk of galloping

No drag force change with wind direction

The first sheathing improvements that were proposed against RWIV increased the drag forces



Higashi-Kobe bridge



Yuge bridge

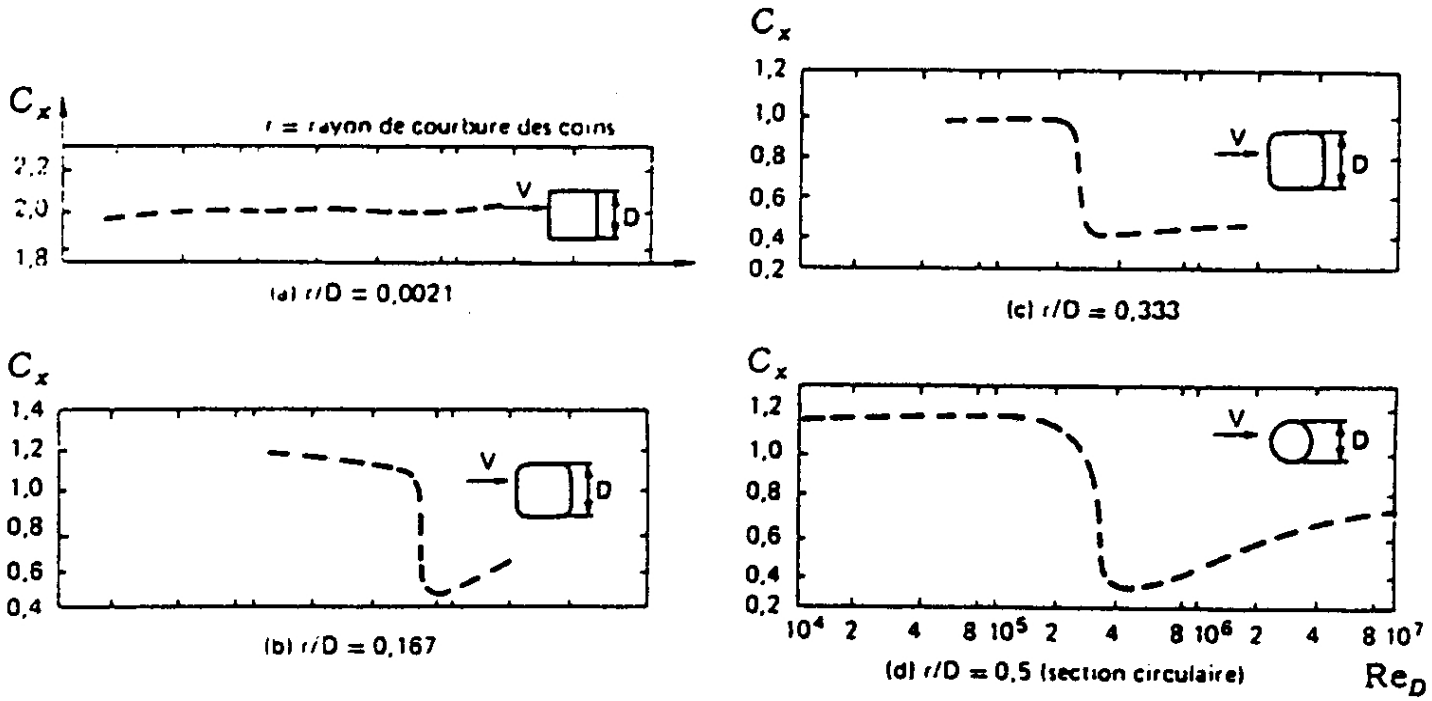
Surface indentation : the Japanese way

The initial idea came from aerodynamicists :

- The shark-skin principle : reducing the forces by a surface processing

- The drag force crisis on circular cylinders can be attained with lower wind speed

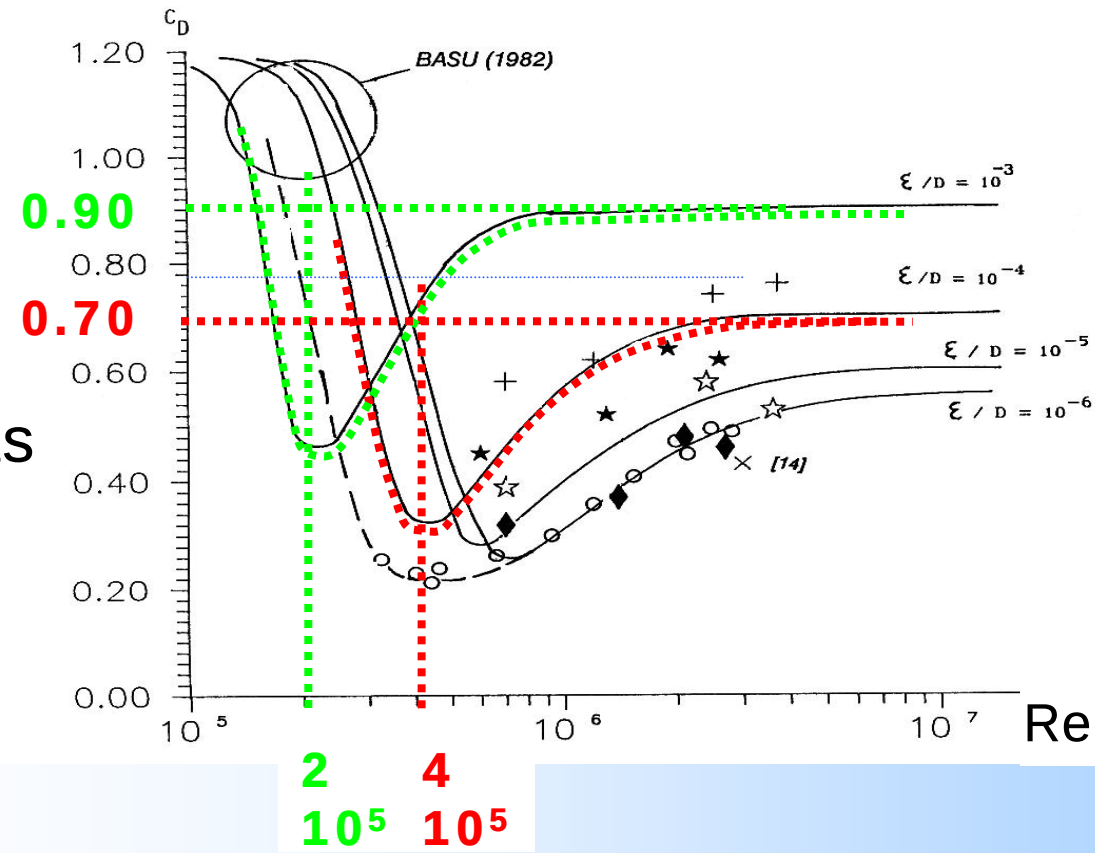
Drag crisis is well documented for cylinders and other shapes



After FAGE A. and WARSAP J.H. - 1930

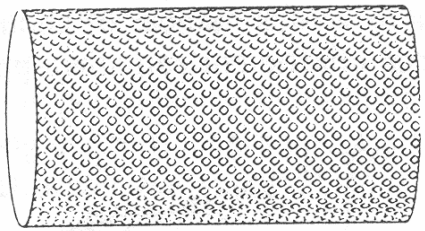
Drag crisis for cylinders depends on the roughness of the surface

But the drag force increases too

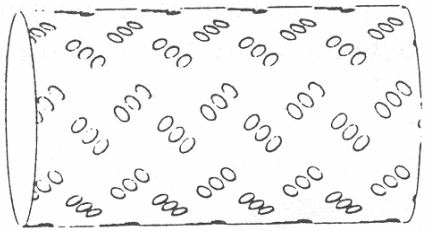


Increasing the roughness, one can trigger the occurrence of supercritical Cd at lower wind speed

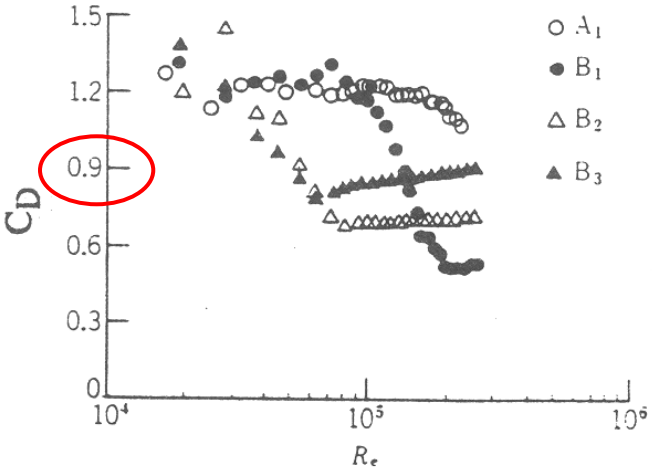
Increasing uniformly the roughness of the surface increases too much the value of supercritical Cd

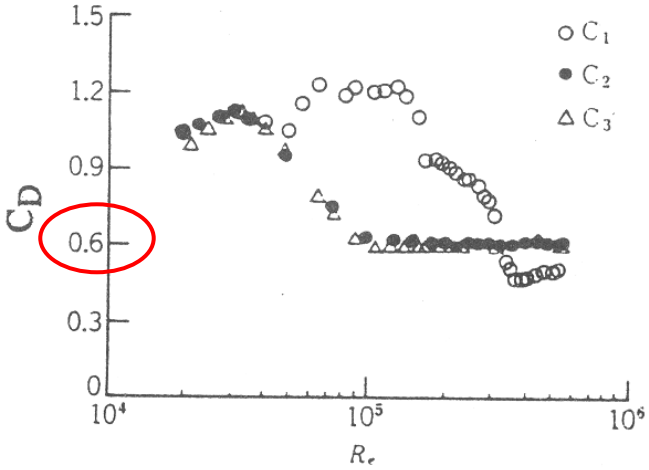


B_3 Model 1.2 mm



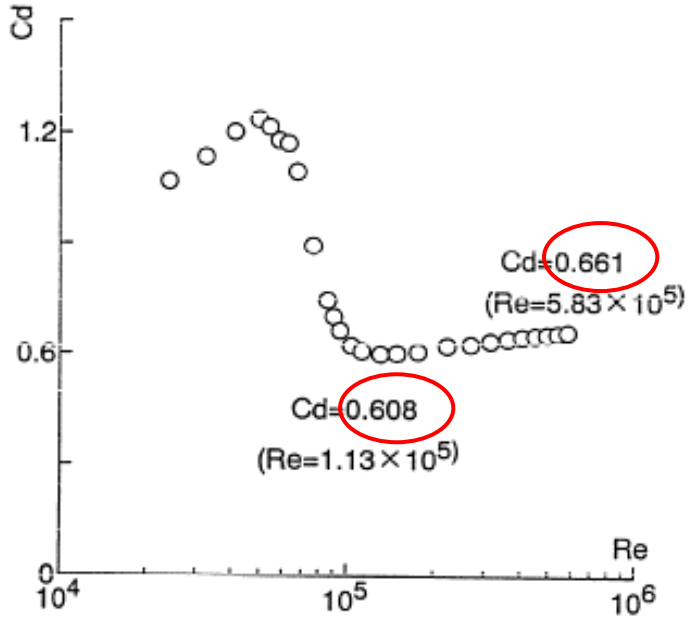
C_2 Model 1.5 mm

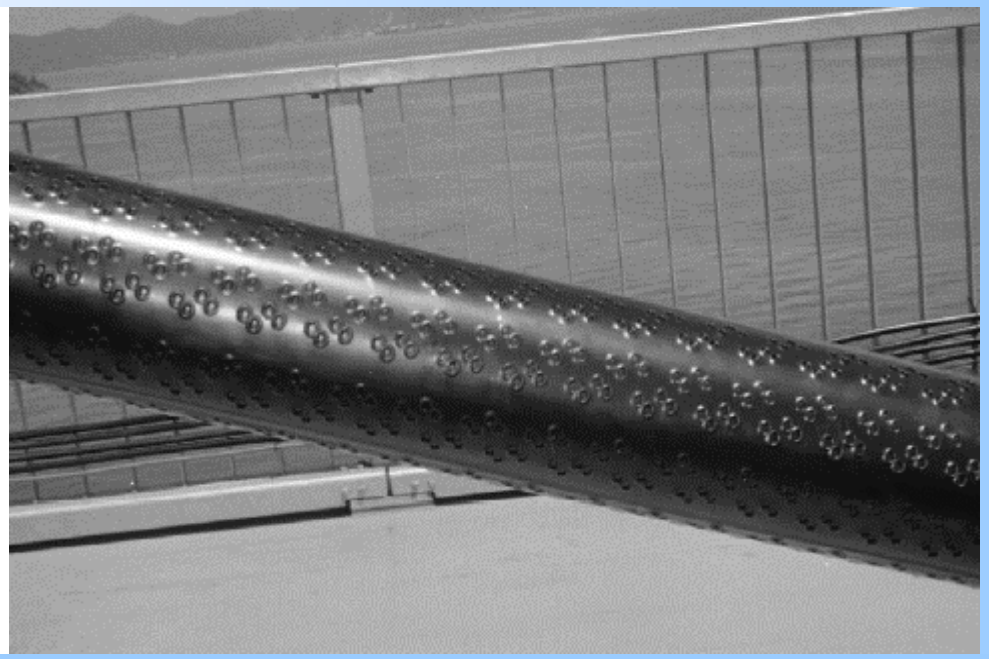




After Miyata et al.

The best solution was found as a non uniform indentation





The supercritical Cd value was not too much increased

The critical state appeared for a relatively low wind speed, 12 m/s

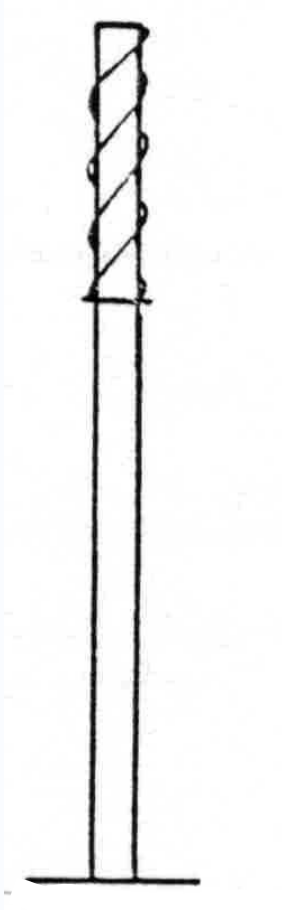
After Yamada

Spiraled wires

The initial idea came from experience :

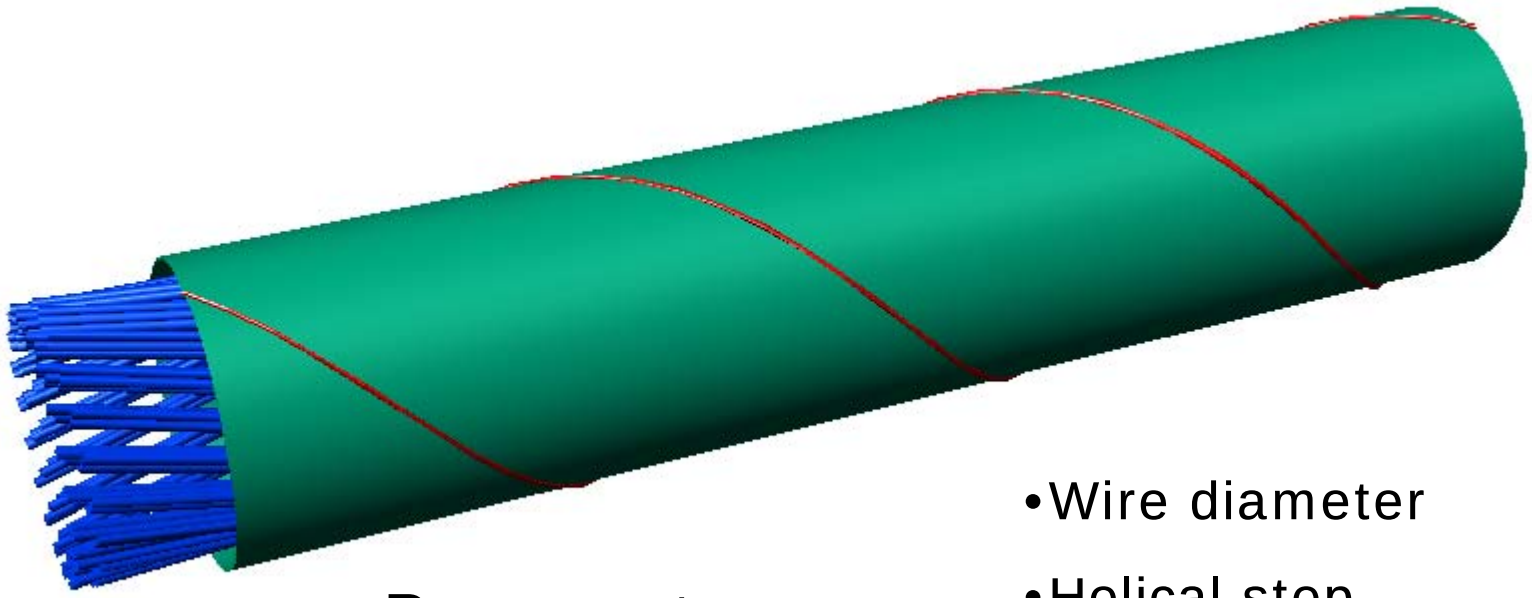
- Another 2 dimensions excitation, the vortex shedding, is easily suppressed when the birth of vortexes is **decorrelated** along the line like structure.
- Spirals are commonly used on cylinders for this purpose

The helical strakes are used on stacks, submarine risers, …



However, they do increase the drag forces

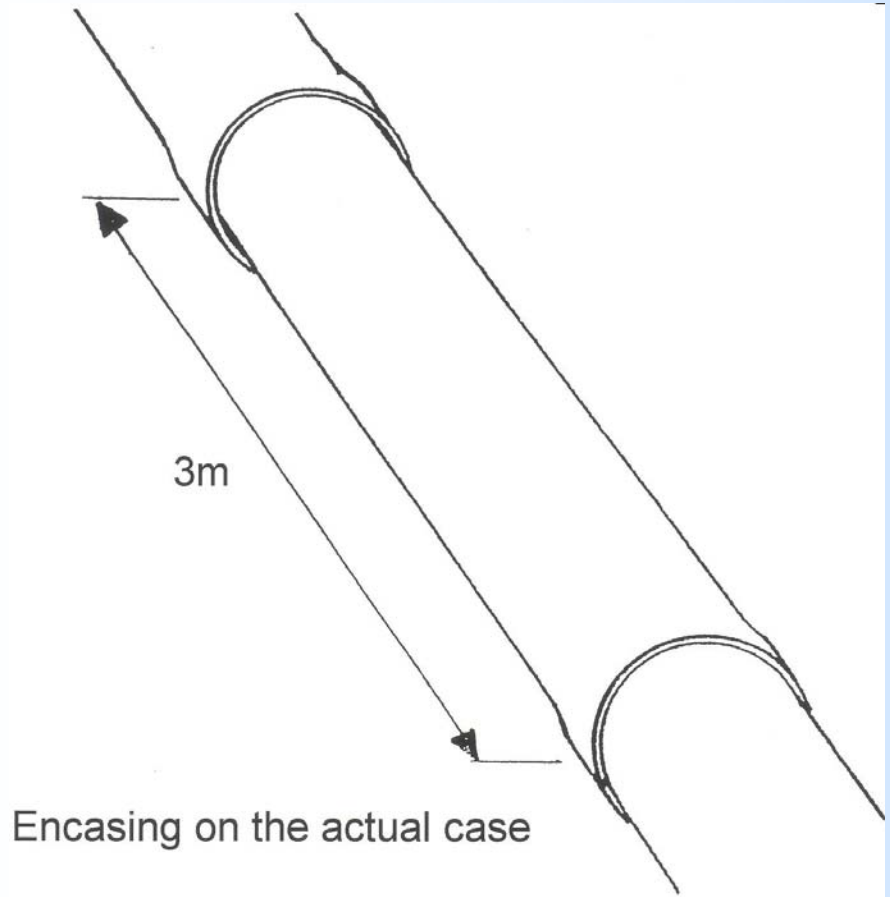
The idea was to design a circular sheathing with a minimum strake

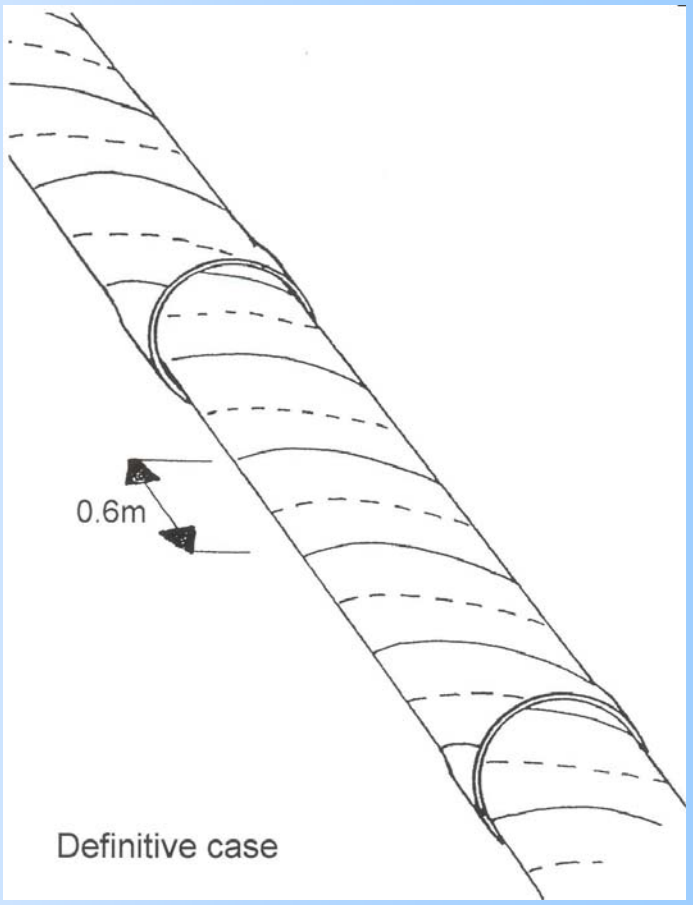


Parameters :

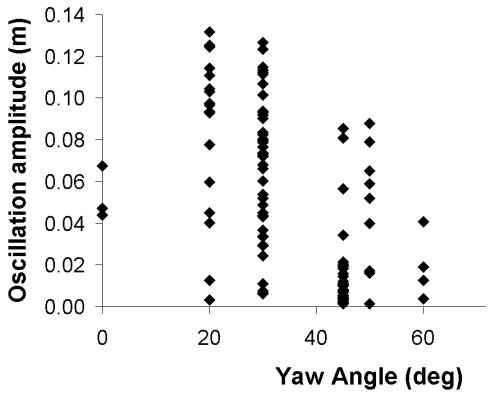
- Wire diameter
- Helical step
- Wire shape

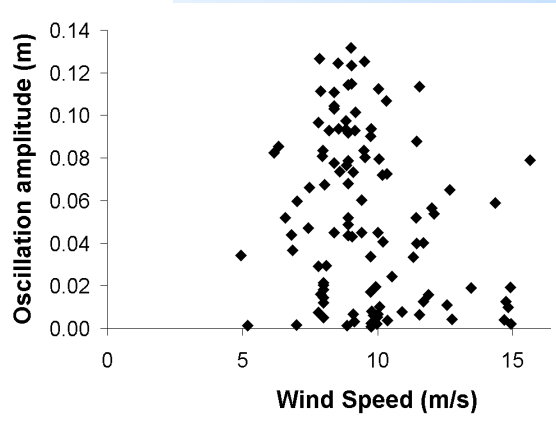
This design was made for the stays of the Normandie bridge

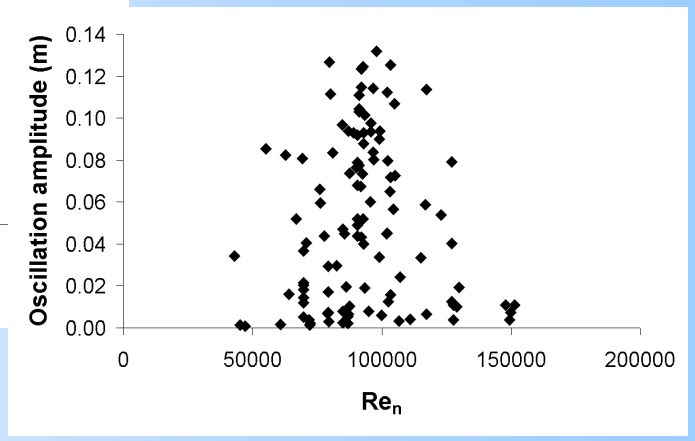




The RWIV was first reproduced in a large climatic wind tunnel on models equipped with smooth sheath







Parametric study for ϕ=0.165

Afterwards
the same parametric conditions
were applied for various wire sizes and steps

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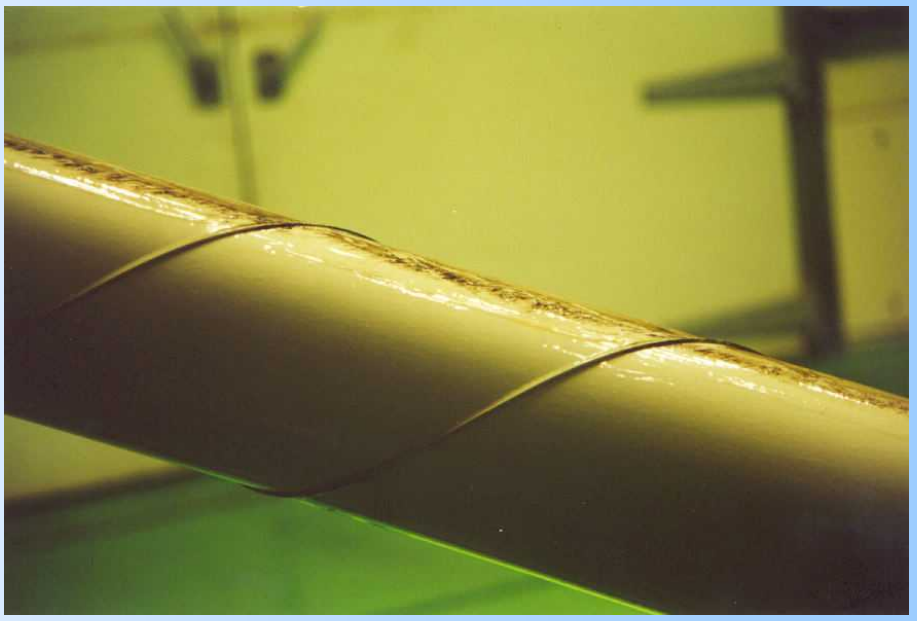
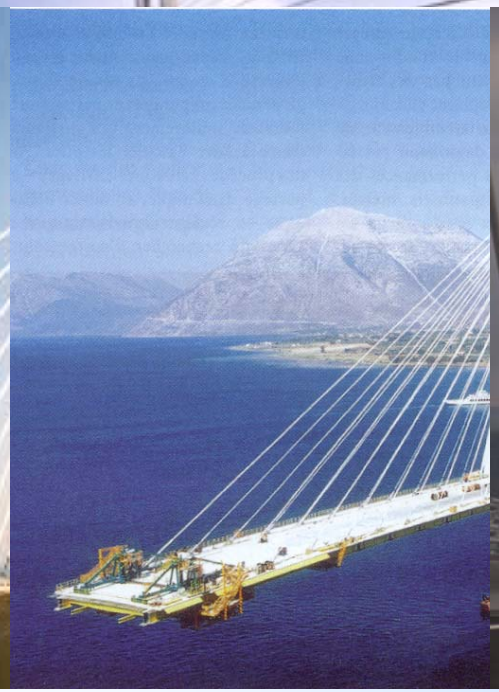
As it was proved to be efficient, the wire size was optimized to yield the smallest drag force, Cx=0.62



Ten years ago we had two solutions at our disposal

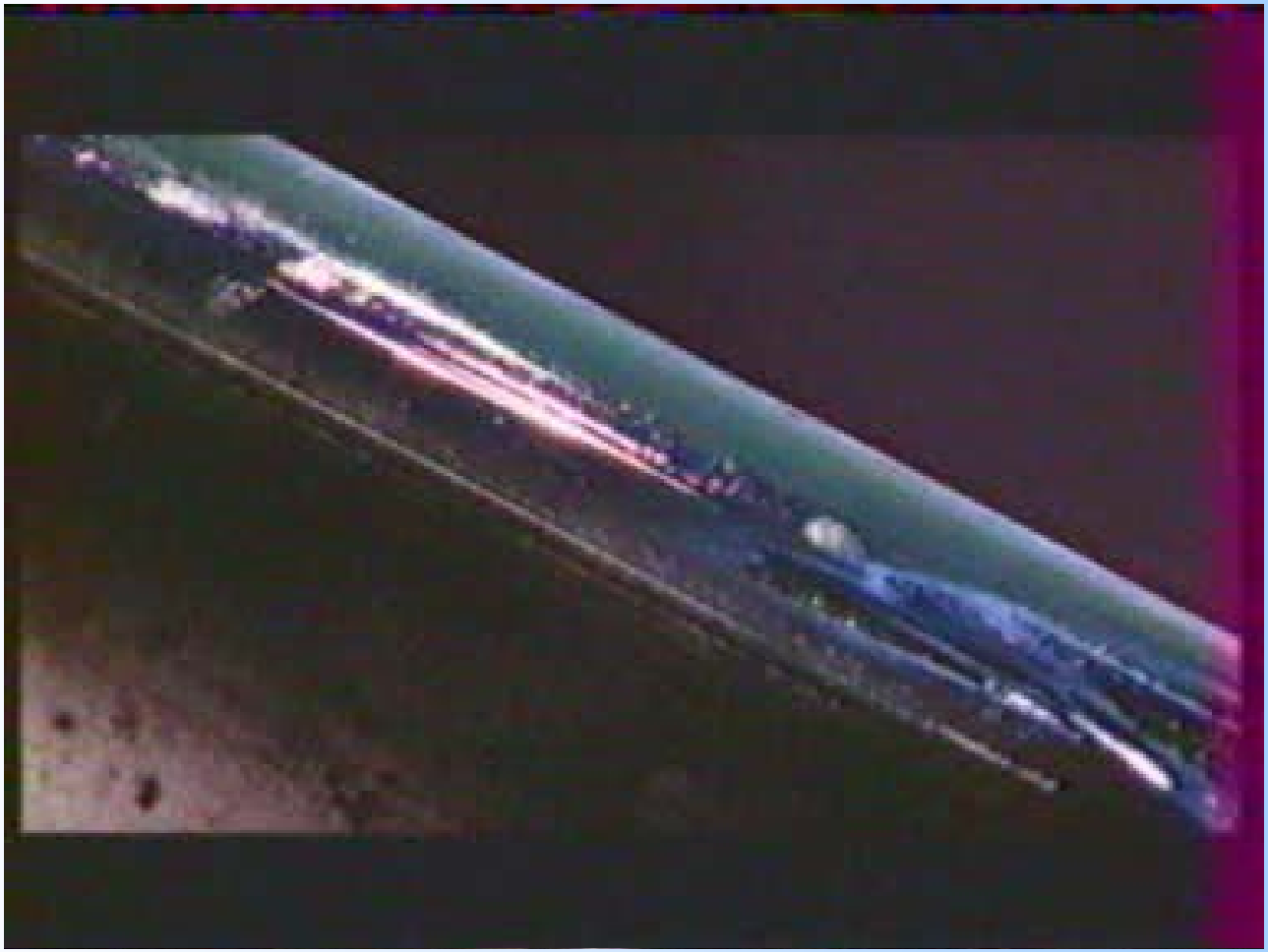


Why was only one of both widely used afterwards ?

Following studies : the same kind of tests with greater size

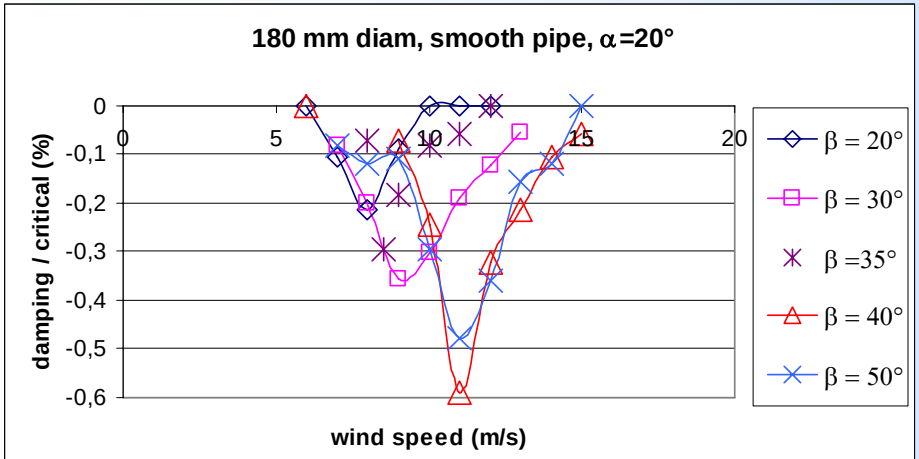
Every time a sheathing was tested, the thickness of the rib was reduced with great care, step by step, to attain the minimum still efficient against RWIV.

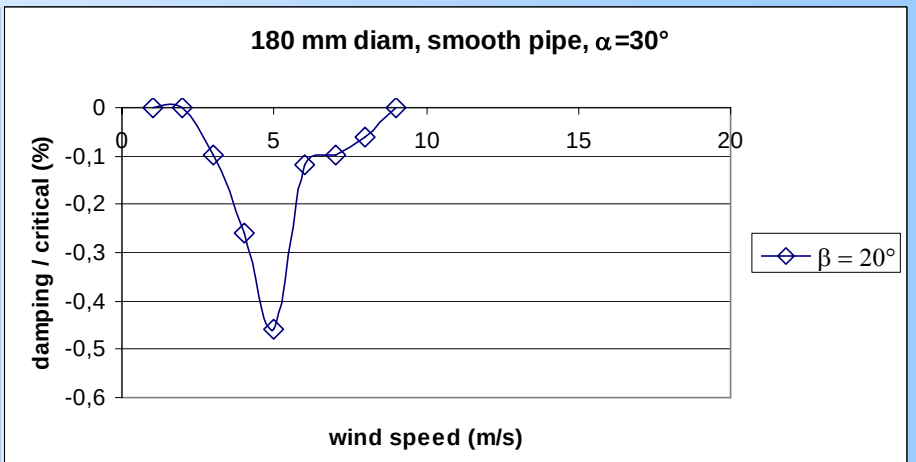
The sheathing were tested against RWIV

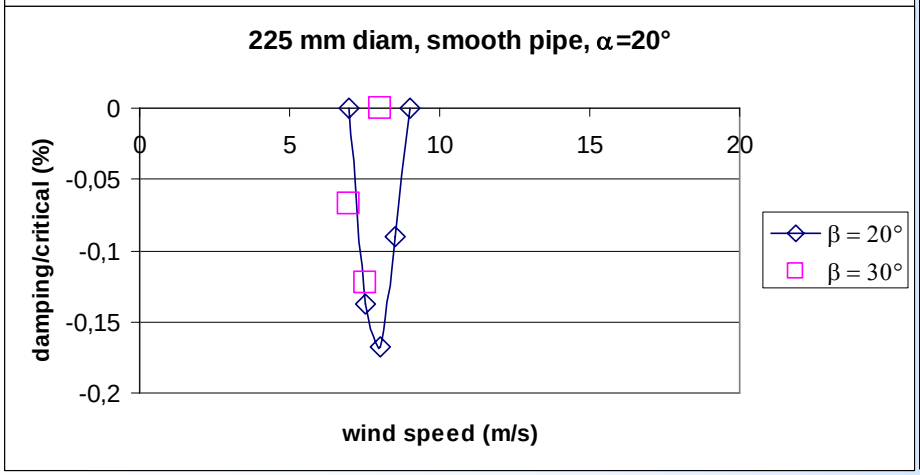


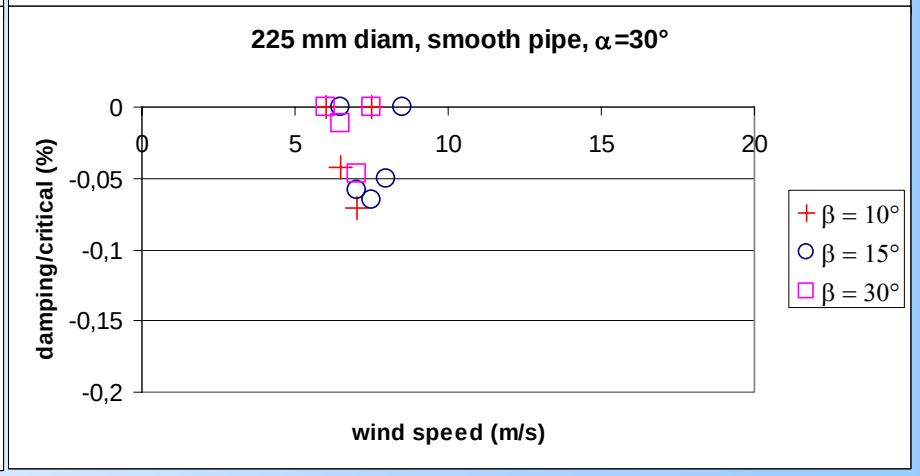
And the drag forces measured

The results for smooth sheathing showed an evolution in the RWIV intensity with increasing diameter

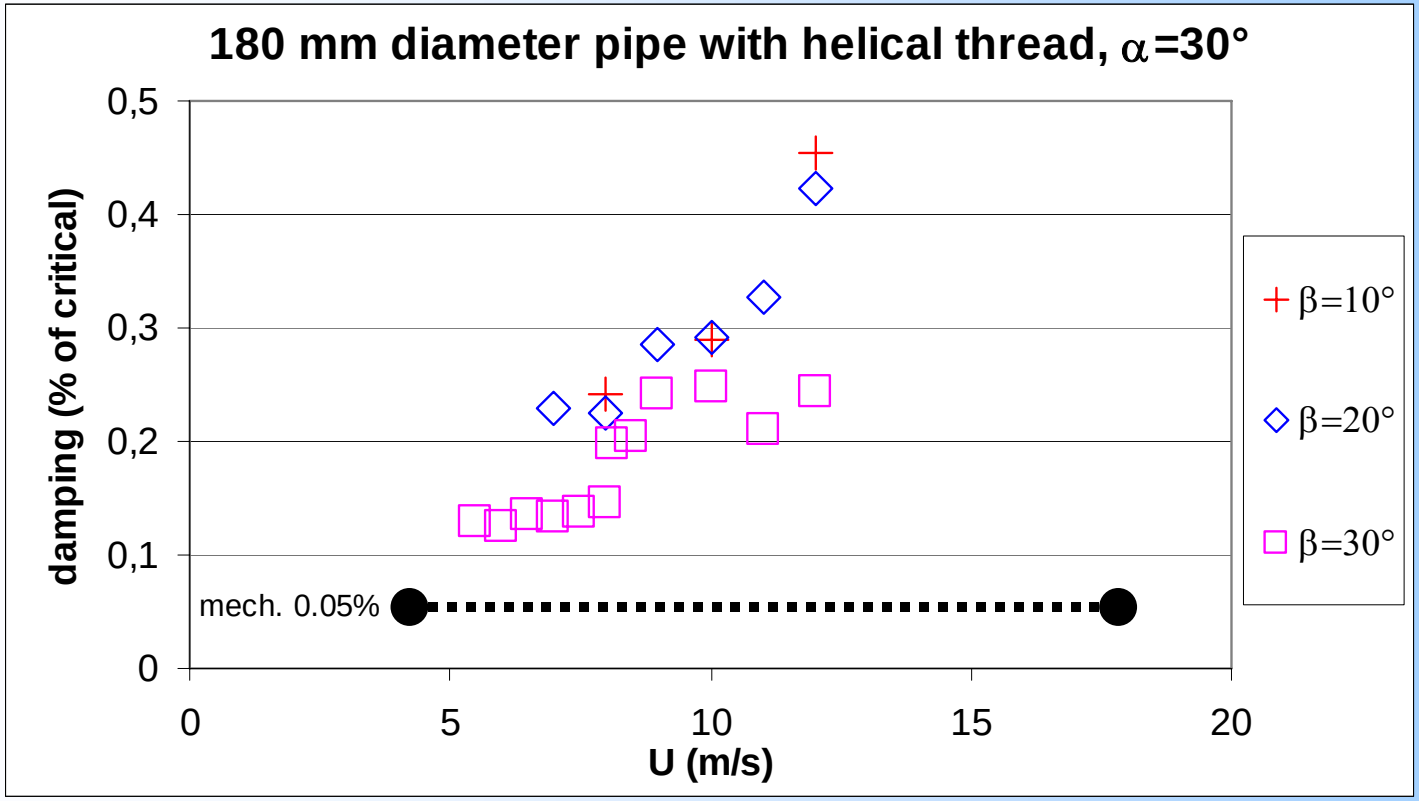




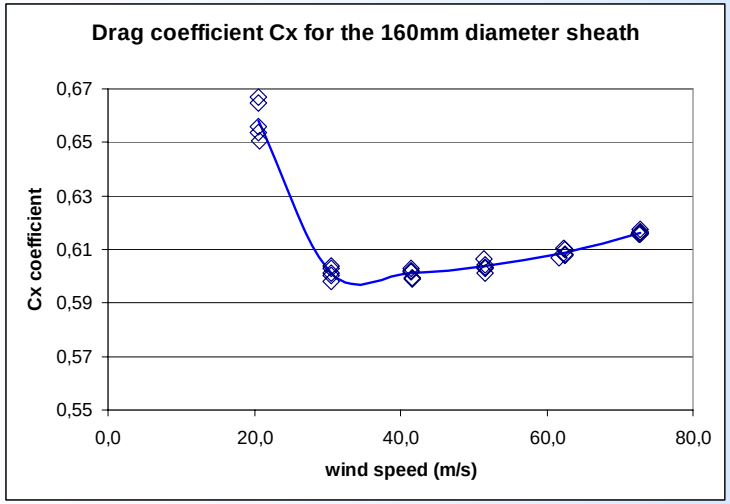


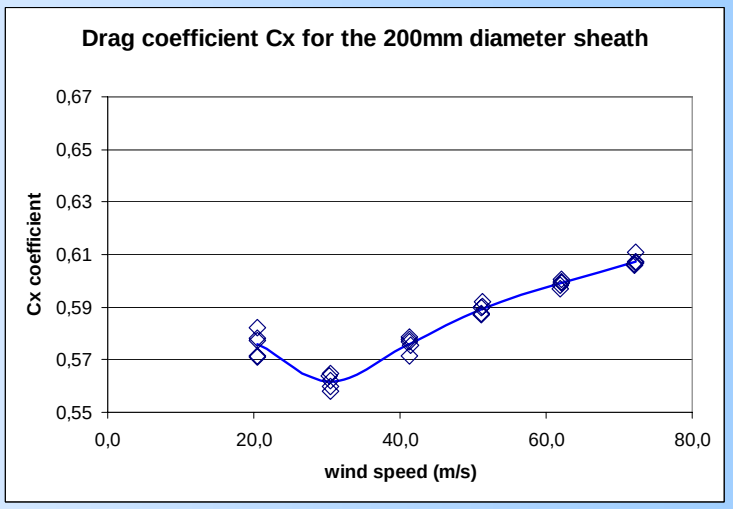


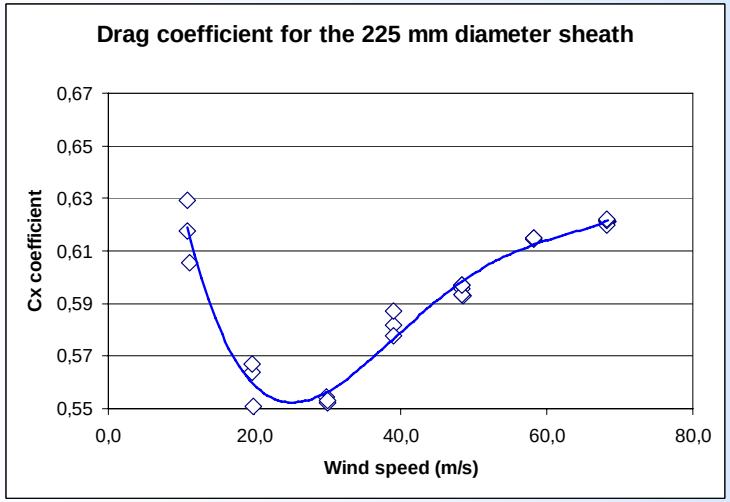
With the same conditions the sheathing with a double helical rib stayed stable at any tested speed.

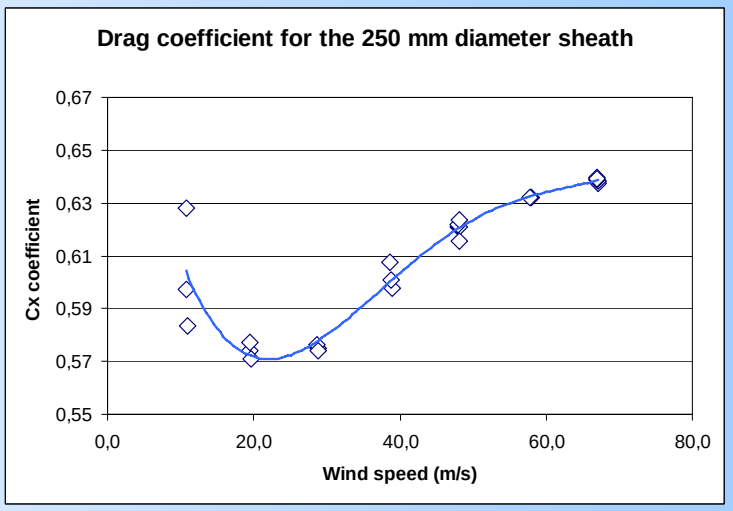


The change in drag force with diameter was noticeable too









It seems there is an optimum size of the stays for the RWIV

Sheathing diameter (m)	0.160	0.200	0.225	0.250
Double helix step (m)	0.600	0.600	0.695	0.780
Rib thickness (mm)	1.45	1.45	1.45	1.45
Cx value at 70 m/s	0.613	0.605	0.624	0.641

For sheath diameter greater than 200mm we saw that :

- the RWIV excitation was decreasing
- the drag force coefficient was increasing

Recent development

The monitoring of more and more in service bridges may yield very useful information, if measurements are made with care.

Minimum requirement : wind speed and direction, 3dof disp. of deck, 2 dof disp. of pylon, 2dof dip. of various cables.

Efficiency of sheath ?

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Another approach

In any case, consider the stay is not **responsible for** the vibration,

but the stay is **dissipating**, though its vibration, the energy contained in the whole bridge structure.

The effect of any of the aerodynamic instabilities

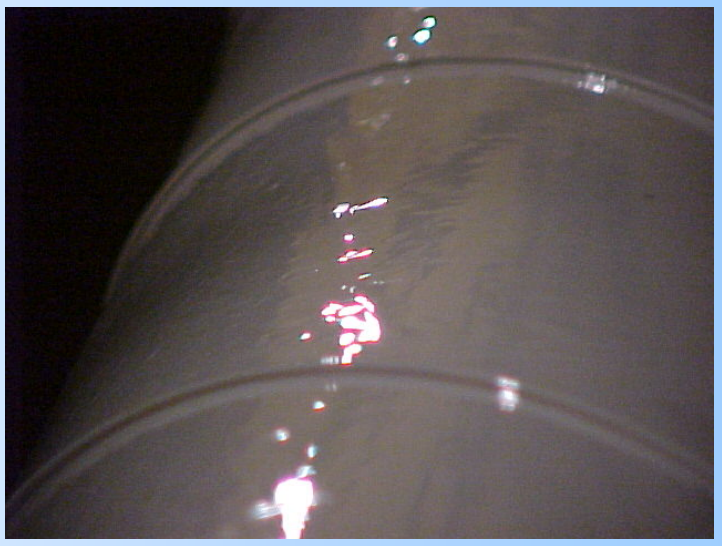
- galloping
- vortex shedding
- RWIV…

is only to reduce the aerodynamic **damping** of the cables.

Research topics

Research is now focused on the modeling of the upper rivulet.

The next step will be to model the aerodynamic damping of the stays, with respect to the outer conditions



Wind speed and direction, rain, ice, roughness and water repellancy of the surface…

Finally, include these model of damping of cables, with models of damping for the deck and the pylons, in a whole bridge calculation, compare it with monitoring data.

Conclusion

For the new generation of very long cable stayed bridges (span >1000 m)

- Careful design of the sheathing with regard to drag forces and efficiency against RWIV
- Design of the bridge as a whole, cables-deck-pylon, taking into account the aerodynamic damping of each part
- Provide additional structural damping