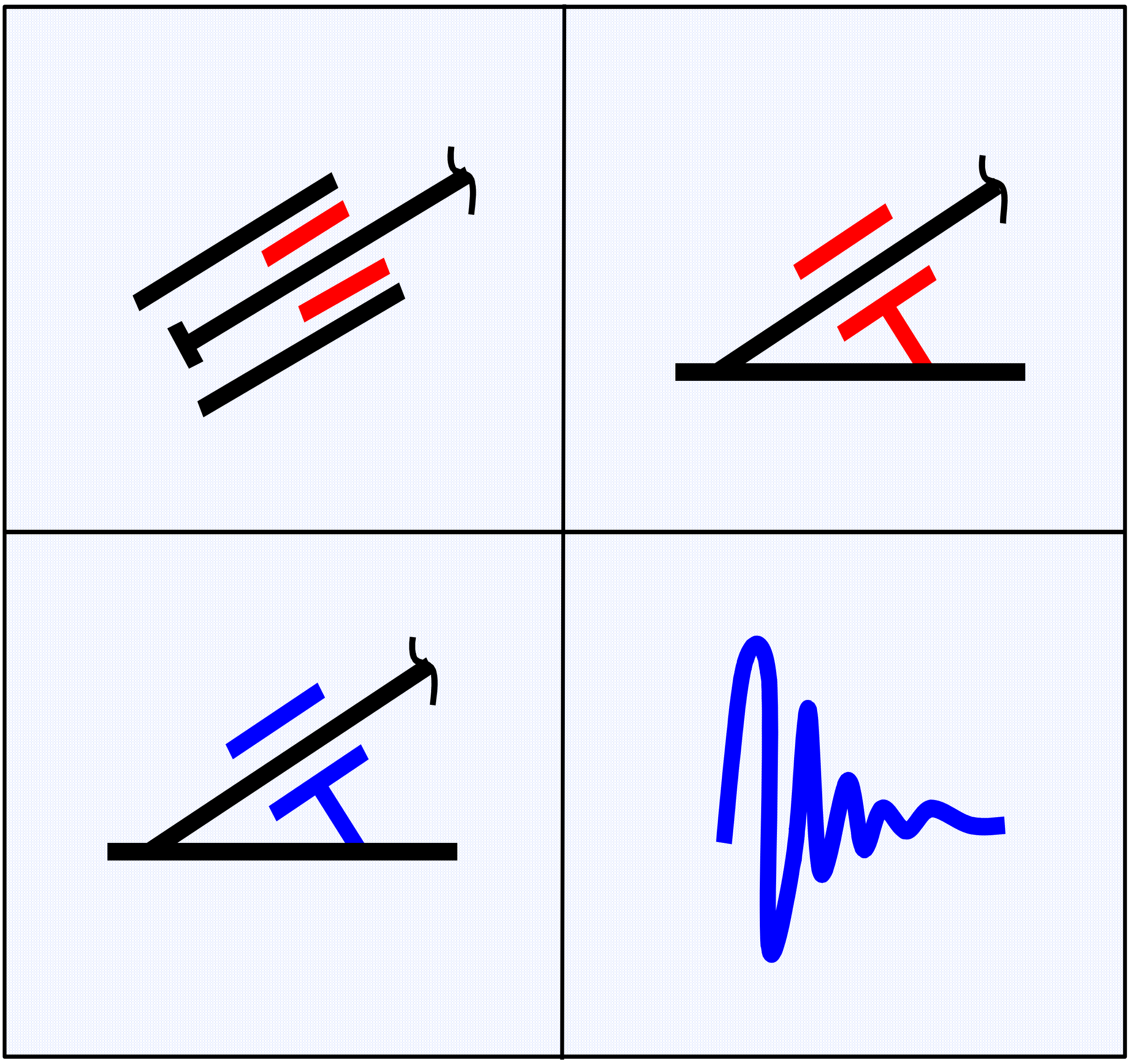
Structural Protection Systems

Head Office
Frankfurter Ring 193, 80807 München/Germany
Telephone +49 89 323 94 - 0
Telefax +49 89 323 94 - 329

Branch Office
Zum Holzplatz 2, 44536 Lünen/Germany
Telephone +49 231 434 01 - 0
Telefax +49 231 434 01 - 11

Subsidiary Plant
P.O. Box 55, 02992 Bernsdorf/Germany
Kamenzer Str. 4-6, 02994 Bernsdorf/Germany
Telephone +49 357 23 237 - 0
Telefax +49 357 23 237 - 20

MAURER
Cable damper systems



MAURER SÖHNE
Innovations in steel
Since 1876

Products and Technical Information

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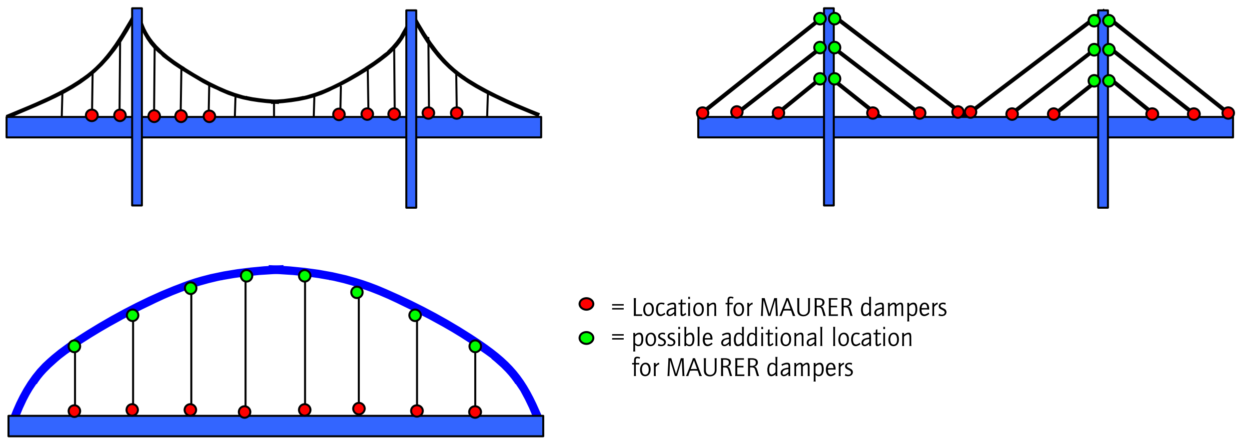
1 Introduction

The growth of bridge spans also leads to an increasing length of required stay cables or suspensions. As longer the steel cables, as more sensitive they are to dynamic excitation – be it from the supported structure, be it from weather conditions. The very small value of inherent damping capacity is not sufficient to eliminate cable vibrations.
Moreover, with increasing cable length, also the number of possibly excited eigenmodes is growing. The capacity of passive damping systems may not be sufficient to protect the cables over the whole range of occurring vibrational modes.
Additionally to conventional elastomeric- or friction dampers, Maurer Söhne developed a semi-active damping system based on viscous damping devices which allows an independent and real-time reaction of the damping device to the occurring vibrations. By using a magnetorheologic damping fluid, the advantages of passive and active systems are combined.

Cable vibrations may lead to several problems:

- Resonance, resulting in structural damages
- Reduction of comfort for traffic crossing the bridge
- Fatigue problems of the cables, hangers or other components, reducing the service life
- Premature failure of the corrosion protection system

MAURER cable dampers effectively reduce the cable displacement amplitudes as well as the accelerations. The dampers are fixed to the cables or hangers without influencing the structural aesthetics. In case the damping at one end of a cable or hanger is not sufficient, additional dampers can be placed at the top end.
For the effective and individual adaptation of the required damping, taylor-made systems can be designed, based on the following systems.



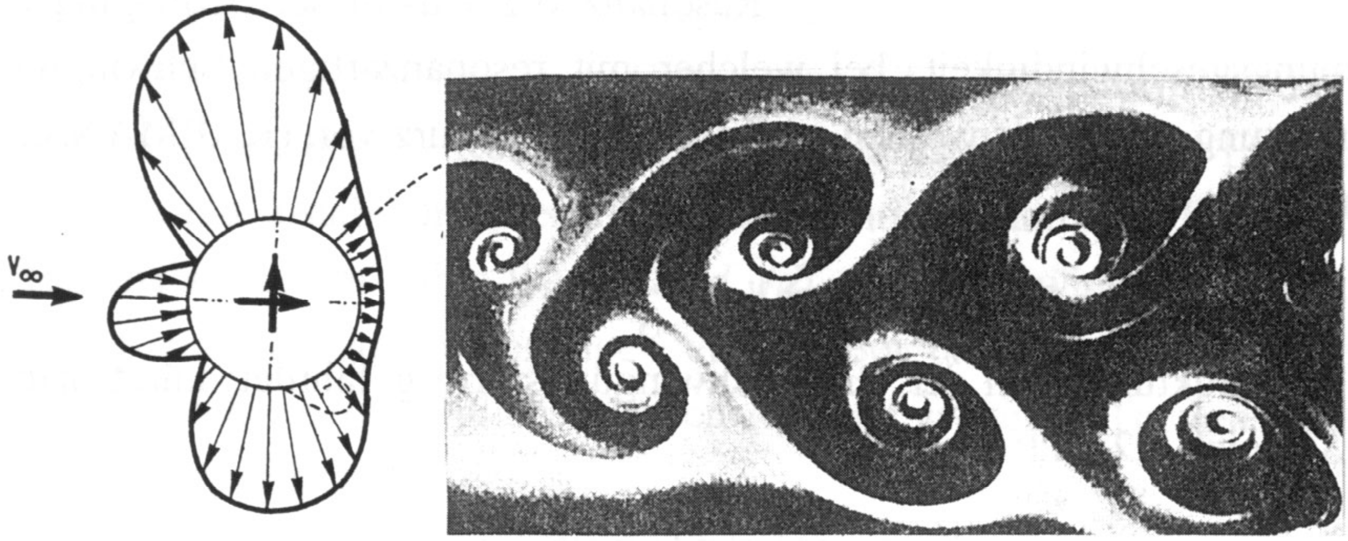
2 Theoretical overview

Modern bridge design meanwhile covers spans which were not even conceivable some decades ago. The employment of high strength materials leads to very slender structures, which forces the designer to consider the dynamic behaviour of the structure. In case of cable-stayed bridges, the increasing cable length leads to vibrations with higher amplitudes.
Apart from the micro-vibrations produced by the traffic load on the bridge deck and induced into the stay-cables, the most frequent type of vibration origins from aero-elastical turbulences.
The following types of vibration excitation may occur:

- Karman-Vortex-Street excitation
- Rain-wind induced galloping
- Gust-induced excitation
- Sudden dropping of ice-/snow film

2.1 Karman-Vortex-Street excitation

Stay-cables represent an obstacle in the wind. The air is forced to deviate from its original flow direction. This “pushing away” goes together with an acceleration of the air compared to the original velocity v_∞. In case of circular obstacles (e.g. stay cables), alternating vortices occur on both sides, i.e. alternating pressure distribution occurs. As soon as the vortex frequency corresponds to one of the natural frequencies of the stay-cables, the same begin to resonate. This kind of dynamic amplification usually is limited to thin cables of short-span bridges (e.g. footbridges).

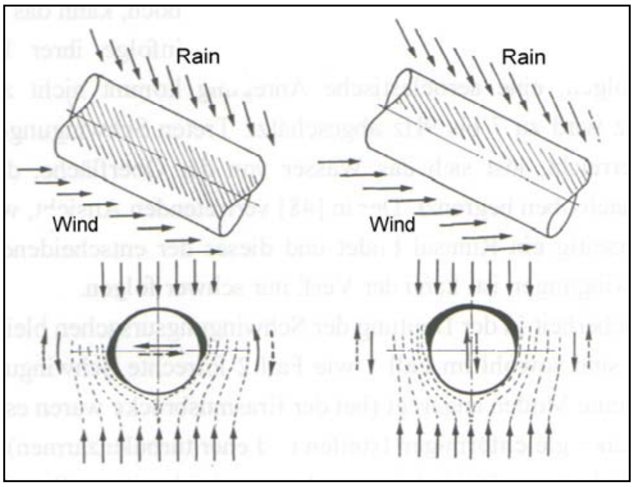


Karman-Vortex-Street excitation of a stay-cable

2.2 Rain-wind induced galloping

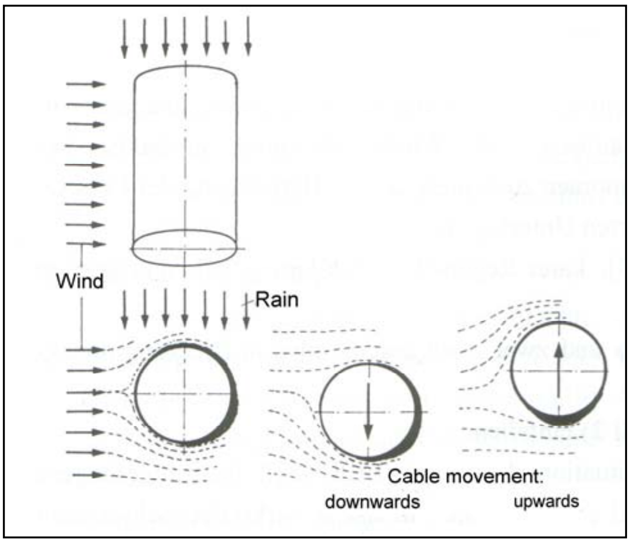
The occurrence of rain-wind induced galloping requires specific conditions regarding wind velocity and rainfall-intensity. However, considerable amplitudes of stay-cables can be traced back to this phenomenon.
Rain-wind galloping at stay-cab les occurs when:

- Wind occurs in direction of the stay-cable (case 1)
- Wind occurs in transverse direction to the cable (case 2)

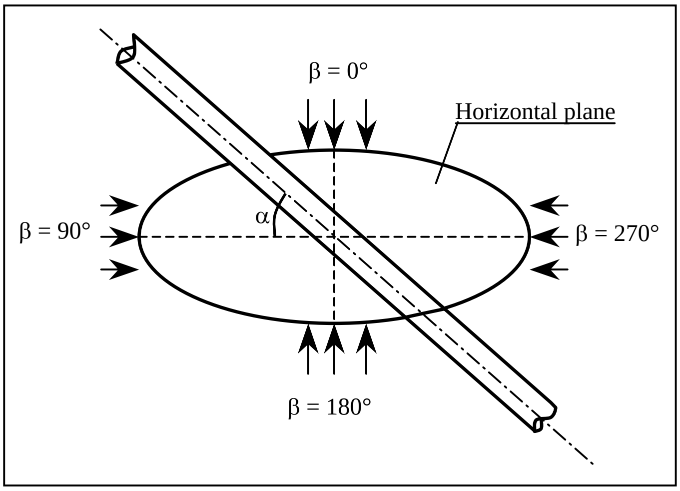


Rain-wind induced galloping, case 1

As long as no wind is blowing, the rain collected on one cable drains down in a rill on the underside of the cable. Occurring wind forces the rain rill to move up around the cable. That way, the cables' flow resistance is modified. The rain rills oscillate in the rhythm of the occurring cable vibration frequency which again increases the amplitudes of the cable



Rain-wind induced galloping, case 2



Definition of cable inclination α and wind blow direction β

The wind has to blow from the sector β=0° to 180° with a "most unfavourable" direction of β=30° to 45°, as otherwise the rain rill will not be influenced by the wind. The biggest amplitudes can then be expected in case of a cable inclination of $\alpha \leq 45°$. As bigger the cable inclination gets, as smaller is the required wind velocity to displace the rain rill from its original location.

A variation of this occurrence is the so-called form-galloping. In this case, not the flowing rain influences the cables' cross section and flow resistance, but snow or ice accumulated on the cable transform the circular cross section in an aerodynamic more unstable cross section.

Comparable to a wing profile, lifting forces occur transverse to the approaching wind flow. The vibrational velocity of the cable and the wind velocity add up vectorial, i.e. the approach angle varies which again increases the cables' amplitudes.

2.3 Gust-induced excitation

As many bridges are very exposed to the weather due to their location high above land- or sea level, high wind velocities can occur.

Stochastical variations of the wind velocity lead to variations of the flow pressure on the cables which may start to vibrate.

2.4 Sudden dropping of ice-/glazed frost-/snow film

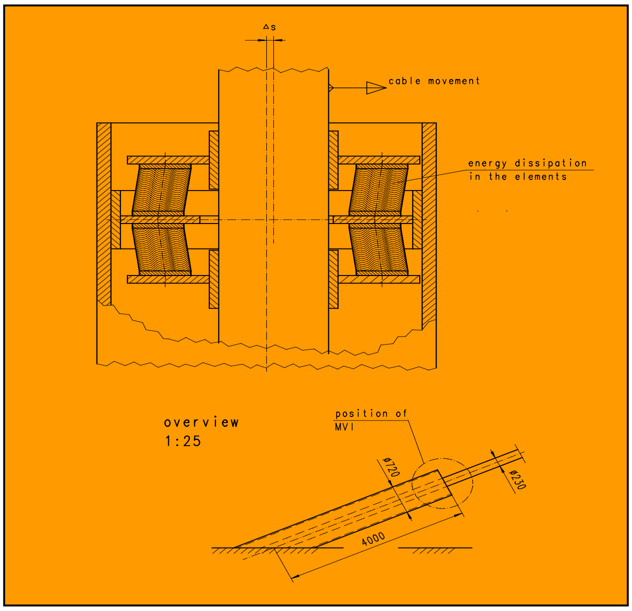
Due to a sudden dropping of an existing snow- or ice layer around the cable, stay cables may shoot up as a reaction to the considerable mass reduction. The occurring vibration frequency usually is low while the amplitudes are high.

3 Damping Systems

3.1 SDI-R: Integrated elastomeric or friction damper

A very esthetical cable- or hanger damping system is the integration of the damping device type SDI-R in the vandalism-tube at the cable- or hanger bottom end. The damper is entirely enclosed into this cover tube. However, it has to be checked whether the damper can be accommodated within the tube and whether the displacement at the damping location is sufficient to activate the damper.

For this damper type, high damping elastomers (20-30% damping), cured in special geometries and cut to special shapes are applied. Alternatively, pre-stressed friction liners can be integrated.
All dampers are individually adapted to the structural requirements (damping, space conditions etc.) and are individually dimensioned.



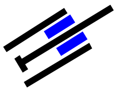
SDI-R: possible arrangement of elastomeric damping element in the protection tube

SDI-R testing at Munich University of Technology

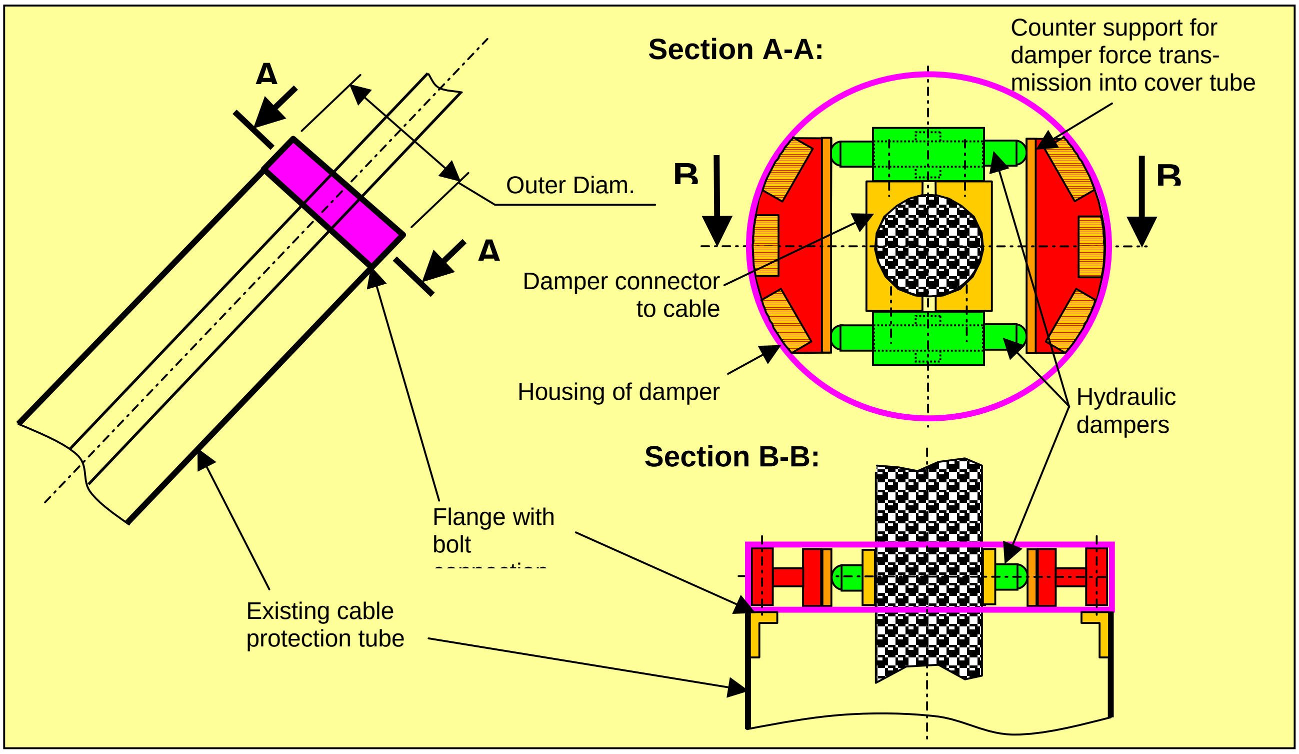
SDI-R: application example: Traunsteg in Wels / Austria

SDI-R testing at Munich University of Technology

3.2 SDI-H: Integrated hydraulic damper

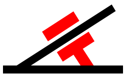


Alternatively to the application of elastomeric damping bodies, the installation of hydraulic dampers in the cable protection tube leads to an increase of the damping capacity (equivalent viscous damping up to 55% possible). Viscous elements show a higher efficiency compared to elastomeric elements as the dissipation capacity is bigger. These devices are applied e.g. in case of strong cable- or hanger vibrations, or cables longer than 70 m.



Possible arrangement of integrated hydraulic damping system

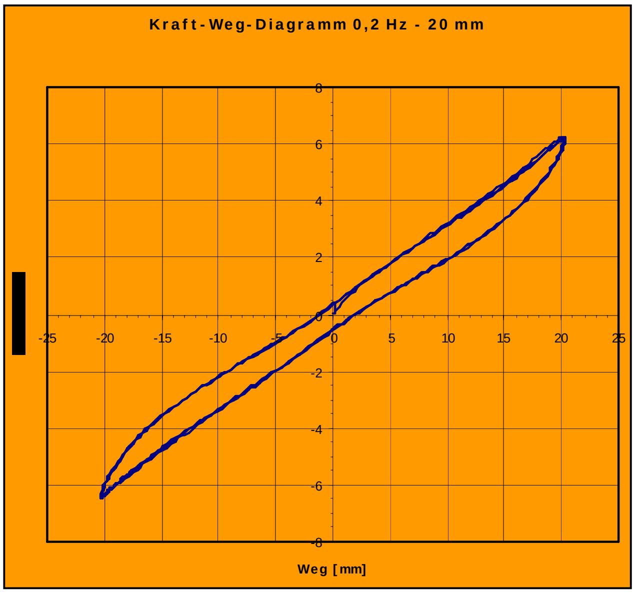
3.3 SDE-R: External elastomeric or friction damper



The SDE-R-Damper is externally mounted with clamps to the cable or hanger in a sufficient distance to the fixing of the cable or hanger. This solution is used when a cover tube is not suitable for an integration of the damper type SDI-R.

Depending on the structure, elastomeric-, friction- or viscous damping elements are applied. The SDE-R type is fitted with special elastomeric or friction damping elements.

All dampers are individually adapted and designed according to the structural requirements (damping, space conditions, etc.).



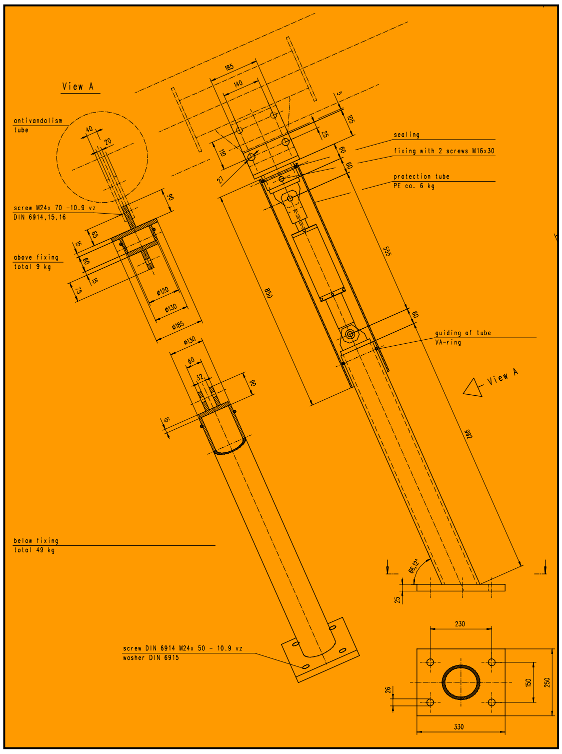
SDE-R: recorded hysteretic loop

SDE-R: application example: Footbridge Forchheim / Germany

SDE-R: detail of Forchheim-Bridge

3.4 SDE-V: External viscous damper

The external damper SDE-V, arranged rectangular to the cable, offers a highly efficient viscous damping element instead of the elastomeric or friction element. The fixing to the cables can be realised by means of clamps. The viscous damping elements are designed in various versions, depending on the individual project requirements.



SDE-V: Externally arranged cable damper – principle sketch

SDE-V: application example: Eilandbrug Kampen / Neherlands

SDE-V fixing clamp for connection damper - cable

SDE-V testing at Munich University of Technology

3.5 ACD – Adaptive Cable Dampers

The efficiency of a cable damper is better as closer the damper is placed to the cables' antinode. Due to practical and optical reasons, external dampers are located close to the root point of the cables, e.g. in a distance of app. 2-6% of the cable length. To still achieve a sufficient cable damping, the damping device has to be tuned to the occurring eigenmode, vibration intensity and cable properties. Constant variation of these values lead to a reduction of the effectiveness of a conventional damping device.
The application of adaptive damping devices helps to always keep the dampers efficiency at an optimum – even in case that different eigenform-values have to be dampened!
The conventional silicone oil is replaced by a so-called magneto-rheologic fluid.

The shear strength of this fluid can be varied by the application of a varying magnetic field. As higher the magnetic field (i.e. as higher the electric input), as higher is the dampers response force.
The required electric power required for the control system of an adaptive cable damper is relatively small and can be provided by a storage-battery which is recharged by a solar panel.

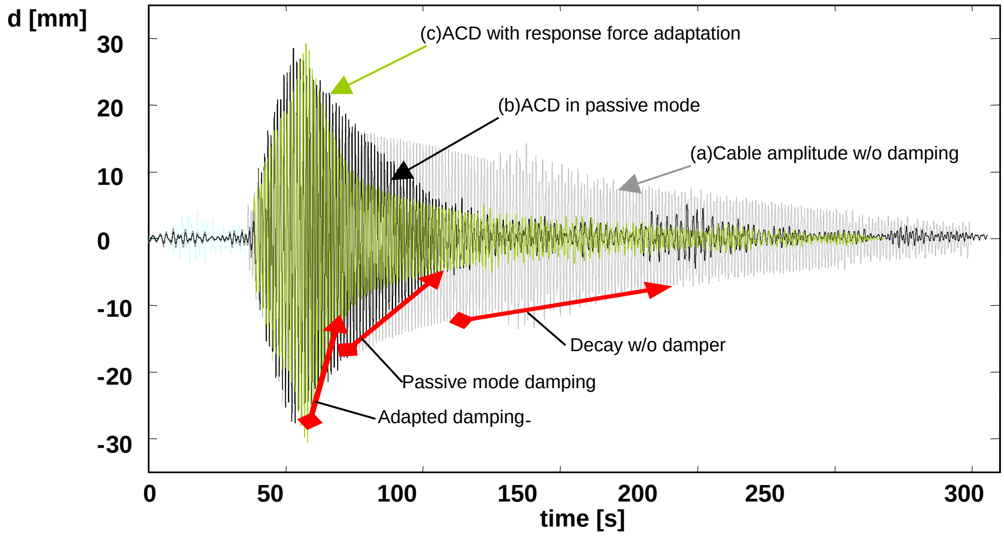
ACD and solar panel for electric power supply

ACD at Eilandbrug Kampen

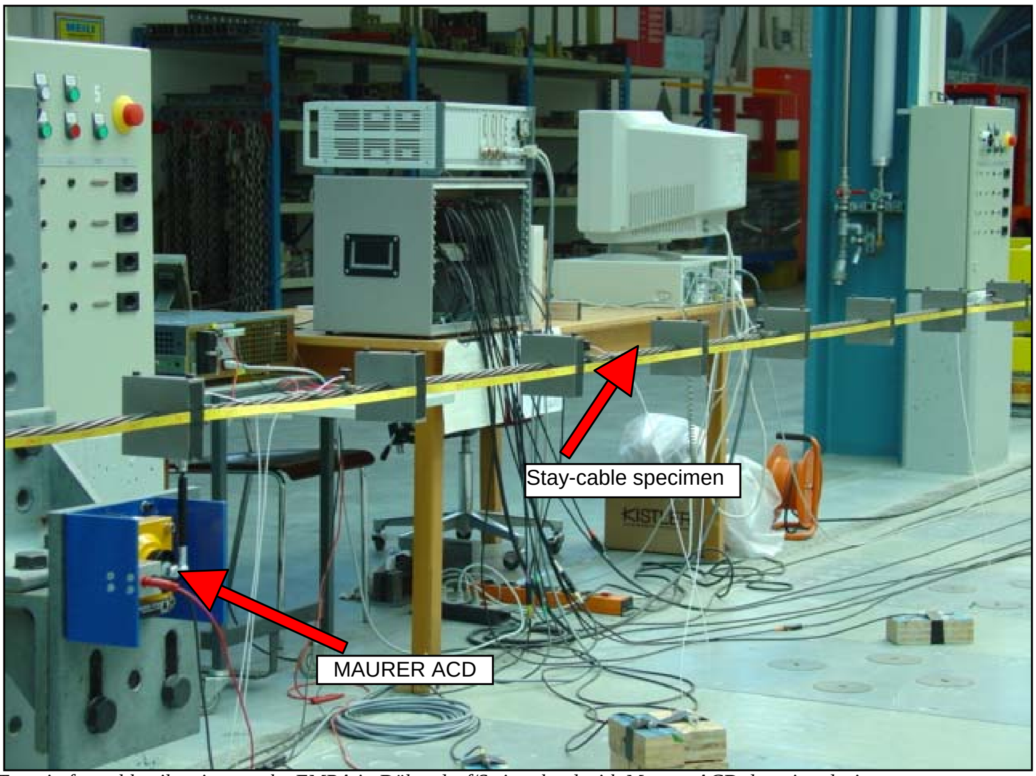
While conventional hydraulic or elastomeric dampers provide one damping force level which is optimal for only one cable amplitude and frequency, the main advantage of adaptive cable dampers is that their damping force is automatically adapted to the required values.

4 Testing of cable and hanger dampers

The tests of the various damper types are continuously carried out with regard to the required quality control for specific projects and with regards to product development.
The specific project testing is to confirm the devices requirements, e.g. damping function, displacement and efficiency respectively.
For all cable and hanger dampers a permanent product development is safeguarded in the company headquarters in Munich, at the Munich University of Technology and at the EMPA (Material Testing Institute) in Dübendorf/Switzerland. At the EMPA laboratories, prototype cable dampers can be tested in a cable vibration testing rig.



Comparison of vibration decay for: (a): no damping, (b): passive damper, (c): adaptive damper



Test rig for cable vibrations at the EMPA in Dübendorf/Switzerland with Maurer ACD damping device

5 Reference projects – Maurer Adaptive Cable Dampers

Eilandbrug Kampen / Netherlands
test installation of Maurer Adaptive Cable Damper:
F *1 – 40 kN*
Stroke ± *60 mm*

Bridge Dubrovnik / Croatia: 20 ACD,
F *1 – 40 kN*
Stroke ± *80 mm*

Sutong Bridge / China, Maurer ACD,
F *1 – 50 kN*
Stroke ± *65 mm*