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Long-term corrosion protection for bridge cables with butyl rubber tapes using the ATIS Cableskin® system

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ATIS Cableskin® is a corrosion protection system for bridge cables which uses proven materials to strike out in a new direction. These innovative ideas mean that, for the first time, corrosion protection work on scaffolds and in enclosures will be a thing of the past, and the costs and traffic restrictions are massively reduced. It is worth highlighting the extremely long lifetime of this corrosion protection.

1 Development

In the beginning there was the butyl rubber. When it was first manufactured on an industrial scale, people were excited by its physical and chemical properties, which made a broad range of applications accessible. One use of butyl rubber is in tyre production, so that tyres retain their air and the embedded steel cord is protected against moisture.

In the 1960s, PE films were inserted into the soft butyl rubber material to prevent overstretching, which massively increased its stability. DENSO Leverkusen developed a procedure in which coextruded interlayers generated a perfect bond between these two different materials. That was crucial for its use as corrosion protection applied in the form of wrapping.

Butyl rubber tapes have been successfully used commercially since 1970, initially for gas and other pipelines underground and open to the weather. Since then, more than 107 million square metres of surface have been protected globally, with no significant cases of damage known. In 2006 this success gave DYWIDAG-Systems International GmbH (DSI), one of the leading global companies for prestressing and stay cable systems, the idea to use these tapes for protecting the stay cables of bridges against corrosion. Alpin Technik und Ingenieurservice GmbH (ATIS) in Leipzig delivered the necessary equipment for the automated application of the tapes on the cables. Today, this company markets and develops this wrapping method globally under the name of ATIS Cableskin®. It has been officially approved in Germany since 2010 and in Europe since 2013 [1], [2].

2 Brief description of ATIS Cableskin® corrosion protection system

The ATIS Cableskin® corrosion protection system consists of two layers of butyl rubber tape wrapped around the cable, Fig. 1.

- The base layer is directly on the cable surface and consists of a three-ply tape, which is wound around with approx. 50 % overlap, Fig. 2a.
- The top layer constitutes the outer corrosion protection and is a two-ply tape, whose outer ply is made of robust UV-stabilized PE film, Fig. 2b. It comes in different colours depending on the owner's specification and forms mechanical protection for the layers underneath. The overlap is also approx. 50 %, so there is a total layer thickness of approx. 2.6 mm.

Interdiffusion of the butyl rubber molecules, so-called cold welding, Fig. 2c, forms a tube-like encasement, which adheres very well to the cable surface and meshes with it, Fig. 3. It is practically impermeable to oxygen and water vapour.

3 Approval tests

In order to obtain official approvals in Germany and Europe, extensive tests were required, which were carried out

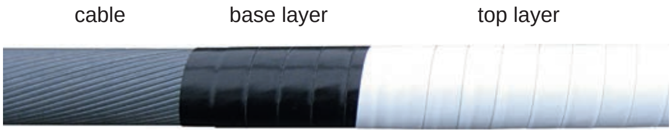

Fig. 1. ATIS Cableskin® corrosion protection system

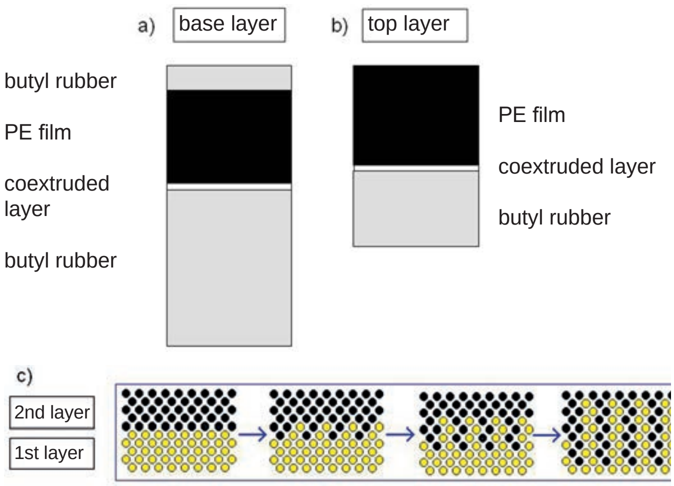

Fig. 2. Make-up of corrosion protection tapes: a) base layer, b) top layer, c) cold welding (interdiffusion)

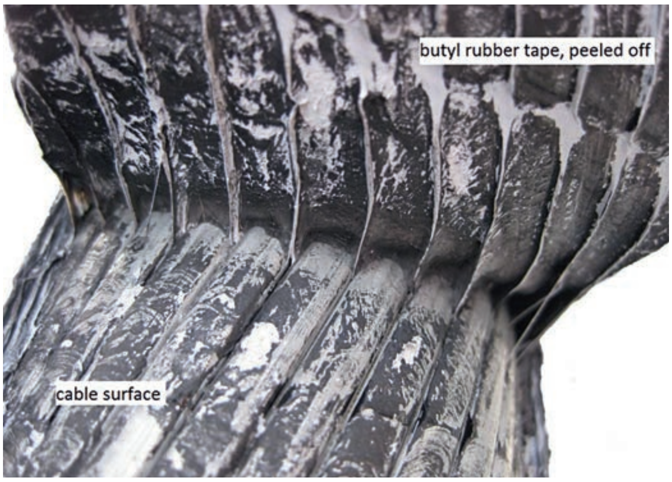

Fig. 3. How the base layer adheres to and meshes with the cable surface

Fig. 4. Samples in the salty fog test

at the Otto Graf Institute of the University of Stuttgart. The test criteria were set in compliance with the corresponding guidelines for coatings [4], [5], [6].

All tests were passed successfully – the most important being:
- Resistance to salty fog, Fig. 4
- Resistance to condensed water
- Resistance to chemicals
- Artificial weathering with xenon radiation
- Artificial weathering in UV test
- Resistance to water vapour

The results were either in line with the requirements or exceeded them by far. They fulfilled the conditions for corrosion protection for industrial and coastal atmospheres C5-I and C5-M according to EN ISO 12944-6 [7], [8].

4 Preliminary investigation of the cables

4.1 Visual inspection

Normally, visual inspection of the cables is carried out with cameras before corrosion protection work starts. There are different systems for this on the market:

Fig. 5. Visual inspection with high-speed camera

- Direct visual inspection
- Inspection with video
- Inspection with high-resolution, high-speed cameras, Fig. 5

The advantage of the third procedure is that it supplies a sharp panorama image whose quality is equivalent to an on-site inspection and which captures the whole scale of the cable. The evaluation takes place with the help of a special analysis and comparison program.

4.2 Magnetic induction (MI) tests

In order to check whether there are any internal wire fractures in the free cable length, there are two MI procedures that differ considerably in significance:

Magnetisation of outer wire layers only
Owing to the low output of the devices, only the outer wires of the cable are magnetised, which means that wire fractures in the interior cannot be detected.

Magnetisation of whole cable cross section
High-performance devices are needed for this. Wire fractures across the entire cross-section are recorded, Fig. 6.

4.3 Ultrasonic tests

In places that cannot be checked with the MI procedure due to geometric design, e.g. anchorages areas, the ultrasonic procedure is employed, which allows wire fractures along a length of approx. 1.40 m to be detected with the help of a transducer placed on the end surface of each individual wire, Fig.7.

Fig. 6. Magnetic induction (MI) unit

Fig. 7. Ultrasonic test

Fig. 8. Test sample subjected to 30 bar interior pressure under the wrapping

Fig. 9. Wrapping robot on painted cables

Fig. 10. Wrapping with hand unit

5 Application of tapes

5.1 Surface preparation

No special pre-treatment of the cable surface, e.g. blasting or sweeping, is required for the wrapping procedure. Any existing coatings may remain in place, too. The surface must only be dry and free from serious contamination and loose material.

Cable filling material that has leaked out must be removed mechanically. No further measures are required. In tests involving applying an internal pressure of 30 bar, it was shown that the wrapping remains tight even under this extreme load, Fig. 8.

5.2. Wrapping

The butyl rubber tapes are usually applied to the cable automatically using a wrapping robot, Fig. 9. It moves along the cable independently and wraps the tape helically under slight tension. Depending on the length and diameter of the cable, joints may be required, which are also produced automatically by the robot. All working steps are controlled from the ground by a monitoring unit and can be saved and archived so that the owner is able to closely monitor what is or was happening.

In the meantime, robots that wrap both the base and top layer in one process have been specially developed for large projects. They are loaded with butyl rubber tapes in place with the help of rope access technology. By this, the wrapping is accelerated considerably.

At places where the geometry does not allow the use of robots, the tape can be wrapped using a manually operated unit, Fig. 10 or directly by hand.

6 Repairing damage

If the wrapped protection is damaged, through vandalism, for example, it can be repaired without extensive base

Fig. 11. *Repairing damage*

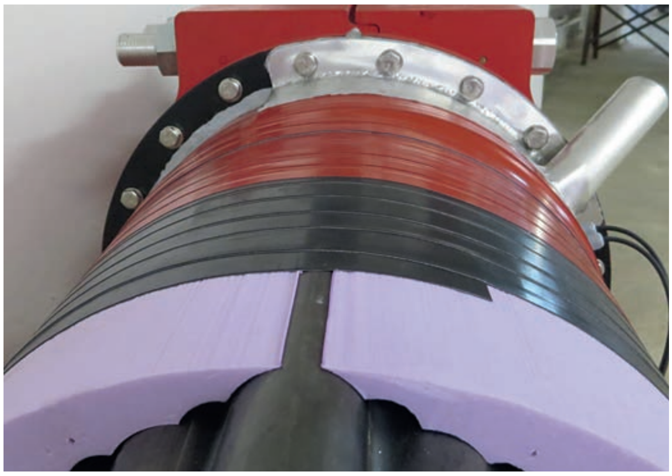

Fig. 13. *Dehumidification channels under the wrapping to a cable bundle (mock-up)*

preparation. To do so, only the damaged area is cut out in circular shapes. The new tape is wrapped around by hand, overlapping the existing tapes, Fig. 11.

7 Control areas

For long-term monitoring of the corrosion protection, control areas can be set up in accordance with the current guidelines [6].

If damage to the existing intact wrapping is to be avoided when carrying out such control tests, an alternative to this is available. An additional 50 cm long wrapping, which can be easily removed while taking appropriate precautions, is applied to the existing wrapping. This allows the corrosion protection performance to be assessed in an easy and careful way under the conditions prevailing at the structure, Fig. 12.

Fig. 12. *Control area on wrapping*

8 Dehumidification

During recent years a procedure has been developed to dehumidify cross-sections of cable bundles on older suspension and cable-stayed bridges. This involves creating one or several channels on the cable surface under the wrapping with the help of mouldings into which dried air is fed. This can target the removal of any residual moisture that might be present in the inside of the cable bundle, Fig. 13.

9 Monitoring

A monitoring system can be installed parallel to applying the ATIS Cableskin® corrosion protection system. This allows frequently updated information about temperatures, humidity and thus the dew point. To achieve this, sensors are mounted under the wrapping on the cable. Wherever the protected structure is located in the world, the data are transmitted by wireless technology to a server, then evaluated and displayed on a web-based page. The owner can check the condition of the structure anytime, anywhere. Usually, this monitoring system is installed on bridges with bundles of ropes, where moisture inside the cable is more likely due to the complex cable structure, Fig. 14.

Fig. 14. *ATIS monitoring system at Ophus suspension bridge, Norway*

10 Examples of applications

The ATIS Cableskin® wrapping system has been employed for several large projects:

First of all, in 2008 it was used for the 80 stay cables of the Passerelle des deux Rives pedestrian and cycle bridge over the Rhine at Kehl/Strasbourg (∅ 60 mm to ∅ 139 mm, total stay cable length approx. 3700 m). The works were performed four years after completing the bridge. No special preparation of the galvanized cable surface was carried out, Fig. 15a [9].

In 2010 the Köhlbrand Bridge in the port of Hamburg followed with 88 cables (up to ∅ 118 mm, approx. 8700 m in total). The cables had been in use since 1978 and were PU-covered. The butyl rubber tapes were applied after manual removal of loose paint coats. Adhesive coating was not removed, Fig. 15b [10].

In 2012 the cables of the Obere Argen Bridge on the A96 motorway nearby Wangen, Allgäu, Germany, were wrapped (24 cables, ∅ 126 mm, total of approx. 1700 m). The existing coating was not removed here, either, Fig. 15c [11].

A further development of the wrapping system was employed on the Ophus suspension bridge in Norway in 2013–14, where the loadbearing main cables were protected, Fig. 14 [12]. Their wrapping is tightly connected to the suspenders with the help of neoprene boots, which can be opened for inspection purposes at any time. The newly developed dehumidifier and monitoring systems were also successfully employed for the first time in this project.

Smaller projects, e.g. the wrapping of masts in Scandinavia and the corrosion protection of cable-supported structures at the airport in Johannesburg, South Africa, have been carried out recently.

The wrapping of the cables of two large cable-stayed bridges in Houston and Port Arthur, Texas/ USA (parallel wire cables with cement grout and PE pipes, total surface 13000 m^2), with the main aim of improving their resistance against UV rays, has started in December 2014 and will take about six months, Fig. 15d.

11 Lifetime

Tenders for cable-stayed bridges usually specify a lifetime of 100 years for the cables. That is a big challenge in view of corrosion protection, too.

In locked coil ropes, the individual wires are protected with zinc or galfan. If the surfaces are exposed to the weather, the SO_2 content of the air will mean that the protective layer will be steadily eroded. The rate of erosion depends on the ambient atmosphere (sea, industry) and increases massively if dirt accumulates between the wires and form moisture pockets in combination with salt. The surface may also have been already damaged by mechanical impact during cable installation operations.

Therefore, another layer of protection is normally applied in order to shield the zinc or galfan from environmental factors – a duplex system with a total thickness of about 400 µm. However, the lifetime of the paint coating normally used has been limited up to now. In general, such a coating is assumed to last up to approx. 25 years.

The use of butyl rubber tapes leads to a significantly longer lifetime. According to the positive experiences col-

Fig. 15. Applications: a) Passerelle des deux Rives, Kehl/Strasbourg, b) Köhlbrand Bridge, Hamburg, c) Obere Argen Bridge on A96 motorway, Wangen/Allgäu, d) Veterans Memorial Bridge, Port Arthur, Texas, USA

lected over more than four decades since the 1970s as well as in new tests, such tapes are likely to last > 60 years. In 2013 the Otto Graf Institute at the University of Stuttgart undertook another set of tests with wrapped samples, which had already been exposed to tests in 2008 (see section 3) and were additionally exposed to environmental conditions for a further five years. Even after this extreme treatment, absolutely no changes to the material or the anti-corrosion effect were evident [13].

A further indication for the long lifetime is the fact that owing to this kind of tape wrapping, there is a total of eight barriers of butyl rubber and PE film to overcome before any damaging influences can get through to the cable surface. Even if the top layer breaks down for example due to vandalism, corrosion protection is still guaranteed, because even the base layer alone has passed the tests listed in section 3.

12 Summary of features

The advantages for using butyl rubber tapes are as follows:
- Officially approved by authorities in Germany and Europe
- Quick, reasonably priced, VOC-free application
- Essentially independent of climatic conditions
- No scaffolds or enclosures, therefore minimal traffic restrictions
- No extensive preparation of the cable surface, e.g. blasting or sweeping, necessary and therefore no disposal of environmentally harmful materials
- Ability to wrap over existing coatings
- Simple repair of damaged areas
- Control areas for long-term monitoring
- Use of monitoring systems
- Use of dehumidifying systems in the case of rope bundles
- 100 % recyclable

The technical features should also be cited, which account for the excellent long-term durability of this wrapping system:
- Lifetime > 60 years
- Robust, multi-layered system made of tough materials with approx. 2.6 mm layer thickness
- Very good adhesion and interlocking with cable surface
- Highly elastic behaviour, which accommodates all temperature and load movements
- No spalling or tearing of the wrapping in the case of possible discharges of cable filling materials or with relative displacements of the wires
- Approved to corrosion categories C5-I and C5-M according to EN ISO 12944-6

13 Concluding remarks

The advantages of the ATIS Cableskin® wrapping system, which is officially approved for use across Europe, are not just the execution and short manufacturing times, but also the easy repair possibilities and the excellent long-term durability in particular. The system requires almost no maintenance. This makes it a high-quality alternative to the coating systems available up to now, which is reasonably priced, quick to apply and adapts optimally to the particular conditions.

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