Prevention of main cable corrosion by dehumidification

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ABSTRACT: Corrosion of main cables on suspension bridges is a major problem on a worldwide basis. The load-carrying wires are covered by wrapping wire and corrosion is therefore hidden and often progresses to a very serious level before it is detected. Many examples have illustrated that traditional corrosion protection systems for main cables do not prevent corrosion, but merely slows it down. This has led to the development and application of dehumidification of main cables, which truly prevents corrosion. A dehumidification system blows dry air through the main cables and keeps the atmosphere in the cables so dry that corrosion cannot occur. This paper describes the details of such a system, design considerations, results of Life Cycle Cost Analysis and experience from systems in operation.

1 INTRODUCTION

Corrosion of main cables on suspension bridges is a major problem on a worldwide basis. The load-carrying wires are covered by wrapping wire and corrosion is therefore hidden and often progresses to a very serious level before it is detected. There have been some cases where it has been necessary to replace the cables at enormous cost to the owner. In some cases it has even been necessary to close the bridge.

Many examples have illustrated that the traditional protection system for main cables, the so-called Roebling system, does not prevent corrosion, but merely slows it down. Older suspension bridges have been able to survive despite corrosion, as the safety factor for the main cables has been quite high, so a decrease of the capacity is acceptable to a certain level. Main cables on newer suspension bridges are generally designed with a much lower safety factor, which makes them more sensitive to corrosion. Relatively serious corrosion attacks on bridge cables have been found on bridges as young as ten years. It is therefore imperative to prevent corrosion of main cables, no matter the age of the bridge. Only one method has been proven to completely prevent corrosion - dehumidification. A dehumidification system blows dry air through the main cables and keeps the atmosphere in the cables so dry that corrosion cannot occur.

This paper presents:

- A description of the dehumidification concept
- A description of systems for main cables
- Considerations for designing a system
- Results of Life Cycle Cost (LCC) Analysis demonstrating that dehumidification is much more economical than a traditional system
- Case stories/experience from systems in service

2 DEHUMIDIFICATION CONCEPT

Many of the main components of major bridges are steel structures. In order to ensure a long service life and provide an appropriate level of safety, these structures must be protected from corrosion. Corrosion protection has traditionally been provided by means of surface treatment, i.e. blasting and painting. In the course of the last 35 years an alternative method - dehumidification - has been developed, implemented and proven. Dehumidification has been proven to be superior to painting in all respects, i.e. technically, economically and environmentally.

The most widespread application for bridges is the protection of the internal surfaces of closed box bridge girders. Dehumidification systems are implemented in new bridges and in existing bridges, which may have insufficient protection or need renewal of corrosion protection.

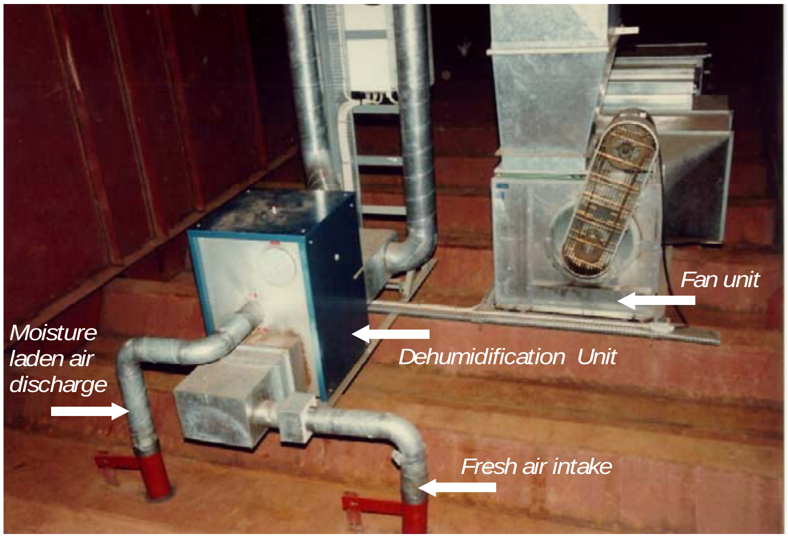

Figure 1 a dehumidification plant in the box girder of the Faroe Bridges, Denmark

Dehumidification systems have also been designed and installed in numerous other bridge structures, including:

- Anchor houses on suspension bridges
- Cables saddles on suspension bridges
- Abutment rooms
- Anchorage boxes on the top of cable-stayed bridge pylons

It has been proven by experience that corrosion does not take place if the relative humidity in the vicinity of a steel structure is kept below 60%. This is the basic concept upon which corrosion protection by dehumidification is based.

The concept of dehumidification has been known for many years and it has been successfully applied to a wide range of applications. A dehumidification plant, such as used in bridge structures, is a well-known and reliable means of keeping the relative humidity in a closed room under an acceptable level. The use of dehumidification for the corrosion protection of enclosed steel surfaces in bridges has been developed by COWI over the last 35 years. During this time the dehumidification concept for bridges has won international acceptance and is a standard requirement in many countries.

The traditional alternative to dehumidification as a means of corrosion protection for the inner surfaces of a steel box girder is surface treatment by blasting and painting. It has been proven that dehumidification by means of sorption is in all respects the superior method. The main advantages of dehumidification are:

- Dehumidification is virtually 100% effective, providing a much higher level of protection than painting.
- The initial cost of dehumidification is only a fraction of the cost of painting.
- The maintenance costs of dehumidification are much lower than for painting.
- The Life Cycle Cost of dehumidification is much lower.
- It is easy to monitor and verify the effectiveness.

- Dehumidification is environmentally friendly, as it does not have the environmental problems that are caused by blasting and painting.

There are two principally different methods of dehumidification: condensation and sorption. Sorption can be either passive or active, the main difference being the use of forced air stream. For bridge structures active sorption is applied, as it is the most effective method.

The passive means of dehumidification by sorption is well known, for example the small sachets of silica gel, which are usually enclosed in packages with electronics or other moisture sensitive products. Larger portions of sorption materials are also used for example for reducing the relative humidity in a damp basement. The passive means is not suitable for corrosion protection of steel bridge structures, where the more effective active means is applied.

The principle for dehumidification by sorption is illustrated in figure 2. This method works by binding the moisture in the process air to a hygroscopic material (a sorbent).

A sorption system contains a rotor that is built up of many small pipes, coated with a sorbent, most commonly lithium chloride. The process air is forced through the rotor and its moisture is absorbed under this process, resulting in dry air. The rotor turns very slowly, allowing time for the process. On the opposite side of the rotor heated intake air is blown through, which dries out the sorbent coating. This air becomes moisture laden and is subsequently discharged.

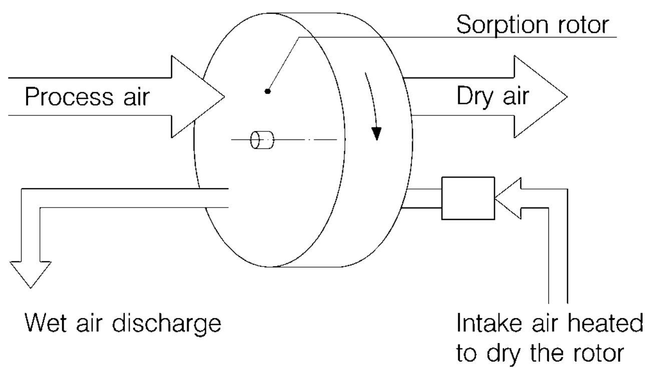

Figure 2 Dehumidification by active sorption

This method is efficient for all air conditions, i.e. there are no temperature and relative humidity limits as with the condensation method. This method is generally applied to various bridge structures with excellent results.

3 SYSTEMS FOR DEHUMIDIFICATION OF MAIN CABLES

Systems for dehumidification of main cables are generally based on the same technology as the above-mentioned applications, as well as many years of experience with these. There are three main components:

- A sealing system for the main cables, including cable bands, saddles and other connected components.
- A dehumidification system capable of producing and blowing dry air through the main cables.
- A control and monitoring system.

3.1 *Sealing system*

We have carried out extensive research, development, workshop testing and on-site testing to determine the best systems for sealing the main cables, cable bands, saddles and other connected components. We have concluded that the best system to seal the cable sections from band to band is the Cableguard™ Wrap System from the D.S. Brown Company. This is an elastomeric wrap with a thickness of 1.1 mm and a width of 200 mm. It is applied with a 50% overlap, so the total thickness is 2.2 mm. It is applied under tension with a special wrapping machine. After wrapping a section it is heat bonded with a special heat blanket, which melts the two layers together and shrinks the material slightly, giving an even tighter fit. Special details have been developed to ensure sealing at the transition to the cable bands and to give a uniform appearance. The main advantages of this system are:

- Lower Life Cycle Cost
- Able to withstand sufficient overpressure
- Environmentally friendly, no paint products to remove or apply
- Can be supplied in numerous colors - requires no paint
- Good working environment, no fumes and no blasting work
- Execution is less sensitive to poor weather
- Shorter construction period
- Virtually maintenance free
- Long lifetime - UV and weather resistant
- Easy to remove and replace - does not bond to the cable

Figure 3 Wrapping and heat bonding of the two layers

For sealing of cable bands, saddles, injection and exhaust collars and other components special details have been developed. These are generally based on a double barrier system with a combination of sealer strips and adhesive caulk. Materials which have been applied for similar usage over many years on bridges are generally applied.

3.2 *Dehumidification system*

The dehumidification system produces dry air and blows it through sections of the main cables. The system assures overpressure inside the sealed cable system. While the sealing system may have minor imperfections in the form of small leaks, no water or moisture will enter the cables, as the overpressure will prevent this.

The dehumidification system is made up of the following main components:

- Dehumidification plants
- Injection points
- Exhaust points

A layout, such as shown below, is developed for the dehumidification system. The layout defines the positions of the dehumidification plants, injection and exhaust points as well as the flow sections.

3.3 *Control and monitoring system*

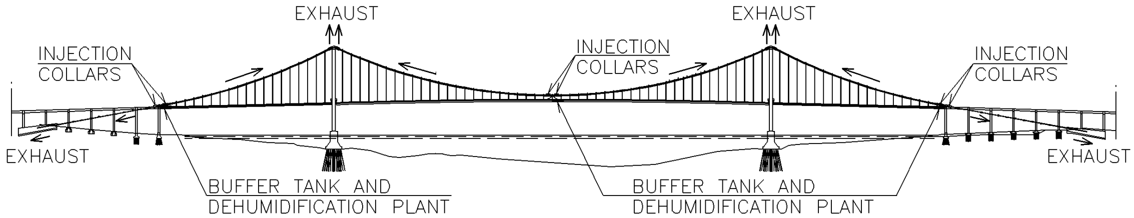

Figure 4 Dehumidification system layout, Little Belt Bridge, Denmark

The dehumidification plants are placed in buffer tanks for several reasons:

- This provides a protected atmosphere.
- Good access.
- Electrical consumption is minimized as the air is mixed up to 40% RH instead of the app. 0% RH that the dehumidification units produce.

The main components of a dehumidification plant are a dehumidification unit, a fan, an electrical board, filters and ducting, such as illustrated below.

Injection points are established by either modify existing bridge components, such as the saddles or by designing purpose suited injection collars, such as illustrated below. Exhaust points are established in the same manner.

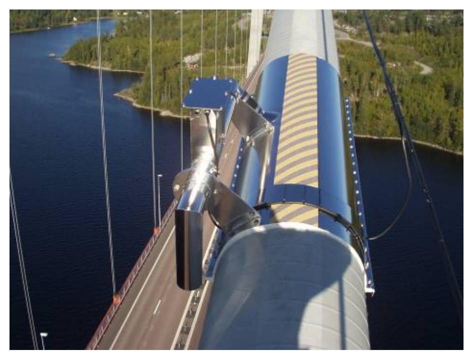

Figure 5 Dehumidification plant (left), injection (upper) and exhaust points (lower)

3.4 *Control and monitoring system*

The control and monitoring system allows adjustment of the system and data from the system documents that the system is performing properly. Instrumentation is arranged at the dehumidification plants, in the buffer tanks and at injection and exhaust points. These instruments and plants are connected to local PLCs (Programmable Logical Computer), which in turn are connected to a central computer, which stores all data. From the central computer it is possible to adjust the system and monitor the readings from all the instruments. Key data to be monitored includes system functionality, relative humidity, temperature, flow, and pressure.

KEY DESIGN CONSIDERATIONS

The key design considerations for a system for dehumidification of main cables are basically the same considerations that are generally applicable to suspension bridge design:

- Optimization of design - lowest Life Cycle Cost (LCC)
- Accessibility
- Durability
- Verifiability
- Minimal traffic disruption

A system for dehumidification of main cables is in itself the optimal corrosion protection system for main cables, cf. chapter 5. The system for each bridge should however be optimized. Optimization starts with the layout, which should be suited to the cable lengths and utilize the bridge's existing elements as integrated parts of the system. An example of this would be to utilize the enclosed room of a box girder as a buffer tank. Electrical consumption should be kept at a minimum by utilizing features such as buffer tanks and minimizing the overpressure in the cables. Utilization of well-documented materials with a long lifetime should also be included in the design. When new details are developed these should be proven and further optimized by full scale testing.

All components which require service should be easily accessible without disturbing the traffic. Dehumidification plants and instrumentation can for example be placed inside the box girder and pylons. As much as possible no components should be installed along the main cable, as this would be detrimental to access to the cables and be an obstruction when carrying out other maintenance activities.

The above-mentioned placement of service requiring components also improves the durability of these components and minimizes the LCC. A monitoring system should be designed such that at all key data to verify the systems functionality and corrosion protection of the main cables is well documented.

4 LIFE CYCLE COST ANALYSIS

A Life Cycle Cost (LCC) Analysis should be carried out to determine the correct methods to be applied to the details of a bridge structure. In such an analysis all costs connected with each detail are considered, including construction, maintenance, repair and replacement. Traffic disruptions due to the works should also be capitalized. The present values for all costs are calculated by use of a compound interest rate, usually in the range of 4 to 6%. The detail with the lowest net present value (sum of present values of all costs) is the optimal detail.

Such analysis has earlier been carried out for corrosion protection of the inner surfaces of a box girder by means of dehumidification contra traditional protection by painting. The conclusion was that the net present value of dehumidification was only a few percent of the net present value of a paint system, resulting in enormous savings during the lifetime of the bridge.

In connection with completed projects we have carried out LLC Analysis for the following cases:

- Renewal of corrosion protection for main cables on existing bridge
- Corrosion protection of new main cables

The conclusion in both cases is that a dehumidification system including elastomeric wrap is by the far optimal solution. The results of these analyses are included in the following two sections.

In the following examples we have not included the costs for:

- Traffic disruptions (extra driving time for users), as this is not standard practice in all countries.
- Traffic regulations (signs, barriers and the like), as this varies greatly from country to country.

If these costs were included a dehumidification system would be even more advantageous, as there are fewer and shorter periods with traffic regulation and disruption.

The costs in the examples are based on European experience from actual projects. The costs are given as reference costs (not in monetary values), as local conditions may give substantial variation. The purpose of the results is to illustrate the relative difference and the economic advantage of a dehumidification system.

The calculations are carried out for a period of 60 years, such that a sufficient amount of major repairs and replacements are included in all strategies, hence the results are representative for the entire lifetime of the bridge.

4.1 *Renewal of corrosion protection*

In this example we have calculated the life cycle costs for the following strategies:

1. Application of elastomeric wrap and a dehumidification system
2. Renewal of paint

The following lifetimes and assumptions for strategy 1 are utilized:

- Elastomeric wrap - lifetime 30 years
- Exposed ducts and details - lifetime 30 years
- Dehumidification system - lifetime 60 years
- Electrical consumption and yearly service included in costs

The following lifetimes and assumptions for strategy 2 are utilized:

- Removal of paint and application of new paint system - lifetime 20 years
- Spot repairs - every 5th year
- The paint system is not red lead

An alternative to strategy 2, strategy 2a, has also been calculated. In strategy 2a the lifetime of the new paint system is more optimistically assumed to be 30 years, such that the following lifetimes and assumptions for strategy 2a are utilized:

- Removal of paint and application of new paint system - lifetime 30 years
- Spot repairs - every 5th year

The results of the LCC analysis - net present values - are shown in figure 6 and 7. The strategy with the highest LCC for each interest rate has been given index 100 and the LCC for the other two strategies are given relative to this.

Strategy	Compound interest rate		
	4%	5%	6%
1. Dehumidification incl. wrap	70	72	75
2. Paint 20 years	100	100	100
2a. Paint 30 years	84	86	87

Figure 6 Results of LCC including initial investment and operation and maintenance costs over 60 years

Strategy	Compound interest rate		
	4%	5%	6%
1. Dehumidification incl. wrap	47	44	42
2. Paint 20 years	100	100	100
2a. Paint 30 years	66	65	63

Figure 7 Results of LCC for operation and maintenance costs over 60 years (excl. initial investment)

The results of the analysis clearly show that strategy 1, dehumidification and wrap, is the optimal strategy. As the initial investment for all three strategies are calculated to be of the same order (strategy 1 is app. 10% lower) the difference between strategy 1 and 2 in figure 6 is not as substantial as for operation and maintenance alone, as shown in figure 7. The results in figure 7 also illustrate that dehumidification is much more maintenance friendly, as there is a substantial difference from the other strategies.

If the following costs were taken into account dehumidification would much more advantageous:

- It is a well-known fact that the main cables will deteriorate to a certain degree when a painting strategy is applied. This results in enormously expensive intrusive inspections and rehabilitation works. These costs and the lost value due to deterioration (reduced load carrying capacity) are not included in the analysis.

- If red lead paint is to be removed/applied the painting strategy would be even more expensive due to environmental costs.
- A painting strategy requires many long traffic disruptions and the costs of traffic regulations and lost time for users are not included.

4.2 *Corrosion protection of new main cables*

In the case of new main cables there are even greater savings to be made by applying dehumidification. Besides the savings mentioned above there are also the following savings:

- The zinc paste and wrapping wire can be omitted.
- Shorter time schedule due to these omissions - indirect savings.
- Less dead load to carry - indirect savings to structures (main cables, pylons, anchorages and foundations).

In this example we have considered a large suspension bridge and calculated the life cycle costs for the following strategies:

1. Traditional system with zinc paste, wrapping wire and paint
2. Dehumidification system with elastomeric wrap (no paste or wrapping wire)

The results of the LCC analysis - net present values - are shown in figure 8. For illustrative purposes the LCC for strategy 1, traditional system, has been given index 100 and the other life cycle costs are given in relation to this. A compound interest rate of 4% has been applied and a representative period of 60 years is considered.

Life Cycle Cost	Strategy	
	1. Traditional	2. Dehumidification
Initial construction	40	8
Operation and maintenance	12	4
Indirect construction *	48	0
Total LCC	100	12

Figure 8 Results of LCC for a 60-year period with interest rate 4%

*) Cost due to dead load of zinc paste and wrapping wire on structures

The results of the analysis show very clearly that strategy 2, dehumidification and wrap, is by far the optimal strategy. If the additional costs concerning strategy 1, traditional system, as described in section 5.1 (traffic disruption and cable deterioration) are also taken into the account the conclusion would be even stronger.

5 CASE STORIES

5.1 *Little Belt Bridge, Denmark*

The Little Belt Suspension Bridge carries the E20 motorway and connects east and west Denmark. The bridge was opened in 1970 and it carries three lanes of traffic in each direction. The suspension bridge has a main span of 600 m and two side spans of 240 m for a total length of 1,080 m. The approach spans have a total length of 620 m, giving a total length of 1,700 m for the entire connection.

Figure 9 Little Belt Bridge, Overview and on-site injection and flow test

The superstructure is a steel box girder with a width of 33.3 m. It is the first bridge structure in the world to be protected from corrosion internally by means of dehumidification.

The main cables are each approximately 1,500 m long with an outer diameter of 580 mm and are made up of helical strands. The original corrosion protection is a modified Roebling system, made up of: 1. Galvanized wires in the strands, 2. Zinc paste on the bundle of strands, 3. Galvanized wrapping wire and 4. Paint on the surface of the wrapping wire.

In 1996 the lifetime of the surface paint was nearly depleted and a series of activities was instigated to determine the optimal strategy for the future corrosion protection. This included in-depth inspections, testing of paint and wrapping systems to seal the cables and pressure and flow tests. Based on the experience from these investigations a technical and financial analysis was carried out, including Life Cycle Cost Analysis. The optimal solution was determined to be wrapping with elastomeric wrap (Cabelguard™) combined with dehumidification.

The works were carried out within the time schedule during 6 months in 2003. The layout of the system is illustrated in figure 4. The system has been in service for 3 years and is performing well, as confirmed by data from the monitoring system and inspections. Data from this period indicates that the relative humidity of the dry air supply in the buffer tanks is generally about 40-45% and that the corresponding exhaust air is generally in the range of about 35-55%, see figure 10. No leakage of the sealing system has developed, which is documented by data from the monitoring system, as the ratio between exhaust and injection flow has been constant.

The buffer tanks ensure a minimal running time of the dehumidification units, which are the only components with a relatively high electrical consumption. The total electrical consumption of the entire system is very low, app. 20,000 kWh per year.

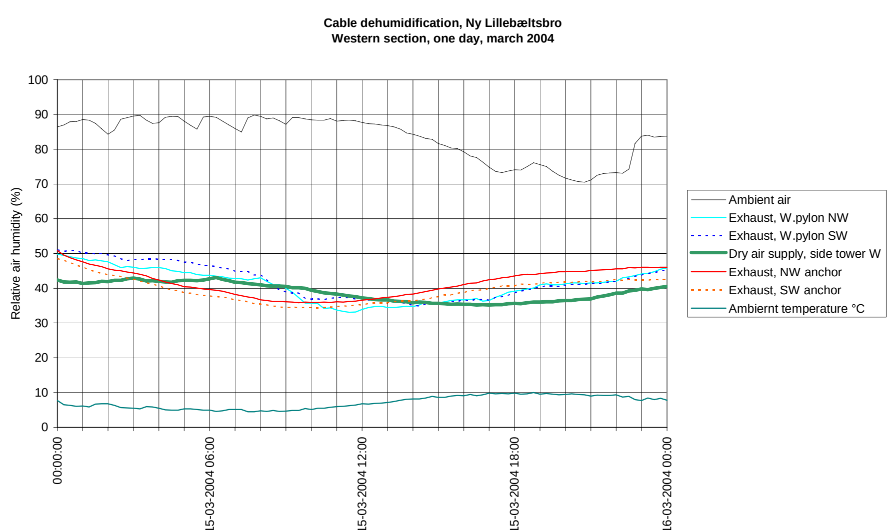

Figure 10 One-day graph: relative humidity of injection air, exhaust air and ambient air and temperature

5.2 *Aquitaine Bridge, France*

The Aquitaine Suspension Bridge crosses the Garonne River in Bordeaux, France and was opened in 1967. The suspension bridge has a 394 m long main span and two 143 m long side spans for a total length of app. 680 m.

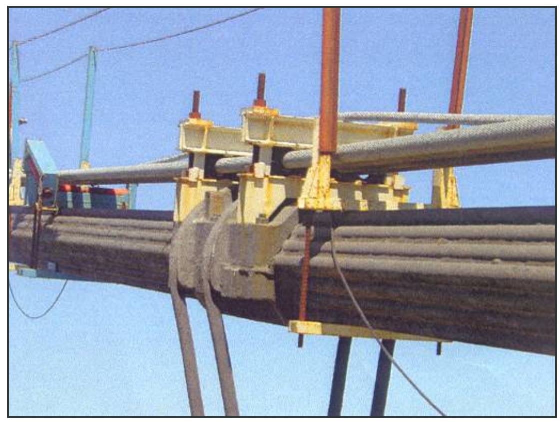

Figure 11 Aquitaine Bridge, Overview and temporarily strengthened main cables

The original main cables were each composed of 37 locked coil strands, see figure 11. Due to tradition in France at that time the wires of the strands were not galvanized. The only corrosion protection for the main cables was therefore the paint applied to the surface of the strands, which was only maintainable on the outer surface of the outer stands on the stretches between cable bands. These circumstances resulted in serious corrosion problems, which were already detected at a very early stage. As early as 1979 a number of ruptured wires were detected. The cable deterioration continued over the following years and was closely monitored. The worst damages were located at the cable bands, where moisture could accumulate and it was not possible to maintain the paint. Ruptures occurred as deep as 4 layers into the strands. Due to the serious condition of the main cables the owner (La Direction Départementale de l´Equipement de la Gironde) decided in 1999 that the entire cable system should be replaced. The carriageway should at the same time be expanded from four to six lanes. The corrosion protection system for the new main cables should obviously be upgraded to the present state of the art.

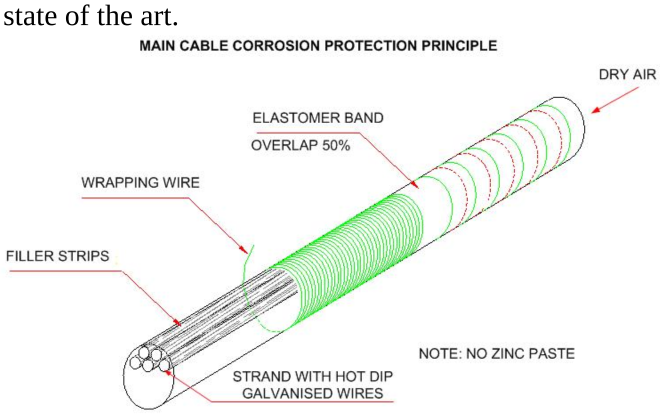

Figure 12 New corrosion protection system

The corrosion protection system for the new main cables is composed of: 1. Hot dip galvanization of all wires in the strands 2. Hot dipped galvanized wrapping wire, 3. Elastomeric wrap and 4. Dry airflow, see figure 12. The normal zinc paste layer has been omitted, as it is not necessary. This gave substantial savings and allowed a much faster installation of the wrapping wire, which was performed in the course of just one week per main cable.

A dehumidification plant is located at the top of each pylon and feeds dry air into the main cables, which flows to exhaust points at the middle of the main span and at the anchorages. The control and monitoring system includes:

- Ambient temperature and relative humidity
- Relative humidity, temperature and pressure at injection and exhaust points, as well as at intermediate points

The construction was completed in 2003 and the system has been performing well. The relative humidity of the exhaust air is quite constant at an average level of app. 25%. Based on operation experience the system can be further optimized to allow a more economical operation. The dehumidification plants can be controlled by the relative humidity of the intermediate points and thereby only run when it is necessary. The target level for a possible optimization is 40% RH with brief peaks of up 50% RH allowed.

5.3 *Högakusten Bridge, Sweden*

The Högakusten Suspension Bridge carries the E4 over the Ångerman River about 400 km north of Stockholm, Sweden and opened in 1998. The main span is 1,210 m long and the side spans are 310 m and 280 m long, giving a total length of 1,800 m. The main cables are made up of parallel wires with an outer diameter of 650 mm. Each cable is approximately 1,900 m long. The corrosion protection system for the main cables was design as a traditional system with galvanized wires, zinc paste, wrapping wire and paint.

Figure 13 Högkusten Bridge, Cable works commenced and condition of wires on bottom of cable

From the very beginning it was observed that large amounts of water flowed through the cables and especially after rainy periods water could be seen dripping out of the open lower joint of the cable bands and the drain holes in the central node. Water ingress was due to several conditions. During construction it was decided to omit the zinc paste. This fact combined with a somewhat defective paint system and other details allowed water to enter the cables and led to an accelerated deterioration of the corrosion protection. The Swedish Corrosion Institute inspected the cables and analyzed the drainage water. The conclusion in 2003 was that the zinc galvanization on the cable wires would be depleted within about ten years. The wrapping wire was removed over a 2 m section at the low point by the central node in 2004, see figure 13, and the condition here confirmed the prediction. The zinc was depleted and there were signs of ferrous corrosion on the bottom wires of the cable and the inside of the wrapping wire.

In early 2004 COWI was awarded the project for a new corrosion protection system to be based on dehumidification and experience from the two above-mentioned bridges. Based on the outline design studies a layout with flow sections of app. 310 m was chosen. The system is arranged with buffer tanks of dry air in the top of the pylons and in the bridge box girder at mid span. From the pylons the dry air flows to exhaust points at the anchorages and half way to the mid span. From the box girder at mid span dry air flows to the mutual exhaust points, half way to the pylons.

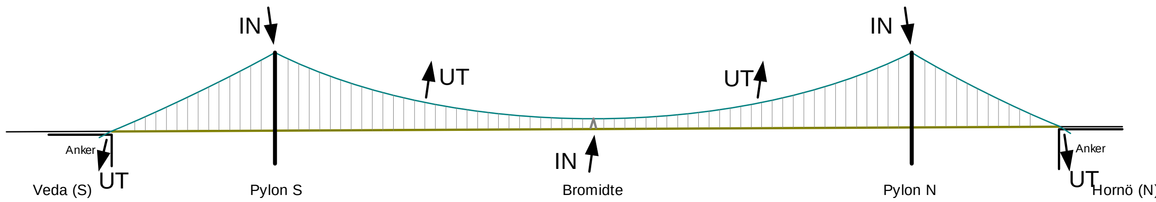

Figure 14 Layout of dehumidification system

The control and monitoring system includes measurement of: 1. Buffer tanks: relative humidity, temperature and functionality of plant, 2. Injection points: dry airflow, 3. Exhaust points: relative humidity, temperature and dry airflow and 4. Ambient: relative humidity and temperature.

Despite 25% downtime due to poor weather, the works were completed in just six months, from April to October 2005. The system has now been in operation for about 7 months and data from the monitoring system indicates that the system is functioning well and that the sealing of the cables has been done very well. As expected the exhaust air is so far quite moist, as it will take some time to dry out the large amounts of water in the cables. The monitoring system also calculates the water content in the injection and exhaust air and the difference between the two levels has been on the average app. 1.5 g/kg. This corresponds to an average of app. 1 litre water per day, which is removed from each cable stretch. When the drying out process is completed it will be possible to calculate the total amount of water removed from the cables. Further analysis of monitoring data is currently underway.

5.4 *Messina Bridge, Italy*

The Messina Bridge, which will connect Calabria with Sicilia in Italy, has a main span of 3,300 m and 380 m tall pylons. There are four main cables, each with a diameter of 1.2 m.

Figure 15 Overview of the Messina Bridge

The bridge authority Stretto di Messina S.p.A. required in the 2005 tender project that dehumidification of the main cables be analyzed with regards to feasibility and Life Cycle Cost and compared with a traditional corrosion protection system. Dehumidification was to be applied if found advantageous. Based on experience from the dehumidification systems on other bridges, a dehumidification system for the main cables was developed. Dehumidification plants are placed in buffer tanks in the top of both pylons and at two positions in the bridge girder. Dry air from the buffer tanks is injected in the main cables and flows to exhaust points. The results of the Life Cycle Cost Analysis indicate that the construction cost for a dehumidification system is 77% less and that the net present value of operation and maintenance over the first 60 years is 71% less than a traditional system. There are also substantial indirect savings in construction costs due to lighter cables.

6 CONCLUSION

A dehumidification system, composed of a sealing system, a dry air system and a monitoring system, is in all regards the state-of-the-art method for protecting main cables from corrosion. This is the only system which completely prevents corrosion, whereas other systems at best can only slow it down.

A dehumidification system can be integrated in the design of a new bridge or new cables, such as the Aquitaine Bridge, or it can be designed to suit the needs of an existing bridge such as the Little Belt Bridge or the Högakusten Bridge. Furthermore, it is equally well suited for main cables made up of parallel wires, such as the Högakusten Bridge, and cables made up of strands such as the Little Belt Bridge or the Aquitaine Bridge.

The major advantages of dehumidification system contra traditional systems are:

- Corrosion is completely prevented.
- Monitoring ensures that this is well documented.
- The Life Cycle Cost is much lower, app. 50 - 80% lower.
- Environmentally friendly - no toxic waste from removal or application of paint or paste.
- Safer for workers - no exposure from removal or application of paint or paste and generally better working conditions.
- Construction is less sensitive to weather conditions and much faster.
- As zinc paste is not necessary the wrapping wire can be applied much faster than usual, giving direct savings as well as extra timesavings.
- Much less traffic disruption due to a shorter construction period and much less maintenance.

The major advantages of a dehumidification system for main cables are clear and the technology is well proven. Many bridge owners have already wisely decided to implement such a system and prevent corrosion of the main cables so they will serve the bridge and its user for many generations to come. All bridge owners should follow suit and ensure the safety of their cables and thereby their bridges.

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