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Air-Dehumidification in a Box Girder Bridge

Déshumidification de l'air dans une poutre à caisson de pont

Luftentfeuchtung im Kastenträger einer Brücke

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SUMMARY

The suspension bridge across Lillebaelt is constructed with a deck comprising a closed box girder made of steel, where the interior faces of the steel girder are protected against corrosion by controlled circulation of air of low relative humidity.
This article describes the design of the ventilation and dehumidification plant, the experience gained after 7 years of running of the plant and the costs of installation and running expenses. Furthermore, a brief outline is scheduled of technical and economical aspects involved in construction of dehumidification plants in bridge structures.

RESUMÉ

Le pont suspendu sur le Lillebaelt possède un tablier constitué d'une poutre à caisson métallique. L'intérieur de cette poutre est protégé de la corrosion par une circulation forcée d'air à faible humidité relative. L'article décrit la structure et le fonctionnement de l'installation de ventilation et de déshumidification et mentionne les expériences acquises au cours de 7 ans d'utilisation; il donne aussi des renseignements sur le coût de l'installation et les frais d'exploitation. L'article présente enfin les aspects techniques et économiques à considérer lors du montage d'une installation de déshumidification dans les ponts.

ZUSAMMENFASSUNG

Der Versteifungsträger der Hängebrücke über den Lillebaelt ist kastenförmig ausgebildet, wobei die Innenflächen durch gesteuerte Zirkulation von Luft mit niedriger relativer Feuchtigkeit geschützt werden.
Der Artikel beschreibt Aufbau und Funktion der Ventilations- und Entfeuchtungsanlage. Betriebserfahrungen über 7 Jahre werden mitgeteilt und Informationen über Kosten für die Installationen und den laufenden Betrieb gegeben. Zudem werden technische und wirtschaftliche Aspekte bezüglich Einbau von Entfeuchtungsanlagen kurz berührt.

1. INTRODUCTION

Most of the major bridge projects are today made with a superstructure consisting of closed box sections supporting the bridge deck. For box sections in steel the initial execution of painting and the following regular maintenance present considerable problems, partly for environmental reasons, partly because of the high costs.

In connection with the construction of the motorway bridge across Lillebælt, Fig.1, [1], which is a suspension bridge with a steel box girder, length approx. 1100 m, and an interior area to be painted exceeding 200,000 sq.m., the initial studies concerning corrosion protection indicated that installation of a dehumidification and fresh-air supply plant within the box girder would be advisable.

The plant circulates air of a low relative humidity through the entire box girder, and thus protects the steel structure against corrosion. At the same time a limited supply of fresh air ensures that the interior of the box can be inspected without presenting any health hazard to the inspection crew.

The plant has now been running for approx. 7 years. After a brief period of trial-runs it is now operating without any problems and at an acceptable economical level.

The effectiveness of the plant is indicated by a number of sand-blasted - but otherwise unprotected - control-plates of steel, hanging within the box girder for more than 5 years without showing any signs of coating or other corrosive attacks.

2. VENTILATION AND DEHUMIDIFICATION OF THE SPACE INSIDE THE BOX GIRDER

The box girder is divided into three compartments, the two between the main towers and the side towers, and the one between the two main towers. The last mentioned has further been divided into two compartments by an airtight partition in the middle so there actually are four compartments of almost the same volume (19-24,000 cub.m.).

The problem is then to secure fresh air in the compartments when under inside inspection and to keep the relative humidity of the air in the space below 40% the year round.

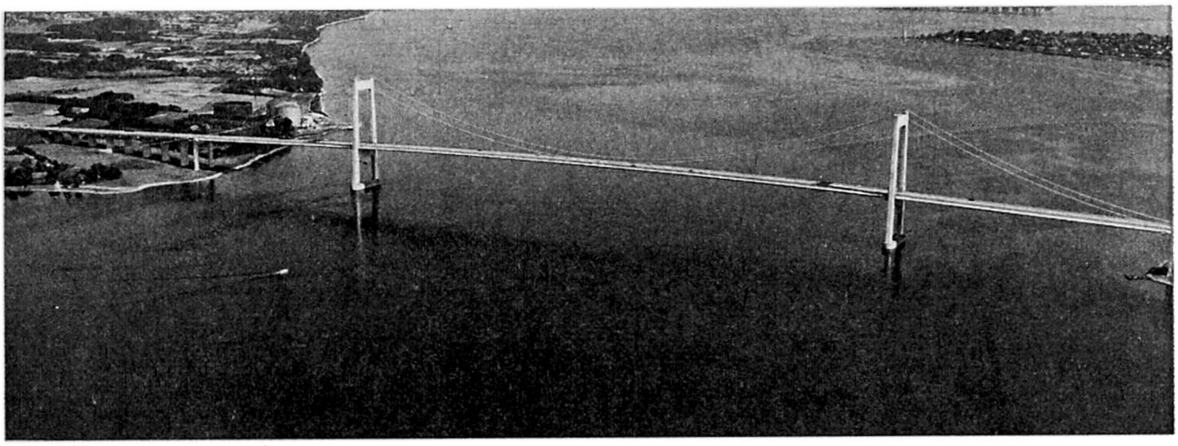

Fig. 1: Lillebaelt Suspension Bridge,
Main span 600 m, box girder width 33 m, height 3 m

The ventilation systems must have an air-intake and it is most convenient to place it in the bottom of the box. The air passes then through a damper to a mixing chamber, a fan, and finally through some duct-work to distribute the air uniformly through the compartment. When the incoming air is uniformly distributed, the return air can just pass through the space and be exhausted through a damper to the outside air, through the bottom of the girder or to the mixing chamber of the fan.

By manoeuvring the dampers by remote control it is possible either to use the aggregate as a fresh-air unit, or as a recirculating unit. The first is necessary when the compartments are under inspection, the second the rest of the year when only dehumidification is necessary.

The dehumidification is done by means of a "Munter's" aggregate which consists of a rotating drum having inside lengthwise sheets covered with lithiumchloride. By rotating the drum, the sheets will pass two airstreams. The first will be the air from the box-girder that needs dehumification, and the second will be electrically heated outside air, able to remove the absorbed humidity from the sheets.

This aggregate is placed in such a way that part of the circulated air is passing through it. The fresh air for dehumidifying the sheets is let in and out through openings in the bottom of the girder.

To prevent dust from accumulating in the aggregates and the box-girder, filters must be provided ahead of the aggregates.

The four aggregates for ventilating and dehumidification are made alike, each having a capacity of 13,000 cub.m./h and able to remove 700 kg water vapour per day. That means that the air in a compartment can be renewed in between 1.5 and 2 hours. The dehumidification is calculated to remove all the excess humidity after an inspection in about 2 hours.

To maintain the relative humidity at 40%, two hygrostats are placed in the compartment, one in each end. The sensitive element is specially prepared cotton-strips, and it stops and starts the ventilating unit which starts the "Munter's" aggregate at the same time. To supervise the conditions in the compartment, three hygrometers are placed there, giving alarm at the bridge-inspector's office, if the humidity exceeds 50%.

The operation of the four plants has been good, although there were a few items that had to be changed when they had been working for some time.

The hygrostats were difficult to keep adjusted to their right setting and needed constant check-up. The dehumidifying aggregates had too high a capacity and often were not in operation for days. Finally, it was decided to let them rum twice each day for ½ hour, and by measuring the conditions in the compartments it was found that it was sufficient, and the hygrostats were set out of control.

It was also important to keep the dampers tight when they were closed because the strong winds could upset the balance and give a high rate of air-change in the compartments and thereby give admission to humid air into the compartment.

The result of the 7 years of operation have given the following specifications adaptable for Danish climate conditions:

1. The ventilating aggregate shall be able to distribute evenly the air corresponding to 0.5 airchange/hour for the volume of the enclosed space.

2. The dehumidifying aggregate shall be able to remove 10 g water vapour/week per cub.m. of the volume of the enclosed space.

3. The ventilating aggregate shall be run by a timer so it is operating every day. The length of time can be found by experiment having a hygrograph placed for some time in the space. It is, of course, also possible to use a different and more stable hygrostat if such is available.

The capacity of the "Munter" aggregates depend upon temperature and humidity, so the above-mentioned capacity is at 0°C and 90% relative humidity.

In the summer at 25°C and 50% relative humidity the capacity is about twice as high.

The most demanding time of the year is in the fall where the humid summer air, gradually being cooled through the night, puts the greatest strain on the dehumidifyer, but if it is calculated as above-mentioned, it will have ample effect.

The drawing [fig. 2] shows the installation of the aggregate in the box girder in the Lillebælt bridge.

To the right the two fresh-air intakes in the bottom of the girder, then the return-air damper and the fresh-air damper, both ahead of the mixing chamber. Then comes the filter and the connection to the "Munter" aggregate and the by-pass, and further to the left the fans and the two ducts, to the right and left side of the girder.

To the left it is shown how the left duct is split up in two, because the aggregate is placed in the middle of the compartment.

In front of the main aggregate, the "Munter" aggregate is placed with its rotating drum in the middle, the filter and the electrically heated element to the left and the fan to the right. Fig. 3 shows the plants diagram.

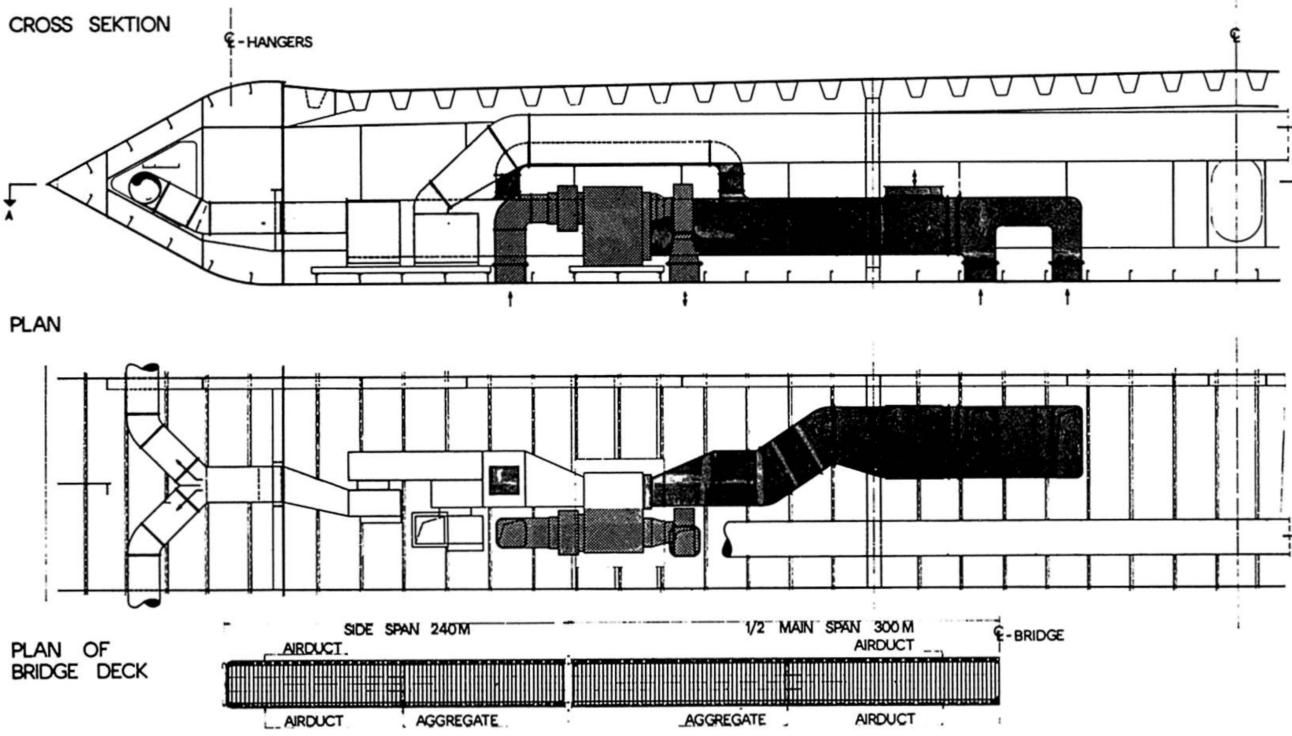

Fig. 2: Installation of the aggregate in the box girder

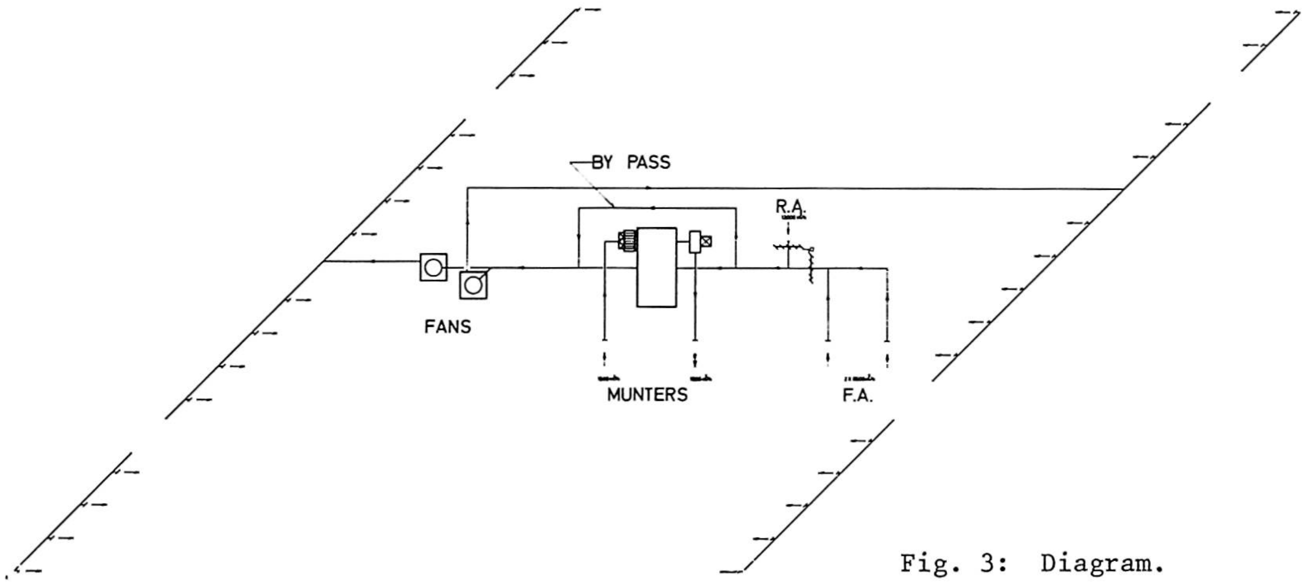

Fig. 3: Diagram.

The capacity of one aggregate is 30 kg water per hour, using 44 kW for power and regeneration. The actual number of operational hours has been 440 per year, using 19,300 kWh per year per compartment.

As mentioned, the capacity of the dehumidification plant is somewhat larger than necessary.

At the time of planning the plant, no relevant records were available from installing such plant in bridge structures. Therefore, in the design we had to allow for the bridge location across water in the special Danish climate, which - for extended periods - is extremely humid.

3. INSTALLATION AND RUNNING OF PLANT, CONSTRUCTION AND RUNNING COSTS

The installation of the plant was carried out concurrently with the positioning and fixing of the box girder elements by placing the airducts in the girder elements prior to their hoisting and fixing to the bridge deck. The four dehumidifying and ventilating aggregates are joined in a way that allows the various parts to be installed, and if necessary replaced, through a manhole in the bridge deck. The plant could operate shortly after fixing of the final box girder units.

The running of the dehumifying plant is controlled by a fixed programme in connection with the general maintenance of the bridge, which is carried out by a Bridge Maintenance Supervisor by the Road Department. A weekly control reading of the air humidity is taken and the plant is serviced once every year. After adjustments during the running-in-period, as mentioned in para 2, the plant has worked satisfactorily. The necessary maintenance is largely limited to cleaning and replacement of filters.

The total cost for supply and erection of the four units of the dehumidifying plant for the bridge across Lillebælt, including all airducts, amounted to approx. 600,000 Danish kroner at 1968 price level.

This amount equals 5 to 7% of the cost of a sound surface treatment on the inside faces of the box girder.

The annual running and maintenance costs of the plant has after the running-in-period been fairly constant as the expenses are largely determined by the electrical power consumption. If we again relate the running and maintenance costs to the cost of the above-mentioned surface treatment we arrive at a figure of 0.15 to 0.20% yearly.

The surface treatment actually carried out on the inside faces of the box girder largely comprises a red-lead-urethan primer and an asphalt paint, and is still undamaged. Judging from 7 years running experience, future maintenance of the surface treatment will scarcely be necessary.

4. FUTURE USAGE IN STEEL BOX GIRDER BRIDGES

The good experiences with the dehumidification of the box girder voids in the bridge across Lillebælt imply that corrosion protection of the inside faces of box type structures will be economically viable where plants of similar nature, as herein described, are installed - even at considerably smaller structures.

The execution and maintenance of surface treatment inside closed box girders constitutes a problem, partly due to the heavy congestion of stiffeners on the internal faces, partly due to the often limited access possibilities. Furthermore, one has to consider the environmental hazards for the maintenance workers, a point where more and more emphasis is put today.

The standard of the surface treatment may be reduced considerably by controlling the dehumidification of the air inside the box girder and thereby one may reduce extent and cost of the work, because the protection in this case may be limited in time to primarily cover the period of installation until the starting up of the plant. In special cases, e.g. at short construction periods, a treatment of shop-priming may suffice.

In the completed stage of the bridge, the maintenance costs will largely equal the running and maintenance costs of the dehumidification plant because the surfaces of the steel probably will not require further treatment when the relative humidity is held at approx. 40%.

The plant will usually adapt well to the available space and normally the system of airducts may be simpler compared to the described system, where a particularly intensive distribution of air was demanded by the close proximity of diaphragms.

Bridge structures with two or more box girders in the cross section may not need a system of airducts when a suitable arrangement of duct connections between the girders is introduced.

5. ACKNOWLEDGEMENT

Details in connection with the daily running and maintenance costs have kindly been made available by the administrative authorities of the bridge. The Bridge Owner is the Ministry of Works, Directorate of Roads.

The engineering design for the dehumidification plant for the bridge across Lillebælt has been carried out by Cowiconsult (formerly Chr. Ostenfeld & W. Jonson) in collaboration with Korrosionscentralen, Denmark - as part of the main design for the entire bridge.

REFERENCES:

[1] "Motorway Bridge across Lillebælt" Technical Publications. Chr. Ostenfeld & W. Jonson, Copenhagen, Denmark 1970.