Effects of

Surface Coatings

and

Cathodic Protection

on

Alkali-Aggregate Reaction

TREATMENT OF STRUCTURES BY WATERPROOF COATING

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ABSTRACT

In the field of the treatment of the structures affected by A.A.R. (Alkali-aggregate reaction), the drying out of concrete represents, in theory, the most judicious way to reduce or to stop the development of this phenomenon. However, its application in ideal conditions is not easy. It requires especially, the application of a sufficiently efficient waterproof treatment on all surfaces exposed to humidity.
In this context, laboratory testing, based on expansion tests of reactive concrete specimens which were, dried, treated and then stored in an atmosphere at 38°C and 100 % relative humidity, was first, carried out to evaluate the effectiveness of various waterproofing systems. Although, these tests showed great variability of the performances of products, they did not find one perfect product.
Nevertheless, the deck of a bridge affected by an evolutive A.A.R. was completely treated with one of the products which gave the best results on test samples, this being a thin coating of acrylic resin-cement. Accurate monitoring of the dimensional variations of the structure, its mechanical behaviour and the condition of its facings show, up to now, no adverse effects. It is still too soon to come to a conclusion on the longterm outcome of this method of treatment on structures affected by alkali-aggregate reaction, and the measurements are being continued.
Keywords : *Alkali-aggregate reaction, expansion test, longterm outcome behaviour, monitoring dimensional variation, waterproofing coating.*

INTRODUCTION

Structures affected by A.A.R. cause management problems, insofar as their treatment has not provided up to the present time a reliable and definitive solution, and disorders caused A.A.R. promote the appearance of other pathological phenomena such as corrosion or frost-thaw damages. Amongst all the parameters having an effect on the development of an A.A.R. in a structure, water is *a priori* the parameter which one can control more easily. If the drying out of concrete represents, in principle, a more judicious process in order to reduce or stop the phenomenon, in practice the thickness of the structures make it difficult to completely dry out concrete.
The first attempts at treating structures affected by A.A.R. were by injecting the cracks, usually with epoxy resins. Whether such attempts took place in France [1]

[B.Godart 1993] or abroad, either they nearly all resulted in failure; some cracks reopened or new cracks appeared beside old ones. It is understandable that if the resin prevents water penetrating the cracks, it provides no protection from the penetration of water or humidity to the major part of the facings.
If methods of treatment using coatings would seem *a priori* better than filling in the cracks, it must be acknowledged that the few attempts made using paint are far from being conclusive, even when paint is applied at the time of construction. On the otherhand, technical literature shows that certain treatments using waterproof coatings would tend to appear effective [3] [B.Godart 1992].

CRITERIA IN THE CHOICE OF COATINGS

In order that coatings are effective against A.A.R., they must comply with a minimum of five criteria as follows :

- Impermeability to water and if necessary to water vapour ;
- Resistance to the progressive cracking of the support (the coating must be able to withstand, thanks to its elasticity, against future cracking when the A.A.R. continues to develop during a certain period after the structure has been treated);
- Durability of the coating, this characteristic covers not only the usual criteria to withstand peeling or blistering, but also the maintenance of its mechanical properties such as elasticity, withstand cracks, etc.
- Resistance to the sun ultra-violet radiation ;
- Sufficient bonding to its support

Even though thick coatings might have to be used in order to comply with the criteria, we thought it would be also useful to test, for comparative purposes, the effectiveness of more standard coatings such as paint, or products whose efficiency has already been praised in technical reports, such as silane-based impregnation products. Finally, we tested a coating using aluminium foil which appeared to us as a product which can be mentioned for reference purposes as a coating which is more watertight than others.
The list of different products used for tests is as follows :

- Water-repellent surface coating (silicones and silanes)
- Stain products and paint used in the building trade (acrylic, polyurethane, polyester, epoxy)
- Thin cement-polymer coatings

EFFICIENCY TESTS

The principle of the test is, after applying the products, to test concrete samples which are potentially expansive due to A.A.R., to measure the elongation of the samples which are kept in an atmosphere favouring the development of A.A.R.
The samples were prisms measuring 7x7x28 cm made of concrete with a mix using 600kg/m^3 Portland cement containing a 1% equivalent of Na2O and highly reactive quartzite aggregates. The samples attained maturity by retaining them at least 2 months in water at 20°C, then they were stored at 20°C in a 50% relative humidity environment for approximately 3 months. The different coatings were then applied on the samples according to the manufacturers' instructions.

After being left to dry for a week, all the samples were placed in metallic containers included a water supply to humidify the air. The containers were placed in a reactor having a stabilized temperature of 38°C and saturated with humidity.
Measurements, which include weighing and extensometry are taken before the treatment which is applied at 38°C, then the samples were measured once a month during 6 months after a 24 hour cooling period at 20°C. In addition to the coatings tested, for reference purposes tests were carried out on a bare concrete sample and two others covered with two thin layers of aluminium foil which were stuck to the samples using epoxidic resin. The results of these tests are shown in Table 1 below and figure 1 next page.

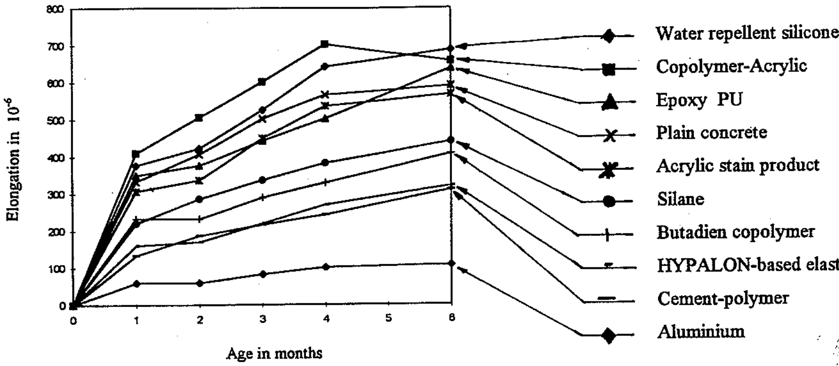
Table 1 Results obtained from measurements taken after 6 months treatment at 38°C, 100% relative humidity, filed in increasing order of elongation

N° Order	Coatings	Elongation (1) 10^{-6}	Efficiency (%)	Weight increase in comparison with original weight
1	Aluminium sheets glued together with epoxidic resin	107	82	1
2	Thin cement-polymer coating	310	47	10
3	Hypalon-based elastomer	320	46	10
4	Butadien copolymer in aqueous dispersion	407	31	20
5	Silane	440	25	20
6	Solvated acrylic stain	567	4	56
7	Bare concrete (comparison) sample	590	0	107
8	Epoxy and polyurethane paint	637	-8	30
9	Copolymer and acrylic paint	657	-11	64
10	Solvated water repellent silicone	687	-16	55

(1) Elongation reduction when compared with the reference sample N° 7

This experiment showed that a reduction in the expansion of concrete or at least its speed of evolution is possible. Apart from the experimental aluminium coating which was far more effective than the other systems and can be used as an optimal reference, relatively good results were achieved using a thin cement-polymer coating and a Hypalon-based elastomer. The effectiveness of other systems was low or even negative. A good correlation was also found between the elongation and increase of weight due to water absorption at the least for products presenting a certain efficiency. Nevertheless, it remains difficult to explain the lack of efficiency of products like paints or water repellent silicone which however reduce the humidity penetration. This experiment still confirms that it is of interest to limit the penetration of humidity in concrete and therefore to warrant the waterproofing of potentially reactive concrete structure facings.

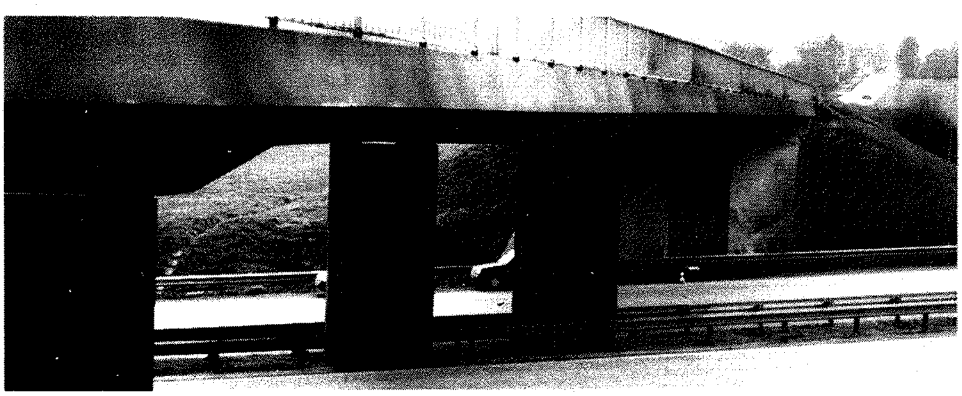
Fig. 1 : Efficiency test on the waterproof coating
(elongation of samples 7x7x28 cm at 38°C and 100% relative humidity)



EXPERIMENTAL TREATMENT OF A BRIDGE

Treatment was attempted on a bridge on the A4 motorway in the Parisian region. This bridge is part of a number of structures affected by A.A.R., two of which have already been destroyed and replaced due to the extent of the disorders. The structure, treated on an experimental basis, is a 4 span continuous reinforced concrete slab, the overall length is 69.50 meters, 10.50 meters wide and 75 centimeters thick, as shown in Fig. 2 below.

Fig. 2 General view of the structure

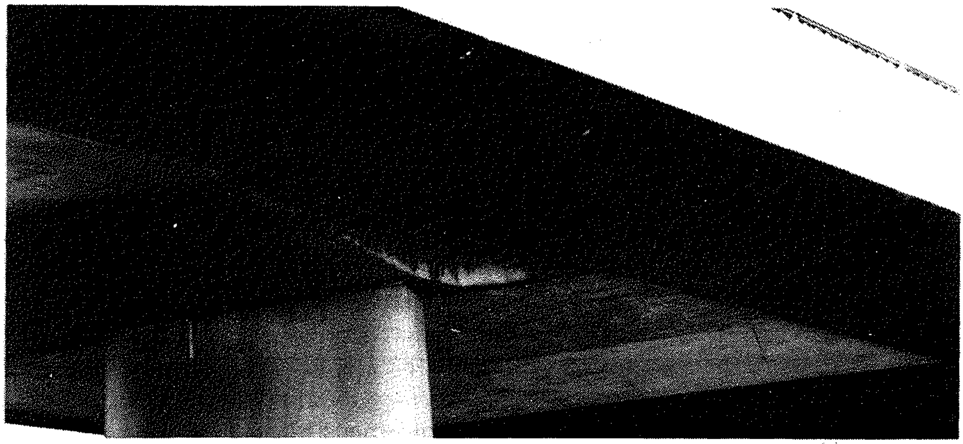


It was built in 1976 and the disorders were noted for the first time in 1986. The disorders mainly concern a network of cracks which affect both the intrados and extrados of the deck and the cantilevers in particular were cracked.
The treatment applied to this structure in 1990 par the Orion (Dune) company, was divided into three major operations :

- The first operation was to strip the deck and to do so it meant removing the carriageway, the pavement joint, the cornices and adjacent cornices, the pavement and the existing epoxy pitch seal.

- The second operation was to protect the complete upper surface of the deck : after bridging over the numerous existing cracks and trimming up the areas requiring reprofiling, using an epoxy resin mortar. A watertight coating was applied successively made up of a cold impregnation coating, a prefabricated polymer bituminous membrane, a protective mechanical layer of gritted asphalt, a coated wearing course was then applied.
- The third operation concerned the protection of the slab intrados, the piles and abutments, as well as the cornices (See Fig. 3 below), using at least two layers of a coating made from mortar which included an hydraulic binder modified by polymers, this PH12 mortar, which had to be on average 3 mm thick. is the same as the N° 2 coating of table 1.

Fig. 3 Details on the intermediate bearing - Cracking resurgence of the cantilevers, as well as efflorescence, (already noted in 1975).



The mortar included :

- a liquid component with an acrylic and copolymer base (30%)
- a pulverulent component with a cement and sand base (70%)

This product is mainly used to waterproof walls or water tanks and its main characteristics are summarized in Table 2 below.

Table 2 Characteristics of the coating (according to VERITAS Report N° DLC/79 416/2)

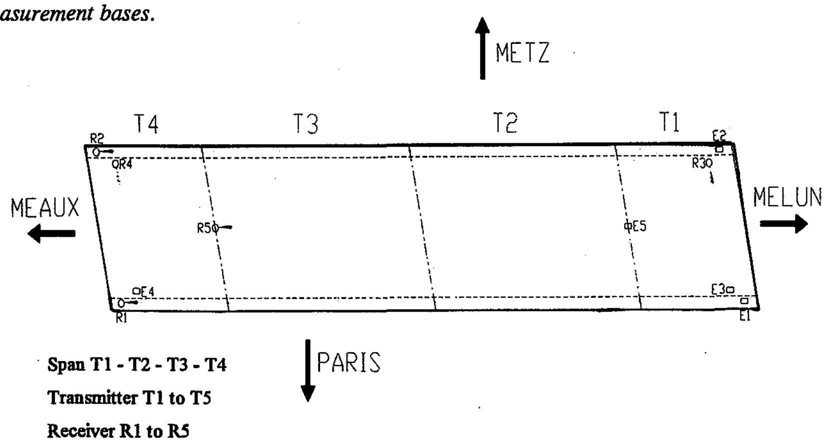
Type of tests	**Results**
Withstands cracking (tensile strength on the cement mortar sample was notched	2.10 mm at 23°C 0.65 mm at 0°C 0.55 mm at -10°C
Adhesion to the support (pull out test)	2.4 MPa on mortar 1.7 MPa on concrete
Permeability to water vapour resulting from the test for possible blistering by measuring the transmission of water vapour (according the AFNOR standard T30-704)	140 gr/m^2 24 hours at 38°C (on the reference sample) 40 gr/m^2 24 hours at 38°C (on the coated sample)

Other characteristics : Elongation at rupture exceeds 30% at 20°C. It withstands temperature variations ranging from -40°C to +50°C and does not produce any major variation by ageing. Finally, its alkali content is lower than 0.4% (according to standard ASTM C 150-83).
Inspection work carried out by Metram on behalf of Scétauroute concerned the quality of preparatory work on supports, the coating's adhesion properties, its thickness and conformity to the producer's specifications. The coating's adhesion values on its support are in the region of from 1.0 and 2.0 MPa on the basis of a direct tensile test.

EXPERIMENTAL MONITORING OF THE STRUCTURE'S BEHAVIOUR

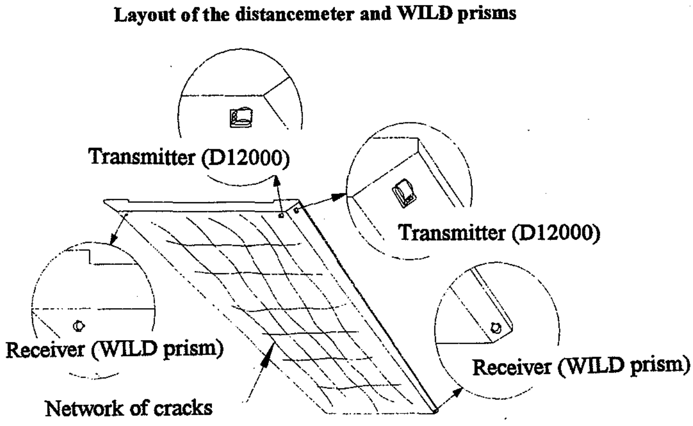
Only the behaviour of the structure's deck was monitored. The principle was to measure the dimensional variation of large bases (several tens of metres) orientated according to the structure's principle axes.
Distance measurements were taken using infrared equipment, including a swivelling transmitter (E) positioned on a lockplate and one or several optical prisms receiver (R) installed on reference studs shown in Fig. 4 and 5 below. These lockplates and studs were glued and mechanically connected to the structure.

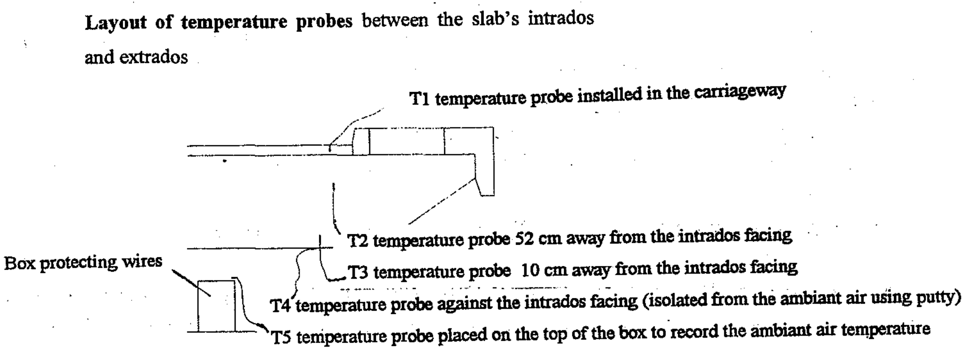
Fig. 4 : Orientation of the PS 25 bridge on the A4 motorway at Coutevroult and layout of the distance measurement bases.



« Second generation » WILD measuring products were used. The regional Bridges and Highways Laboratory in Lille adapted the equipment for specific use on the sites. Its accuracy characteristics are : Distance type ≤ 1mm + 1 part per million for a distance of ≤ 100 m.
Simultaneously temperature, hygrometrical and external barometric parameters were measured as well as the temperature distribution gradient within the structure, using temperature probes embedded at different levels in the thickness of the slab. The elements enable one to calculate the means of correcting elongation or shortening values, to be applied to calculations for the analysis programme. A microcomputer and processing software for this information is also used in the measurement acquisition procedure [2] [B.Godart-P.Fasseu-M.Michel 1992].

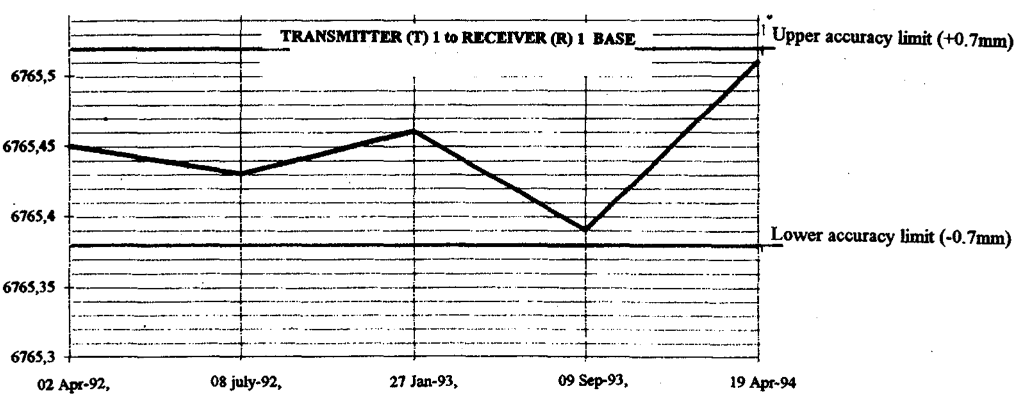
Fig.5 : Layout of the distancemeter WILD prisms and temperature probes

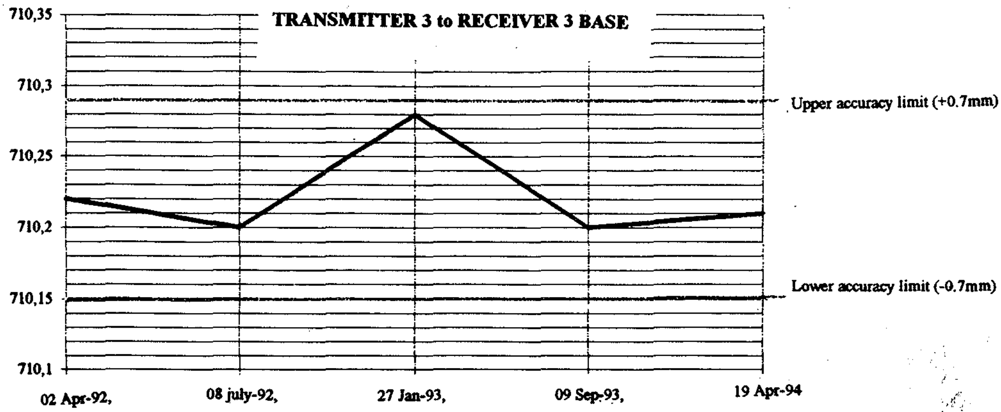




From April 1992 (namely approximately two years after applying the protective coating to April 1994, 5 series of measurements were taken following the principle mentioned above. Whether taken on a longitudinal or transveral axis the dimensional variations, measured in relation to zero at the start, remain mainly between a $\pm$ 0,7 mm gap, corresponding to the accuracy of the method used on site.

Fig.6 : Results of measurements of dimensional variations





COMMENTS AND CONCLUSIONS

Four years after the treatment, we are able to establish the following assessment : the coating is globally intact if one excludes some local zones covering the extrados of the pavements and the intrados zones of the cantilevers on either side of the intermediate bearings where we found :

- Reparation of the coating on the extrados zone
- Resurgence of transversal cracks observed during inspection carried out before the tests
- There was a whitish bloom (efflorescences) with the cracks (see Fig. 3).

However, due to its elasticity, it should be noted that this type of coating can hide the development of cracking for a certain length of time. The dimensional variation measurements of the limits confirm however there is no global expansion of the structure. Even if these results are encouraging, nevertheless it is still too soon to give a definite opinion on the efficiency of this treatment and even less on its durability ; the monitoring programme needs to be pursued.

References

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