Thermal Sprayed Zinc as Sacrificial Anode for Cathodic Corrosion Protection in a Covered Car Park Suffering from Chloride Corrosion- An Optimized, Durable and Time Effective Repair Method

C. Gianocca, C. Haldemann, IM Maggia Engineering SA, Locarno / Switzerland

Summary

The Car Park in Saas Fee was found to suffer from pitting corrosion caused from chlorides coming from de-icing salts. Cathodic Corrosion Protection via thermal sprayed Zinc was chosen as repairement systems and some tests were taken to prove the effectiveness of this methods in this special structure. The corrosion was found to be stopped but the surfaces showed the formation of osmotic bubbles. Additional tests were performed to determine the cause of this defects, which was found to be the substratum preparation via high pression water leading to an higher concrete humidity. The test proved that Cathodic Corrosion Protection with thermal sprayed zinc as sacrificial anode, with an additional surface protection system and sandblasting as substratum preparation technique, is an effective and adequate repair system for the car park in Saas Fee.

1 Introduction

The covered parking lot of Saas Fee has been investigate due to visual damages, that clearly showed signs of corrosion. After an investigation and by comparing different solutions, the Cathodic Corrosion Protection has been chosen to renew the car park and some tests have been undertaken to determinate the effectiveness of the method on such a large surface. The present article tells about tests that have been done, its results and conclusions.

2 Building

2.1 Building description

The car park has 900 spaces and is divided in 2 parts constructed in different years. The first part was built at the beginning of the eighties and the newest part in 1995. It is located in Saas Fee, a car-free village in the Swiss alps (at 1800m above sea level) and is exposed to hard atmospheric conditions (between -20°C in winter and +20 in summer and very low relative humidity). In 2009, due to visual damages, an investigation has been done to determine the state of conservation of the car park and to evaluate the possibility of reparation, always considering the special conditions of the building (atmospheric conditions, large surface and the impossibility to completely close the car park due to the tourist seasons).

2.2 Investigation

To establish the state of conservation and the entity of the damages the following analysis were performed:

- Chloride amount measurement at different depth
- Electrochemical potential measurement
- Iron bar coverture measurement
- Concrete carbonation depth

The investigation has been done in two parts of the car park and in different elements (in the base plane and pillar on different floors and the ramp on last floor) in 2009.

2.3 Results (State of preservation)

The measurements showed the followings results:

- In both P3 and P5 the chloride amount is by far higher than the considered limit.
- The iron bar coverture in both sectors is not sufficient to provide enough protection from the atmospheric influence and in particular case the chloride penetration.
- In P3 the carbonation depth has reached 13mm and the coverture is about 21mm, in this case there is no risk of carbonation induced corrosion.
- Carbonation depth has locally joined the iron bar, therefore in few years carbonation induced corrosion could appear.
- The values obtain through potential measurements showed corrosion (pitting corrosion in progress); the amount of iron bars suffering from pitting corrosion changes in function of the floor. The first floors have a higher percentage as they are used the most (less use means less de-icing salt is transported from the cars).

The parking is suffering from corrosion due to high chloride amount and an insufficient iron bar coverture. Chloride (content in the de-icing salt) penetrates in the concrete and causes the depassivation of iron bars, which leads to the appearance of corrosion (pitting corrosion). The damages are quite substantial and renewal is required to assure mid-term life of the car park. Saas Fee is a holiday resort and a car-free village, this requires to find an effective repair method that assures at the same time an optimal logistic and a good timing solution.

3 Repair methods

3.1 Restoration system

Due to the high amount of chloride repair is urgently needed. Following two actions need to be taken:

- Refurbish the zone where iron bars are suffering from pitting corrosion
- General intervention to stop pitting corrosion on the whole surface

To restore the concrete of the parking lot and avoid the expansion of the pitting corrosion, the following methods are applicable:

- Removal of chloride contaminated concrete and conventional surface protection system
- Only conventional surface protection
- Cathodic Corrosion Protection via sacrificial anode

3.1.1 Cathodic Corrosion Protection via sacrificial anode

An attentive comparison between different technology repair solutions has be done: due to the particular conditions (thermal conditions and the logistic problems) an optimal repair method was identified in Cathodic Corrosion Protection (CCP) with a surface protection system as an additional protection against chloride attack. The CCP is to apply in the zone where corrosion occurs (these zones were identified via electrochemical potential measurement), while the unaffected zone will be treated only with the surface protection system. As far as the timing is concerned, this CCP system has the advantage that it can be done pro phase, which allows the closure of just a sector of the parking lot (ex. one floor per year). Furthermore CCP is widely used as an effective protection of concrete structure in different forms. In this specific case it was chosen to perform a Cathodic Corrosion System with thermal sprayed zinc as a sacrificial anode. The type of anode was chosen for the easiness of this application

and the independence of external electrical source. The system consists in a thin zinc coating working as an anode, while the concrete has the role of electrolyte. The Zinc anode is connected electrically to the irons bars, which prevents the iron dissolution (by produced countercurrent).
In addition, on top of the Zinc coating, a top coat is applied to offer an additional protection and avoid penetration of external substances and to extend the lifetime of the cathodic protection. With this system the lifetime of the car park could increase of approximately 20 years.
Some tests in Germany proved the effectiveness of this methods for car parks [1] , but due to the particular conditions of the car park in Saas Fee some tests were needed to prove the applicability of this method.
Several test surfaces were prepared to prove the effectiveness of the method, with a Control System to record the electrical current and the potential value.
The cathodic protection has the following structure:

– Thermal sprayed Zinc (sacrificial anode) on concrete surface,
– Top coating (Epoxide resin) on Zinc coating
– Contact between Zinc and Iron Bar to permit the electric flow

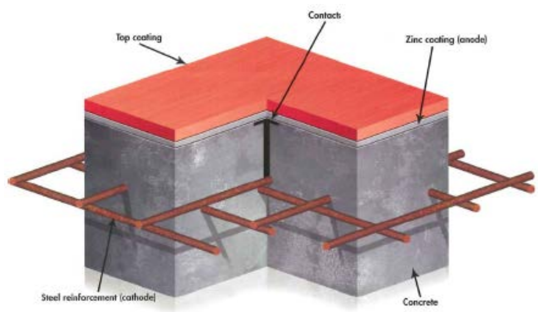

Figure 1: Cathodic Protection via sacrificial anode , Grillo System[2]

3.2 Tests

3.2.1 First series of tests (Summer 2010)

The first series of tests surface were performed in the Summer 2010 with the following characteristic:

- Surface 1: located in P3 floor 3, size: 14.4 x 2.6 m
- Surface 2: located in P5 floor 4, size: 12.1 x 3.6 m
- 5 independent measurement systems to check electrical issues (3x P3, 2 x P5)
- substrate preparation via high pressure water
- application of the thermal sprayed Zinc (temperature and humidity conditions were achieved)
- top coating applied after 3 weeks of drying time

The cathodic protection used was the Grillo –CP Concrete System.
Depolarisation measurement were installed to check if system is working well and the criteria achieved.

3.2.2 Results

The first series of tests showed good corrosion protection results.
Depolarisation measurement showed that the system is working fine and the criteria achieved. The potential showed increasing tendency, which confirms the good operation of the cathodic protection.

Although the cathodic protection was achieved, after 4 months osmotic bubbles have appeared on the top coating surface.
The bubbles had the following properties:
- diameter: ca. 5 cm
- the bubbles sounded empty by tapping
- many showed cracks on the surface

By breaking the bubbles it appeared that the top coating was intact and the fracture was in the Zinc coating. In the osmotic bubbles there wasn't any humidity. The numbers of the bubbles remained constant and didn't increase with the time after their appearance.
Theoretic research on osmotic bubbles formation showed that this phenomenon could appear due to following aspects:
- formulation of the epoxide resin
- pressure in concrete pores [3]

By analysing the situation it seemed possible that the formation of osmotic bubbles were caused by high concrete humidity. This humidity could have been caused by the substrate preparation (high pressure water). The water used to prepare the surface remained in the concrete pore and despite the waiting time of 3 weeks before the application of the zinc, probably wasn't enough. The humidity on the surface required the criteria for zinc application but it's possible that some residual higher humidity remained in the lower profundity of the concrete structure.
Although the corrosion has been stopped by this system, it was decided to perform another series of tests to eliminate the osmotic bubbles formation and to determinate their cause.

3.3.1 Second series of test (Summer 2011)

To determinate the cause of the osmotic bubbles formation in summer 2011 the 3 following new surface tests were undertaken:
- the substrate was prepared with sandblast (to avoid high humidity), for comparison purposes one surface was prepared with high pressure water
- the top coating was performed with different formulation, to prove the independence of resin composition from osmotic bubbles formation (see table 1)
- the surfaces were located both on valley and mountain side (to prove the incidence of high air humidity)

The cathodic corrosion was done by thermal sprayed Zinc on 2 surfaces, in addition on 1 surface a zinc net was used. All surfaces were located on the 4th floor in P3.

	1	2	3	4	5
Adhesion N/mm^2	1.51 Broked in Beton	1.80 Broked in Beton	1.60 Broked in Beton	1.50 Broked in Beton	1.63 Broked in Beton
	MC-Dur1200VKZ ca.550 g/m2	MC-Dur1220VK ca.550 g/m2	MC-Dur1101 ca. 550 g/m2	MC-Dur 1177 WV-A ca300 g/m2	Grillo Stelpant PU-Repair
	MC-Dur 1200VKZ 1:1 with QS 0.1-0.3 Resin ca-1.2 kg/m2	MC-Dur1220VK 1:1 with QS 0.1-0.3 Resin ca-1.1 kg/m2	MC-Dur 1252 Resin ca-2.5 kg/m2	MCDur1101 1:1 gefüllt mit QS 0.1-0.3 Resin ca- 1.4 kg/m2 With QS 0.1-0.3	MC-Dur 1200VKZ 1:1with QS 0.1-0.3 Resin ca-1.4 kg/m2

	MC-Dur 1252, MC-grau, with QS 0.1 – 0.3 mm, Resin : ca. 2.3 kg/m2 with QS 0.6 – 1.2 mm
	MC-Dur 1252, MC-grau, Resin ca. 1.4 kg/m2

Table 1: Top coating formulation

3.3.2 Results

Once the surfaces were completed, they were controlled on a regular basis. The results after 1 year (April 2012) are listed in In the following table (table 2) .

Table 2: tests results

Surface	Position	Substrate Preparation	Typ CCP	Top Coating	Corrosion Protection	Osmotic Bubbles
1	Valley Side	Sandblast	Thermal sprayed Zinc (GRILLO)	1	✓	Any
				2	✓	Isolated bubbles
				3	✓	Any
				4	✓	Any
				5	✓	Any
2	Valley Side (Middle)	High pressure water	Thermal sprayed Zinc (GRILLO)	1	✓	Yes
				2	✓	Yes
				3	✓	Yes
				4	✓	Any
				5	✓	Any
3	Mountain Side	Sandblast	Zinc Net	Specific Mortar	✓	Any

Both cathodic protection systems performed well, the depolarization values respects the required criteria and the corrosion stopped.
The surface 3 (with Zinc Net) showed an insufficient adhesion value for the mortar, consequently this system has been excluded.
After a few months, most surfaces prepared with high pressure water, showed osmotic bubbles. While, with just one exception, the surfaces prepared with sandblast didn't show any. This proves that the cause of the appearance of the bubbles was the substrate preparation that leads to a high concrete humidity

4 Conclusions

The undertaken tests permit to lead to the following conclusions:
- the cathodic protection was achieved with both thermal sprayed zinc and Zinc Net
- The System with Zinc Net showed an insufficient mortar adhesion value
- the formation of osmotic bubbles was avoided by using sandblast instead of high pressure water to prepare the concrete substrate
- the top coating assures a good non-slippery-safety
- the Zinc and the top coating have a good application yield and they could be applied in phases without compromising the good result and the operation of the car park (works can be done one floor per year)

To conclude, the Cathodic Corrosion Protection via thermal sprayed Zinc and the adequate protection system with epoxide resin has been proven to be the effective solution for this car park and can be applied on the whole structure.

5 References

[1] T.Eichler et al., Application Of Thermal Sprayed Zinc Anode for CP of a Multi-Storey-Car-Park (2009)
[2] www.kks-beton.de
[3] L.Wollf, Mechanismen der Blasenbildung bei Reaktionsharzbeschichtungen (2009)