

The effect of road environment on corrosion of the infrastructure constructions

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Summary

The development of modern transport infrastructure, transport systems and vehicles belongs between fundamentals of competitiveness. The basis for choice and verification of materials and surface corrosion treatments long-term exposed to atmospheric environment is degree of corrosivity.

For the atmospheric corrosion there are two dominant corrosion stimulators – industrial air pollution represented by SO₂ and salinity. Offshore structures require specific attention in order to be able to withstand the severe corrosion stresses to which they are exposed during their service life. But in the countries without seaside the chloride from de-icings salts plays very important role. The corrosion loss of carbon steel, zinc and galvanized steel exposed in 7 localities around the road in the Czech Republic were compared with corrosion loss without this effect. This evaluation shows intensively increasing corrosion damages together with specific corrosion mechanism due chloride deposition.

1 Introduction

Rate of corrosion attack of construction materials including zinc coatings can be estimated from data of atmospheric corrosivity (ISO 9223, ISO 9224, EN ISO 14713). Currently structural metals and metallic coatings lifetime is relatively high in normal atmospheric environment in the Czech Republic [[1] - [4]]. A significant reduction of their lifetime still occurs due to several factors including specific corrosion stress.

One of the specific corrosion environment is surroundings of roads where the impact of increased emission concentrations and de-icing salt occur. Especially chlorides are an important stimulator of atmospheric corrosion. Strong corrosive affect of chlorides is given by their high hygroscopicity and high conductivity of formed electrolytes.

Aerosol of de-icing salt is formed as the tires of moving vehicles spray salt water or salt particles into the air. The turbulence caused by moving vehicles creates a vertical column of wet or dry salt particles and the wind transports those particles away from the road. Wind and vehicle speed, type of vehicle and the density of traffic all influence the amount of formed salt mist and how far it is carried from roads. Large saltwater droplets land up to 15 m far away from roads. This distance is called the splash zone. Concentration of chlorides is very high also in dust fall in surroundings of roads and it deposits of metal surface like the secondary dustiness. Affect of chlo-

rides of de-icing salts is detected up to 1,9 km far away from highways with high traffic intensity (Figure 1) and up to about 150 m high [[4] - [7]].

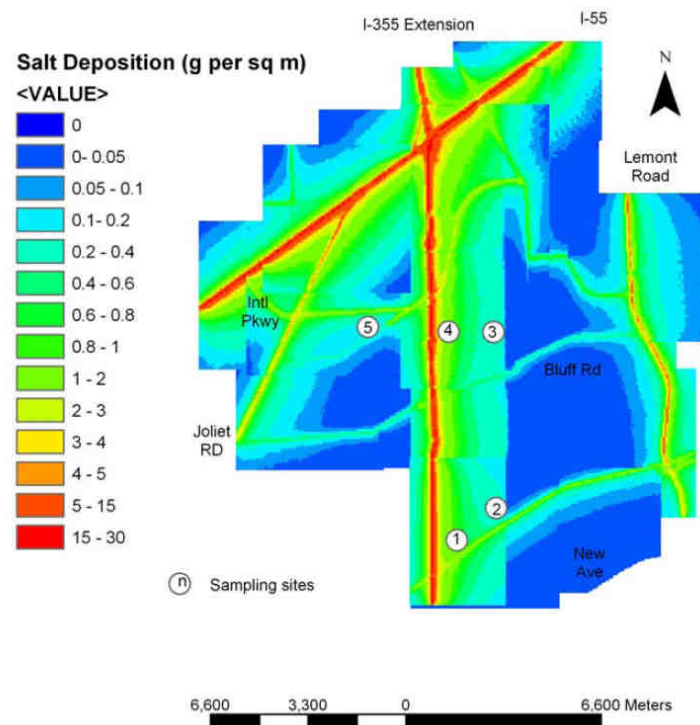


Figure 1: Model projection of annual de-icing salt deposition around highways and roads, Chicago, USA (model assumes that the de-icing salt is applied 17 times per year)

The effect of de-icing salt is the most negative corrosion stimulator for road infrastructures. The basic problem for estimation of this effect is large uncertainty of source data. The amount of de-icing salt on area unit or road unit (1 km) depends on various factors including climatic conditions of locality. E.g. the average usage of de-icing salts was 19 738 t, i.e. ca 36 t de-icing salt/km in winter season of years 2000/04 in the CR. During snow calamity 28/29 November 2010 the usage of de-icing salt was 7 000 t together with 1 600 000 L of salt solution [8].

2 Evaluation of corrosion on the road infrastructure structures

2.1 Open atmosphere conditions

Chloride deposition of de-icing salt was monitored in different periods and localities on various samples of structures (inert surfaces without corrosion) – Table 1. The total number of deposits and chloride depositions then depends on climatic conditions at the time of sampling and on immediately previous period (deposits are washed off by precipitation). The value of deposition depends on duration of deposition process i.e., the period when the dust was not removed from the surface by precipitation.

Table 1: Average chloride deposition

exposure conditions	chloride concentration (g Cl ⁻ /m ²)	
	spring	autumn
open atmosphere	0,02	1,50
“shelter“	1,50	2,63

Note: Chloride analysis had been performed in season without de-icing salts application.

Corrosion damage was detected on the road infrastructure structures after 3 years of exposure (Figure 2) [9]:

- pitting corrosion of stainless steels (5000 pits/m²) with depth 5 – 10 µm occurred, the pitting corrosion in crevice under washers reached to 30 µm,
- electrolytic zinc coating with a thickness of about 8 µm was completely corroded in 30% of cases on bolt connections and corrosion of the substrate occurred,
- hot dip galvanized structures with thickness of the zinc coating about 80 µm showed a strong corrosion of the zinc coating as white voluminous layers of corrosion products,
- corrosion under layer of coating system occurred in many cases of the use of duplex coating system as surface treatment and consequently cracking and peeling of the paint was caused by action of voluminous corrosion products.



Figure 2: The examples of corrosion on the road infrastructure constructions

Corrosion products of carbon steel were mixture of akaganeite, goethite and lepidocrocite. The average chloride content was ca 0.14 g.m^{-2} at open atmosphere and ca 0.80 g.m^{-2} at „shelter“ conditions.

A sample of corrosion products of zinc coating was collected from the surface of road barriers located in the level of anchoring of abutment on D8 highway (the road only for service vehicles, about 10 m under the bridge deck) – Figure 3. Chloride content in the sample was 0.30 g.m^{-2} (3,97 %), pH 6,2 and conductivity was $78 \mu\text{S.cm}^{-1}$. Corrosion products contained a dominant gordaite $\text{NaZn}_4(\text{SO}_4)(\text{OH})_6\text{Cl}(\text{H}_2\text{O})_6$, further a small amount of $\text{Zn}(\text{OH})_2$ and traces of zincite ZnO and smithsonite ZnCO_3 .



Figure 3: Zinc coating condition on road barriers

2.2 Shelter atmosphere conditions

Specific environments are in the tunnels. The quickly degradation and service life decreasing of materials and surface treatments applied in tunnels occur (Figure 4). The most exposed materials are stainless steel (degree 1.4301) and carbon steel with various corrosion protection systems.

The maximum and average ion depositions after 6 months of service are given in Table 2 (see Figure 4). Even if the surface of tunnel's equipments is periodically cleaned by washing, the deposition of corrosion stimulators occurred – the values analysed 1 month after cleaning are in Table 2, too.

Table 2: Analysis of surface deposition

sample	conductivity ($\mu\text{S.cm}^{-1}$)	pH	concentration (g.m^{-2})		
			Cl^-	SO_4^{2-}	NO_3^-
surface before cleaning					
average	95	5,5	10,9	6,2	0,26
maximum	104	4,0	20,3	11,9	0,66
surface 1 month after cleaning					
average	126	7,1	0,3	0,05	0,06
maximum	220	7,3	0,4	0,10	0,07



Figure 4: The corrosion attack of materials in tunnel after ½ year service (1 winter season)

In tunnel’s environment the higher gaseous emission has an effect onto metallic materials corrosion, too.

3 Atmospheric corrosion tests in the road environments

In 2009, the atmospheric corrosion test was carried out in the neighbourhood of the road. Samples of carbon steel, zinc and hot dip zinc with dimension 50 x 75 mm were exposed in three localities in the Czech Republic under different conditions – in the open atmosphere, i.e. exposed to all environmental influences, and „covered with shelter“, i.e. without rinsing by precipitation (Figures 4 - 5). The localities were not highway but roads with very high intensity of transport.

Figure 3 – Exposure localities



Figure 4: Exposure localities

There was no significant difference between samples exposed in different distance from the road (0.3 and 1.2 m) for any of exposed materials. The amount of chlorides in surface layers of corrosion products and deposits was determined on the surface of samples too – the amount of chlorides ranged in 0.12 – 0.15 g.m⁻².

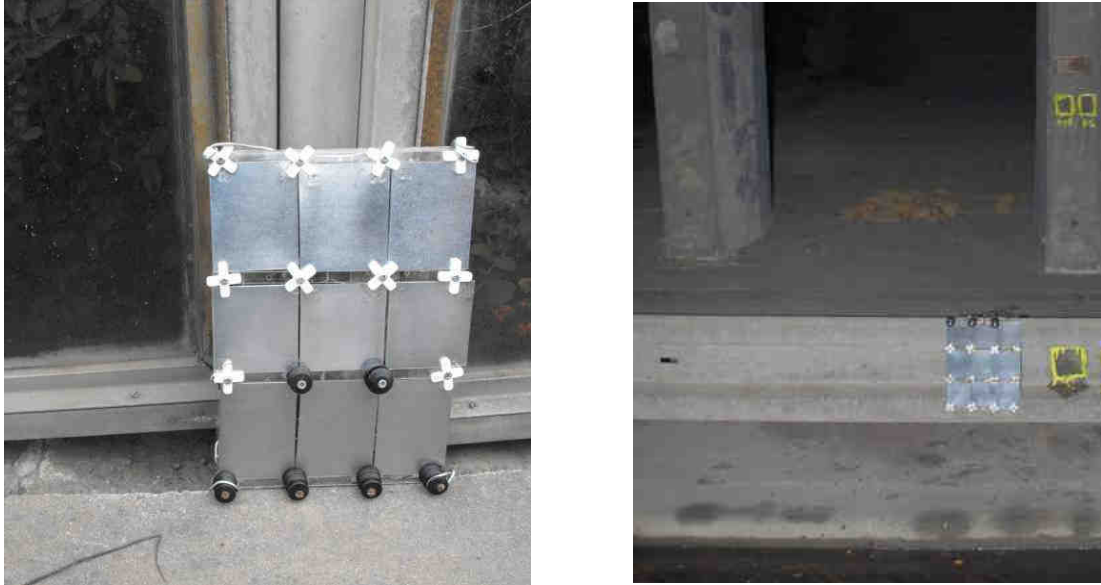


Figure 5: Way of samples' exposure

Table 3: Corrosion loss of structural metals' samples

localities	of exposure	distance from road (m)	height (m)	corrosion loss	
				(g.m ⁻²)	(µm)
carbon steel					
Prague	atmosphere	0,3	0,3	277	35
	atmosphere	1,2	0,3	275	35
	shelter	1,2	0,3	463	59
Ostrava	atmosphere	0,3	0,3	249	32
	shelter	0,5	1,0	310	40
Otrokovice	atmosphere	0,3	0,3	300	38
	shelter	0,5	1,0	528	67
Zinc					
Prague	atmosphere	0,3	0,3	16	2,3
	atmosphere	1,2	0,3	15	2,2
	shelter	1,2	0,3	45	6,3
Ostrava	atmosphere	0,3	0,3	70	8,6
	shelter	0,5	1,0	61	9,5
Otrokovice	atmosphere	0,3	0,3	27	3,7
	shelter	0,5	1,0	41	5,7

Corrosion loss of structural metals on open atmosphere near the road is about 3 times higher than on open atmosphere without the influence of road (de-icing salts) for carbon steel and 5 – 10 times higher for zinc - Figure 6. Under conditions of exposure without rinsing by precipitation (shelter) corrosion loss is even higher – depending on traffic density on the road (Table 3). The increase of corrosion loss in „shelter“ exposure is about 2 – 3 times higher than the corrosion loss in the surroundings of the road on open atmosphere. The similar results as for zinc were estimated for galvanized coating.

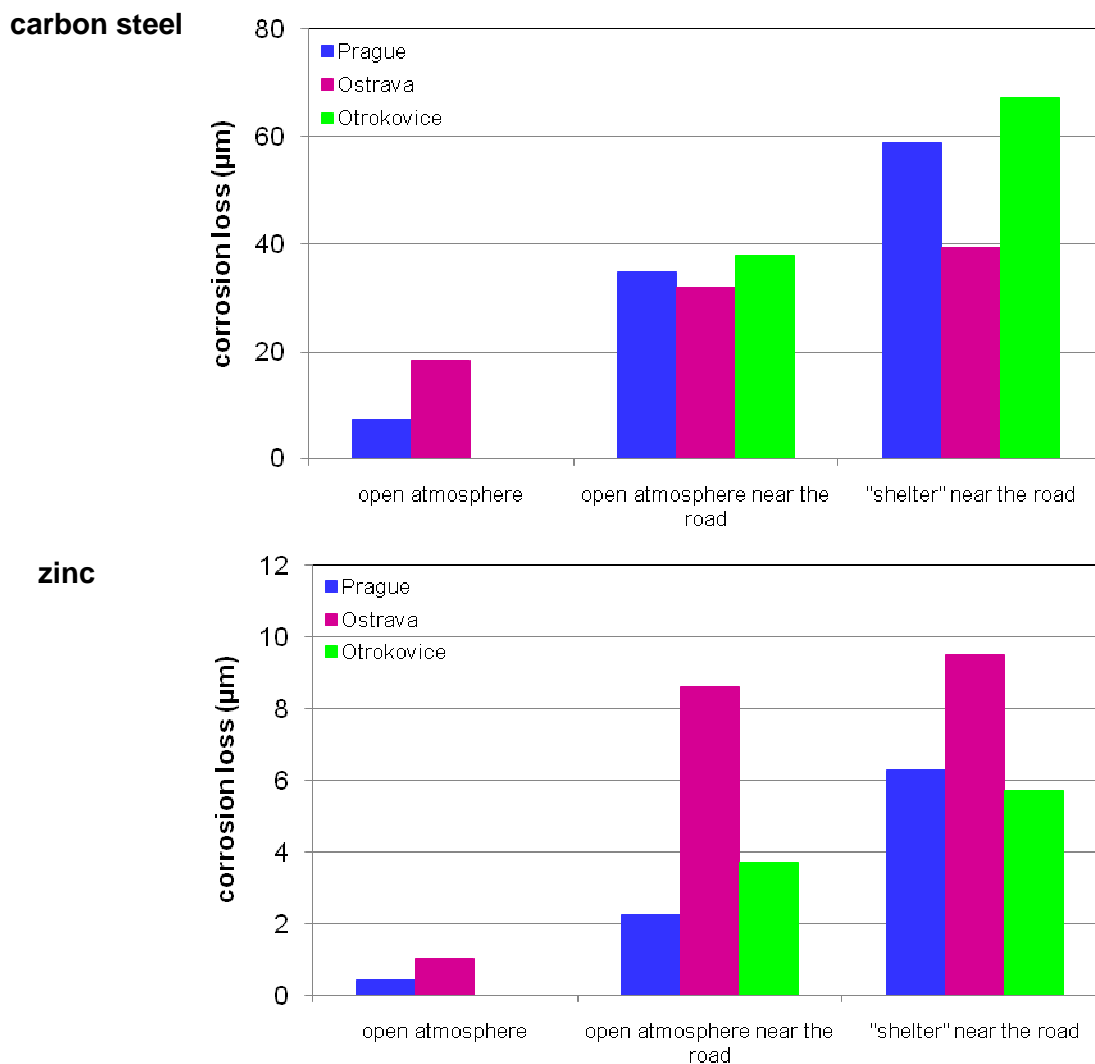


Figure 6: Comparison of corrosion loss after 1 year exposure

Conclusion

The secondary deposition of chloride ion on the road infrastructure from dust is very intensive corrosion stimulators because it affected for whole year.

The corrosivity of normal atmospheric environment for carbon steel and zinc was on level C2 in Prague and C3 for zinc in Ostrava in monitored localities. Environment in surroundings of roads is significantly influenced by de-icing salt and increased corro-

sion stress occurs not only in winter season but also in other seasons when chlorides deposit on surface due to secondary dustiness. This specific corrosion environment cannot be explicitly assigned to any category of corrosivity because the influence of chlorides is outside of considered action according to ISO 9223 (seaside salinity) – in some countries they have created specific classifications for this environment included also intensity of traffic.

Nevertheless, it can be estimated that corrosivity in surroundings of roads on open atmosphere is in category C3 and in „shelter“ positions of structures is even in C4 or C5 and CX – Table 4.

Table 4: Microclimate corrosivity

locality	material	corrosivity		
		open atmosphere	open atmosphere near the road	shelter near the road
Prague	carbon steel	C2	C3	C4
	zinc	C2	C3	C5
Ostrava	carbon steel	C2	C3	C3
	zinc	C3	>C5	>C5
Otrokovice	carbon steel	-	C3	C4
	zinc	-	C4	C5

Paper had been elaborated in frame of project TA01031043 Quantification of specific pollution effect on materials and corrosion protection in tunnels.

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