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Influence of Distance from Roads on Corrosion Loss in Weathering Steel Bridges

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Abstract

There are numerous steel bridges worldwide, many of which are made from weathering steel. Trademarks of weathering steel, such as Corten (the United States), Atmofix (the Czech Republic), NAW-TEN and CORSPACE (Japan), or Q345CNH (China) are commonly used. Inland steel bridges are impacted by chloride ions, primarily dispersed into the air by road traffic from de-icing salt (NaCl) and brine solutions used in winter road maintenance, which can compromise the integrity of the bridges' load-bearing structures. The quantity of deposited chlorides fluctuates based on the distance from the source, especially for inland bridges, where it is determined by the distance from the road. There is also a difference between the winter season and the rest of the year. The study presents in-situ measurement data from two sites, analyzing the corrosion loss. Additionally, a regression analysis is conducted to understand the relationship between the distance from the road guide line and the corrosion loss.

Keywords

Corrosion loss, corrosivity, influence of distance, weathering steel bridges

1 Introduction

Weathering steel is used for many steel constructions including bridges. There are several trade marks as Corten (in the United States, licensed also in other countries), Atmofix (in the Czech Republic), NAW-TEN and CORSPACE (in Japan), or Q345CNH (in China) [1 – 4]. These bridges do not have any protection coatings. Instead, they develop a natural protective layer known as a patina, which forms due to the steel's functions of alloying elements (Cr, Ni, Cu and others) and exposure conditions. However, even with this patina, some minimal corrosion damage can occur over the long term [5].

The first option for predicting corrosion loss is by the category of atmospheric corrosivity. The second option of prediction is by normative corrosivity estimation based on calculated first-year corrosion losses. This approach contains factor of annual average temperature, annual average relative humidity, annual average SO2 deposition and annual average Cl- deposition. Both are mentioned in the ISO 9223 standard [6].

The deposition rate of chloride ions significantly influences the corrosion rate in steel bridge constructions. As the distance from the road increases, the deposition rate of chloride ions decreases [7]. Due to the main influence of the deposition rate of chloride ions (as an annual average value) on corrosion loss after one-year exposure, there is a hypothesis that there is a relationship between corrosion loss and the distance of the stand (which can be thought of as a bridge structure) from the road's guide strip.

There are two comparable locations with similar traffic, orientation, and both are arranged as road cuts. These two locations can be considered as comparable, and their results can be compared with each other and used as input for the analysis.

2 Methods

Two locations for measuring the deposition rate of chloride ions and steel corrosion loss are situated in the road cut arrangement with similar north orientation. The distance between these locations is approximately 7.5 km by air. Both of these locations are on the I/11 road in the Czech republic, near Ostrava-Poruba (signed as Vřesinská) and Hrabyně-Josefovice (signed as Hrabyně). Position of each

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locality are pointed on the map on the Figure 1.

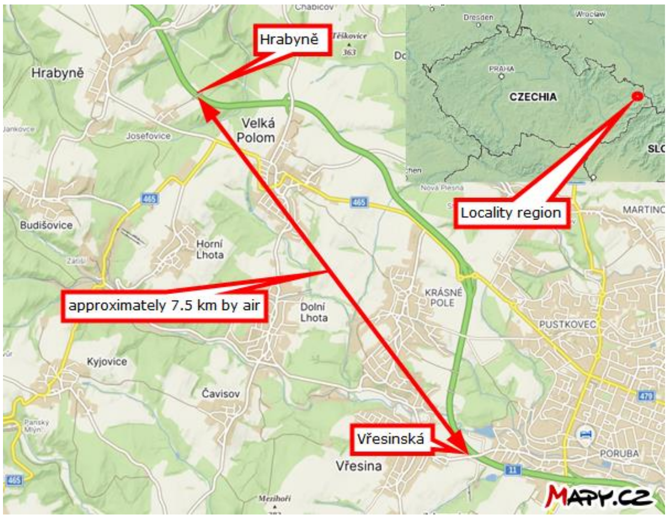

Figure 1 Position of locations (source: mapy.cz)

Steel corrosion rates after one year exposure are determined using the procedure outlined in ISO 9223 [6] on measuring stands on both locations. The corrosion coupons, which are used for measurement, are positioned both horizontally and vertically to simulate the main orientations of real surfaces on steel bridges. The back surface of these coupon is covered to protect unexposed surface. Typical stand is on the Figure 2. Height of platform is about 1.5 m above terrain. Geometry of stand is according to the ISO 9225 standard [9].

Figure 2 Typical stand

The annual average temperature, annual average relative humidity, and annual average SO2 deposition all have similar values for the period under investigation [8]. In addition to these input parameters, the deposition rate of chloride ions was also investigated through in-situ measurements [10,11]. The results of annual average deposition rate of chloride ions for each stand were similar over the investigation period. The influence of these variables can likely be neglected as they recur approximately periodically.

3 Results

The results indicate a dependence between the deposition rate of chloride ions and the distance from the road's guide strip [10,11]. The results also suggest that the orientation of the surface influences this rate. This was investigated using the dry plate measurement method, as per the ISO 9225 standard [9].

The corrosion loss results after the first year of exposure at each location and stand are presented in the Table 1. Figure 3 plots the corrosion loss (y-axis) against the distance from the road's guide line (x-axis) for both horizontal (blue) and vertical (orange) orientations. Regression lines have been plotted for each orientation. The power regression lines provide the best fit for both orientations.

Table 1 Corrosion loss on each stand

Locality	Exposition time (month/year)	Stand	Distance from the road's guide line (m)	Corrosion loss (g/m^2)		Mean value of thickness of patina (µm)	
				horizontal	vertical	horizontal	vertical
Vřesinská	10/21 - 10/22	1	3	202	310	89	151
		2	5	206	314	88	123
		3	9	203	250	103	130
		4	13	190	190	86	98
	10/22 - 10/23	1	3	223	311	116	160
		2	5	210	319	38	149
		3	9	211	272	96	146
		4	13	180	217	79	124
Hrabyně	1/21 - 1/22	1	7	156	Missing	74	Missing
		3	45	122	128	56	61
		5	180	121	90	57	51
	1/22 - 1/23	1	7	141	144	81	82
		3	45	112	78	69	65
		5	180	121	91	66	77

Note: Missing – Experimental steel plate was lost.

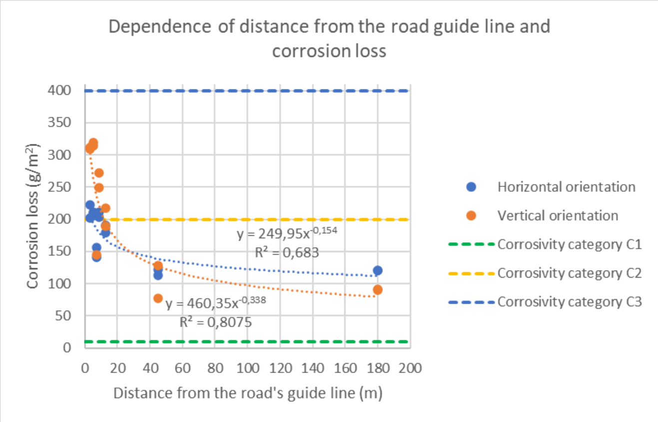

Figure 3 Dependence of distance from the road guide line and corrosion loss

4 Discussion

As observed in Figure 3, the vertical orientation of the steel corrosion coupons exhibits a higher corrosion loss compared to the horizontal orientation, up to a distance of approximately 30 m. This specific distance corresponds to the slope of the road cut and is situated roughly 15 m behind the crown of the road cut.

Beyond this 30-meter mark, an interesting trend reversal occurs. The corrosion coupons oriented horizontally start to show a greater degree of corrosion loss compared to their vertically oriented counterparts. This phenomenon can be attributed to the deposition pattern of chloride ions, which tend to deposit more heavily on surfaces that are vertically oriented closer to the road.

However, as the distance from the road increases, the deposition pattern of the chloride ions, which are attached to aerosols or dust particles, changes. These ions begin to fall and settle down on horizontal surfaces. This shift in deposition pattern could explain why horizontally oriented corrosion coupons exhibit a higher corrosion loss at greater distances from the road.

5 Conclusion

This study has provided valuable insights into the corrosion behavior of weathering steel used in bridge constructions. The results highlight the importance of the distance from the road and the orientation of the surface.

The study revealed that vertically oriented steel corrosion coupons exhibit a higher corrosion loss compared to horizontally oriented ones up to a distance of approximately 30 m from the road. Beyond this point, the trend reverses, with horizontally oriented coupons showing a greater degree of corrosion loss. This shift is attributed to the changing deposition pattern of chloride ions, which tend to deposit more heavily on surfaces that are vertically oriented closer to the road but settle down on horizontal surfaces as the distance from the road increases.

The corrosion behavior of the steel is monitored by regular maintenance and inspection, especially in areas closer to the road where higher corrosion losses are expected. If there is a vertical surface close to the road, more attention should be paid to it. More attention should also be paid to horizontal surfaces further from the road where chloride ions are deposited.

These findings underscore the need for considering both the orientation of the surface and its distance from the road when predicting corrosion loss in weathering steel structures. Further research is recommended to validate these findings across different environmental conditions and bridge designs.

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