Impact of environmental actions on steel structures

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Abstract. The durability of steel constructions is strongly influenced by damage due to environmental actions, which need to be consider in design and maintenance of new and also existing structures. Corrosion aggressiveness of the atmospheric environment is classified by the corrosion rate, what it represents thickness losses of structural steel. That leads to a smaller resistant area, producing a decrease in the structural performance in terms of resistance, stiffness and ductility. The object of this contribution is to present a partial report of experimental research of corrosion processes influence on steel bridges in Slovakia and Poland.

1. Introduction

Several factors influence the service life of metal structures. Atmospheric corrosion is recognized to be one of the major risks, which decrease the resistance of constructions, resulting in huge economic and social losses [1]. Corrosion life prediction provides a key part for the optimum selection of materials or coatings for those structures. Studies made over the last year's show that the world's climate is changing. Besides global warming, there are also changes in other parameters which affect aggressiveness of environment.

Researchers in many countries all around the world have accomplish exposure tests to investigate the effects of the environment on corrosion rates what leads to classify category of corrosivity of atmosphere from C1 to CX by European standard STN EN ISO 9223 [2]. This standard allows also other way to determine category by dose-response function from the data related to the environment like rainfall, pollution, humidity or average temperature. These information lead to the formation of corrosion maps for different materials [3, 4] to show the environmental effect of the atmosphere on engineering structures.

2. Observation of corrosion process in Žilina

Roadway and railway bridges together with other structures, like tunnels, are the most critical components of transport infrastructures not only in Slovakia but also in all European countries. Also other types of engineering structures connected with traffic are affected, like stations or parking houses [5]. Real bridge structures are affected by environmental conditions. The environmental actions in time cause the degradation of bridge members what leads to a decreasing cross-section area, or in other words significantly affect safety of structure [6, 7]. Monitoring process of corrosion degradation during time on existing bridge structures is challenging, on the other hand with test sample placed at construction it is much easier.

For the study of the corrosion effects Žilina self-governing region was selected, where 12 bridges on the road or railway were selected. Those structures overpass various types of obstacles like a river or a highway and different structural design types as a girder, truss or composite bridge. Samples of structural steel with dimensions of 150×100×3 mm were placed on the bridges at the position of the angle of 45° figure 1. Each sample was measured and weighed with accuracy of 0.01 mm and 0.01 g.

Figure 1. Test samples "Y" placed at bridge near Nová Bystrica – Vychylovka.

Test samples were exposed to aggressive environment and their degradation due to pollution and chloride ions from traffic was measured annually. Every sample after period of exposure was cleaned and compared with initial values at the beginning of experiment. Figure 2 shows a test sample before and after cleaning.

a) b)

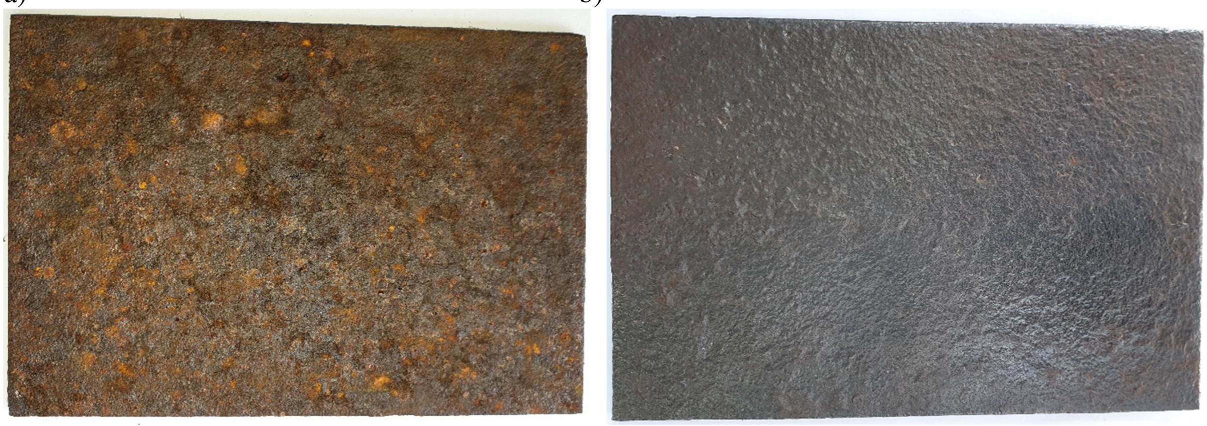

Figure 2. Test samples a) before cleaning, b) after cleaning.

Corrosion rate r_{corr} which is thickness loss in micrometres per year can be influenced by many effects. Within in-situ measurement, it was decided to determine the impact of repeated cleaning - figure 3. Test samples were exposed to aggressive environment during last three years. Discussed samples "Y" are placed on concrete roadway bridge, it is a connection between Orava and Kysuce districts, location with significant snowfall during winter. The first set was cleaned three-times after first, second and third year (Y1, Y2), the second set of samples was cleaned once after second year (Y3 – Y5) and the last third set was cleaned also once but after three years (Y6 – Y8). Chart shows results that the repeated cleaning of steel structural members has negative impact on thickness losses.

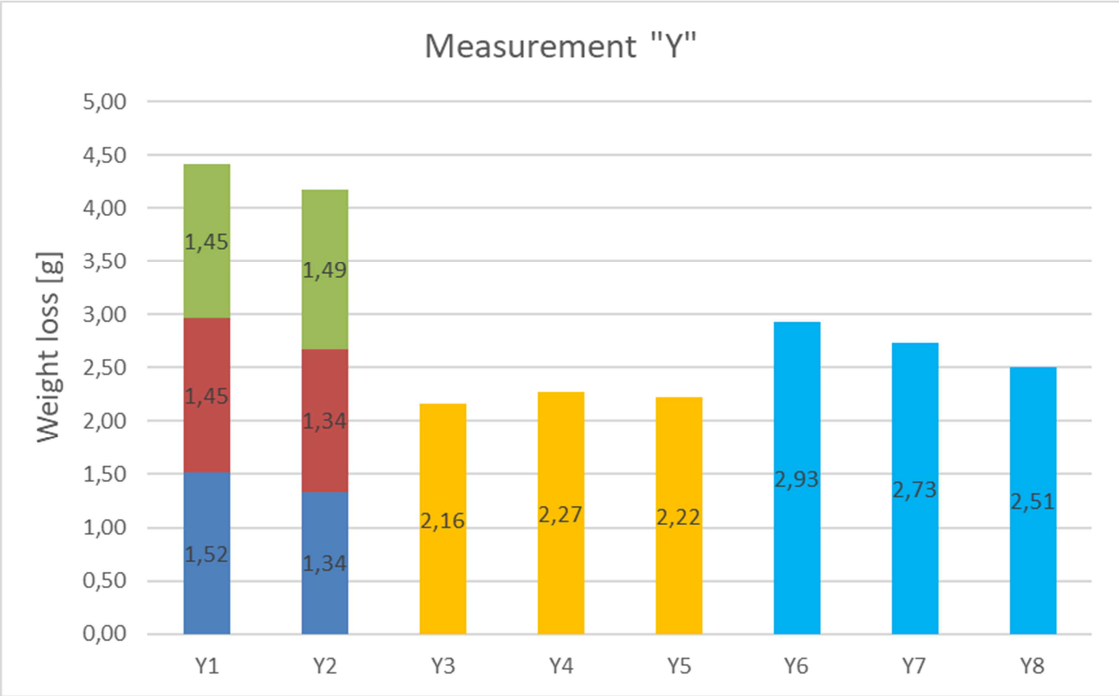

Figure 3. Impact of repeated cleaning of samples during three years exposure.

As it can be seen in figure 3, samples Y1,Y2 have far greater weight loses after three years of exposure compared to samples Y6, Y7, Y8, which can indicate that repeated cleaning of corrosion products cause bigger mass loses. However, the results on different bridges are not identical. From total twelve sets of samples placed on bridges, three locations in Žilina region show similar loses between 3-times and once cleaned samples after third year of experiment. These discrepancies will be monitored in next years of our long-term experiment of environmental action effects on steel bridges.

3. Observation of corrosion process at Silesia

The basic function of bridges is, above all, to ensure reliable traffic, so that the bridge does not become a limiting element of performance and permeability of the road [8]. The administrators of bridge structures with quality and qualified maintenance, repairs and reconstructions ensure fulfilment of this function. For these purposes it is necessary to know not only the current state of the structure, but also how it will degrade in the future [9]. The main factors influencing the condition of bridges is increasing traffic intensities and especially the degradation processes of structural elements, which are caused by environmental action from the surrounding environment [10]. Polluted air has a significant impact on the degradation of all materials used in the transport infrastructure. As pollution is increasing, the polluted air becomes considerably more aggressive with a bigger influence on the structural parts of bridges.

In Poland, five classes of winter maintenance are classified, in which the roads are divided by traffic, and 3 of these classes are located in the Silesia region where a study of the influence of chloride ions, such as winter maintenance products, on corrosion processes. In selected locations, the samples of structural steel with dimensions 150x100x2 mm were placed on 11 bridges. A total of 12 samples were placed for the horizontal (upper side of the lower flange), as well as the vertical (beam web).

After third year of in-situ experimental measurement three samples were taken from the horizontal and vertical positions and after cleaning they were weighed. The measured data were processed, evaluated and result are presented in table 1. where higher standard deviation signalize that even bridges which are in the same type of winter maintenance don't have similar degradation of test samples due to impact of environmental load combined with chloride ions.

Table 1. Results after the third year of exposition on bridges.

Type of WRM	Place of installation	Weight loss g/m^2/year	
		mean	standard dev.
WRM I	web of I-beam	218.94	29.22
	bottom flange of I-beam	265.07	264.97
WRM II	web of I-beam	97.56	29.01
	bottom flange of I-beam	116.37	18.62
WRM III	web of I-beam	190.81	110.97
	bottom flange of I-beam	226.67	158.63

Comparison of results after three years exposition at aggressive environment are shown in figure 4, where outcomes are divided to 3 types of winter maintenance and 2 types of positioning, web of I beam and bottom flange of girder.

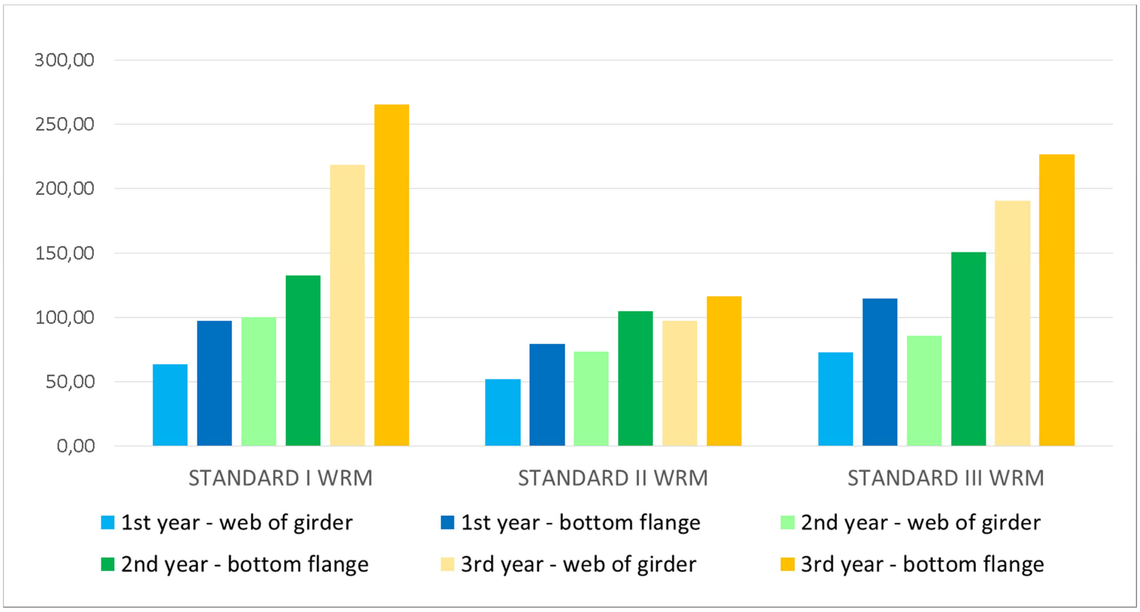

Figure 4. Comparison of results after three years of exposure.

The same approach as on bridges were used for samples placed in reference stations, where samples are both horizontally and vertically positioned. Collected data from stations after third year of measurement are in table 2, where Poraj, Katowice and Ustroń represent three districts at Silesia region. Results of horizontal and vertical positions are together presented in table 2, what have impact on the higher standard deviation.

Table 2. Results after the third year of exposition at reference stations.

Location	Weight loss (g/m^2/year)	
	mean	standard dev
Poraj	173.06	64.69
Katowice	103.11	20.76
Ustroń	114.45	62.78

Significant increment after first year does not continue as it can be seen in figure 5, but it only grows slowly. This results can be affected by several impacts like average temperature and rainfall during years, also protection of sample by corrosion itself, where greater weight losses after initial time of corrosion processes are exchanged by slower progress of material degradation.

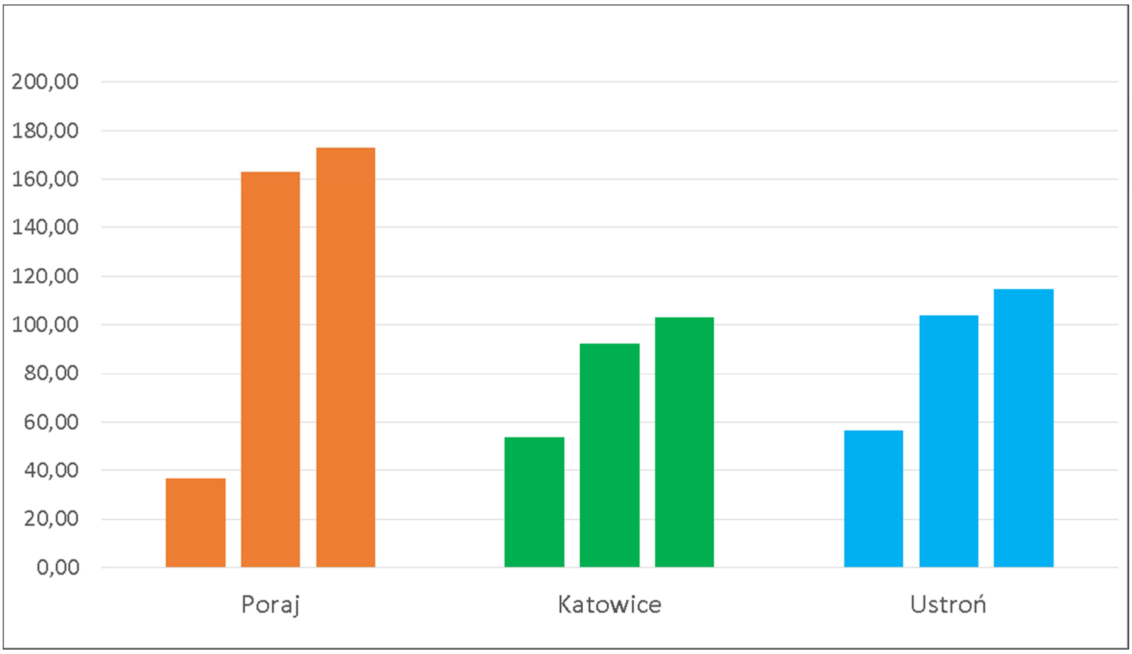

Figure 5. Comparison of results from the reference stations after three years.

4. Conclusions

Even though efforts during the design and construction of bridge structures, various damages and failures ensue within design lifetime. Without proper maintenance, small defects can develop into failures significantly affecting bridge load-carrying capacity, traffic safety and bridge remaining lifetime. Process of analyses considering environmental degradation processes and their future development is complicated and problematic

Corrosion has a stochastic character and it dependents on factors like average temperature, humidity or rainfall, also on material characteristics, but even on structural design of the bridge. The results obtainable in this article approve the randomness of corrosion. More relevant data for the estimation of the influence of corrosion on any structure can be obtained only from long-term measurements. Therefore, the experimental investigation of impacts of aggressive environment should continue.

Acknowledgments

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