

## Improving the Corrosion Resistance of Weathering Steel Bridges

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### Abstract

Weathering steel has been used almost exclusively by the Ministry of Transportation Ontario (MTO) for construction of steel bridges since 1968. This steel, under normal weathering cycles, oxidizes to form a tough layer of rust or 'patina', which protects the steel from unabated corrosion. Although many of these bridges exhibit stable patina in most locations, some bridges have recently exhibited accelerated corrosion over the driving lanes (from road salt exposure) with the corrosion products disbanding from the parent steel. Analysis of the corrosion products indicated that the corroding regions contained akaganeite ( $\beta$ -FeOOH-Cl) and some lepidocrocite ( $\gamma$ -FeOOH), while the uncorroded or less-corroded regions exhibited greater amounts of goethite ( $\alpha$ -FeOOH). These findings were consistent with published literature [1]. Akaganeite is porous and can act as an effective cathode thus increasing the rate of anodic reactions on the steel. To some extent, lepidocrocite ( $\gamma$ -FeOOH) will also accelerate the cathodic reaction due to its tendency to decompose and reform, thus facilitating the cathodic reaction process. In contrast, goethite ( $\alpha$ -FeOOH) is thermodynamically stable and can be partially reduced only at low cathodic potentials.

Thus, there are strong incentives to form goethite even under exposure to deicing salts to reduce the corrosion of weathering steel. In this project, attempts have been made to achieve this through the modification of weathering steel composition. A literature review indicated that the alloying elements Ni, Cr, Mo and Ti promote the formation of the goethite. Consequently, four new steels were cast containing the alloying elements Mo+P, Nb+B and Ni+Cr+Mo at slightly greater concentrations. In addition, a 12% Cr steel (A1010), high Ni steel (3.35%Ni) and another commercial steel (HPS70W) were also investigated. The composition of these steels is presented in Table 1.

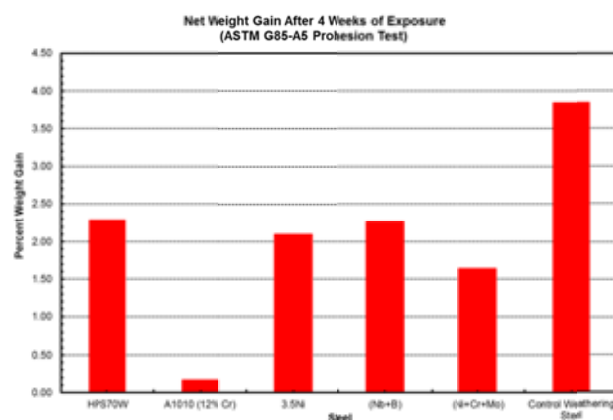
**Table 1. Composition of the steels investigated**

Element	Steel Sample Code							
	Control Weathering Steel - CSA Spec	9024-2 (Mo+P)	9025-2 (Ni+Cr+Mo)	9026-2 (Nb+B)	9027-2 (Ni+Cr+Mo)	3.5% Ni	High Cr A1010	HPS 70W
C	0.2	0.055	0.055	0.051	0.046	0.1	0.03	0.11
Mn	0.75 / 1.35	1.453	1.43	1.44	1.44	0.5	1.5	1.10/1.35
S	0.04	0.0014	0.0012	0.0014	0.0015	0.001	max 0.005	max 0.006
P	0.03	0.0275	0.005	0.004	0.005	0.007	0.04	0.02
Si	0.15/0.50	0.51	0.53	0.57	0.48	0.22	1	0.30/0.50
Cr	0.7	0.56	0.49	0.025	0.71	0.1	12.5	0.45/0.70
Ni	0.9	0.31	0.71	0.3	1.2	3.35	1.5	0.25/0.40
Cu	0.2/0.6	0.31	0.35	0.35	0.31	0.12		0.25/0.40
Mo		0.37	0.37	0.28	0.47	0.02		0.02/0.08
Al(l)		0.029	0.031	0.026	0.024	0.018		
Al(s)		0.026	0.029	0.024	0.02			
Cb		0.002	0.002	0.035	0.003	0.001		0.04/0.08
V	0.1	0.077	0.077	0.004	0.005	0.002		
B		0.0003	0.0002	0.0047	0.0004			
Ti		0.0069	0.0037	0.036	0.005	0.002		
Zr		-	-	-	-			
Ca		0.0014	0.002	0.0014	0.0018			
Te		-	-	-	-			
Sn		-	-	-	-			
N		-	-	-	-		max 0.030	

Corrosion behaviour was investigated using ASTM G85-A5 and a modified form of the GM-9540P salt spray test. Linear polarization resistance (LPR) and electrochemical impedance spectroscopy (EIS) were also performed. The

corrosion product layers were characterized using scanning electron microscopy coupled with energy dispersive X-ray analysis (SEM/EDX), laser Raman spectroscopy, and Mössbauer spectroscopy.

The results from these investigations will be presented and the effect of alloying elements on the corrosion resistance of weathering steels discussed. For example, the net weight gains after 4 weeks of exposure in the ASTM G85-A5 test are shown in Figure 1. This figure shows that the new steels such as Nb+B, Ni+Cr+Mo and 3.5% Ni steels exhibited approximately less than half of the net weight gain by the weathering steel currently in use. In addition, the net weight gain on the A1010 (12% Cr steel) is negligible compared to that on the other steels. These results are also consistent with electrochemical measurements. Surface analysis indicated the incorporation of chromium into the oxide layer for the A1010 steel and the presence of slightly greater amounts of goethite phase for the new steels compared to the steel presently used.



**Figure 1.** Net weight gain on selected steel panels after exposure to the ASTM G85-A5 test for a period of 4 weeks.

### Reference

[1] Desmond Cook, "Understanding the Corrosion Process Using Spectroscopic Techniques", Proc. Int. Sym. Ind. Appl. Mössbauer Effect, paper T2a104, 2000.