



Passivation and chloride-induced corrosion of a duplex alloy steel in alkali-activated slag extract solutions



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HIGHLIGHTS

- Alloy steel has high corrosion resistance in ordinary Portland cement extract.
- Alkali-activated slag extract results in less protective passive film for steels.
- Alloy steel is not recommended to be utilized in alkali-activated slag concrete.

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ABSTRACT

In this study, the passivation and chloride-induced corrosion behavior of a novel duplex alloy steel (00Cr10MoV) and low-carbon (LC) steel in ordinary Portland cement (OPC) extract solution and alkali-activated slag (AAS) extract solution were evaluated by electrochemical measurements and corrosion morphology observation. Seawater corrosion-resistant 00Cr10MoV steel with the addition of alloying elements Cr and Mo was designed to be used in concrete structures exposed to the tidal zone. The results show that 00Cr10MoV steel exhibits significantly higher corrosion resistance than LC steel in OPC extract with chlorides due to the formation of a more protective passive film. However, the high corrosion resistance of 00Cr10MoV steel is less pronounced in AAS extract with chlorides. Accordingly, this duplex alloy steel is not recommended to be utilized in combination with AAS materials in marine environments.

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1. Introduction

The main challenge of marine structures is the corrosion of embedded reinforcing steels after long-term exposure [1–4]. Thus, corrosion-resistant steels have been developed to replace low-carbon steels in order to prolong the service life of marine structures. Conventional stainless steels have been proved to have superior corrosion resistance in cement-based materials, even after long-term exposure to severe environments [5–9]. As is well known that the most important limitation of stainless steels used in constructions lies in the high price of alloying elements Ni, Mo and Cr added. Therefore, low-Ni stainless steels and lean duplex stainless steels have emerged to reduce the initial production cost with satisfied corrosion resistance [10–12].

Meanwhile, much cheaper alloy steels with various concentrations of alloying elements have been widely investigated [13–23]. 12%Cr steel was confirmed to be a durable reinforcing material in concrete after long-term exposure to severe marine

environments [13]. However, it was suggested that the hot-roll scale of 12%Cr steel should be removed before being used in concrete. It is noteworthy that, in the last two decades the 9%Cr micro-composite steel with special ferritic-martensitic microstructure was intensively investigated in Northern America for its high chloride threshold level in concrete [14,15].

Recently, corrosion-resistant steels with 3%–16%Cr were studied for their passivation behavior and the properties of corrosion products. It was found that protective passive film and/or compact rust layer can be formed for these corrosion-resistant steels, which results in their high corrosion resistance [16–20]. Moreover, low-alloy steels with Cr content less than 1% also attracted wide attention due to their much lower cost compared with stainless steels [21–24]. The good anti-corrosion feature of low-alloy steels is mainly attributed to the formation of compact rust layer rather than the protective passive film [21,22,24].

With the advent of low-carbon economy, increasing interest has been given to low-carbon materials. In the civil engineering field, alkali-activated materials (AAMs) serve as the main ingredients of low-carbon concrete [12,25–42]. Among them, alkali-activated fly ash (AAFA) and alkali-activated slag (AAS) are widely studied

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for their possible replacement of ordinary Portland cement (OPC). It was confirmed that the corrosion resistance of steels in AAMs is equal to or higher than those in OPC mortars/concretes, though the mechanism of the improved corrosion resistance is somehow uncertain [12,27,28,36,37,40,43,44]. However, contradictory conclusions can also be obtained due to the fast carbonation of AAMs, which can depassivate the embedded steels at early age [26,38].

Although the corrosion resistance of stainless steels has been evaluated in AAFA mortars [12,44], so far there is few research concerning the corrosion behavior of Cr-bearing alloy steels in AAS materials. Therefore, the purpose of this study is to compare the spontaneous passivation behavior and chloride-induced corrosion resistance of conventional low-carbon steel and a novel duplex alloy steel in alkali-activated slag (AAS) extract solution using elec-

Table 1
Chemical composition (wt.%) of OPC and GGBFS.

Material	SiO ₂	CaO	K ₂ O	Na ₂ O	SO ₃	Al ₂ O ₃	Fe ₂ O ₃	MgO	P ₂ O ₅	Loss on ignition
OPC	19.52	56.22	0.85	1.0	4.59	6.19	2.81	1.8	6.64	0.33
GGBFS	32.66	33.85	0.45	–	3.12	16.95	0.42	6.4	4.74	1.35

Table 2
Chemical composition (wt.%) of investigated steels.

Steel	Fe	C	Si	Mn	P	S	V	Cr	Mo
LC	Bal.	0.22	0.53	1.44	0.025	0.022	0.038	–	–
00Cr10MoV	Bal.	0.014	0.487	1.49	0.013	0.007	0.059	10.37	1.16

Note: Bal. is the balance content.

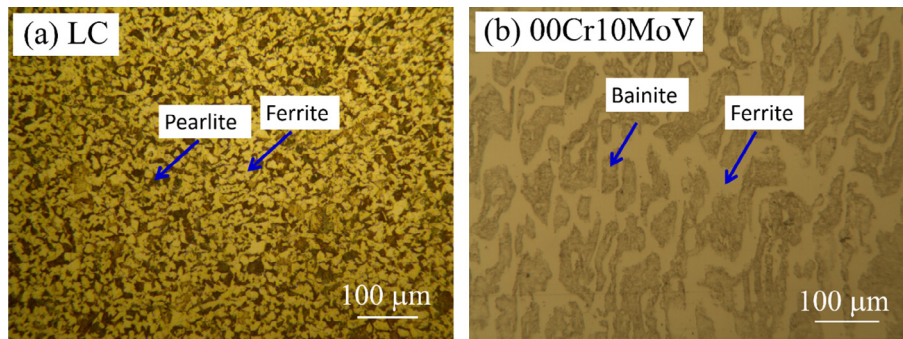


Fig. 1. Optical micrographs of investigated steels. (a) LC steel with pearlite and ferrite phases, and (b) 00Cr10MoV steel with ferrite and bainite phases.

Table 3
Chemical composition (ppm) of OPC and AAS extracts measured by ICP-OES.

Extract	Si	Ca	Al	S	K	Na
OPC	1.09	>562.87	<0.0004	>1060.55	>1381.96	22.73
AAS	>5594.31	4.01	>81.89	>540.04	>151.42	>180.48

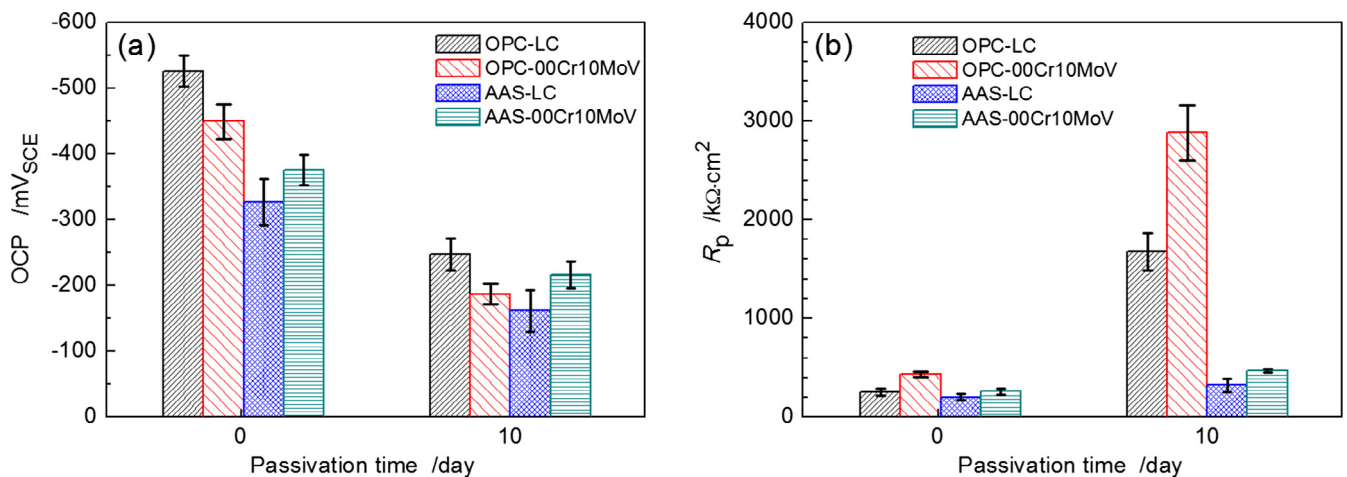


Fig. 2. Electrochemical behavior of LC and 00Cr10MoV steels immersed in OPC and AAS extracts during the passivation stage. (a) OCP values, and (b) R_p values.

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