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Development and Application of High-Cr Ferritic Stainless Steels as Building Exterior Materials

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Stainless steels have been widely used as a building exterior materials in Asian countries for the last decade. It is required for the materials in this field to have an aesthetic appearance, a relatively high strength, and an excellent corrosion resistance. Other metallic materials such as copper, aluminum, and carbon steels have been also used as the exterior materials. Considering the cost of maintenance, stainless steel, having the outstanding corrosion resistance, is replacing other materials in the several parts in the building exteriors. Ferritic stainless steel has been applied as the roofing materials because its thermal expansion is much smaller than that of austenitic stainless steel. Therefore, it is suitable for the large-scale construction such as airport terminal, convention center, and football stadium. To improve the corrosion resistance of the ferritic stainless steels, the modification of alloy composition has been studied to develop new grade materials and the progress in the surface technology has been introduced. Corrosion properties of these materials were evaluated in the laboratory and in the field for longer than two years. High-Cr ferritic stainless steel showed excellent corrosion resistance to the atmospheric environments. In the region close to the sea, the corrosion resistance of high-Cr ferritic stainless steel was much superior to that of other materials, which may prove this steel to be the appropriate materials for the construction around seashore. In some of the large constructions around seashore in South Korea, high-Cr ferritic stainless steels have been used as the building exterior materials for six years.

Keywords *: stainless steels, building exterior, roof, corrosion, atmospheric environment, aesthetic appearance, ferritic, composition.*

1. Introduction

Stainless steels have been used for the building exterior materials such as a roof and wall because of its aesthetic appearance and good corrosion resistance.[1)] In Korea, the large-scale constructions have been made of the stainless steels as shown in Fig. 1.

Several kinds of stainless steel (SS) have been used for these constructions. SS 446M was applied for the roof and ceiling in ASEM convention center in 1998 and for the roof of Incheon international airport in 1999. This grade of the ferritic stainless steel is highly alloyed with 26 wt.% of Cr and 2 wt.% of Mo. (Fig. 2) SS 316, having 18 wt.% of Cr and 2 wt.% of Mo, was used for the roofs in KTX (Korea High Speed Rail) Chonan station and in Kwangju Worldcup Stadium in 2000.

The basic requirements for the building exterior materials are mechanical properties of strength and bendability, weldability, corrosion resistance in atmospheric environments, physical properties such as thermal expansion coefficient, and aesthetic appearance.

Stainless steel has the benefits as building exterior material. It has excellent corrosion resistance so that it does not need to paint on the surface for the protection from the corrosion. Stainless steel has a long life time and also is a recyclable material. It has good surface appearance and can be applicable for the wide range of surface finishes.

Recently, the cost for the use of austenitic stainless steel has rapidly increased due to high price of Ni. Therefore, it has been required to expand the application field of ferritic stainless steel and to develop new ferritic stainless steel as building materials. In this paper, some beneficial features of ferritic stainless steel for building exterior materials are described.

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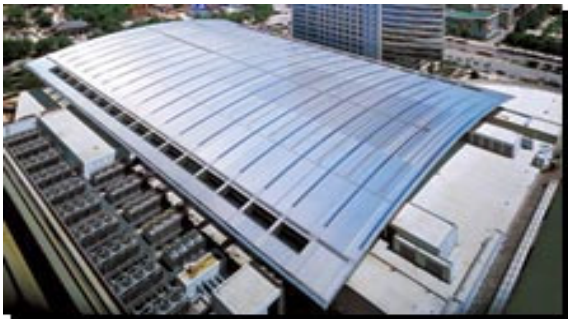
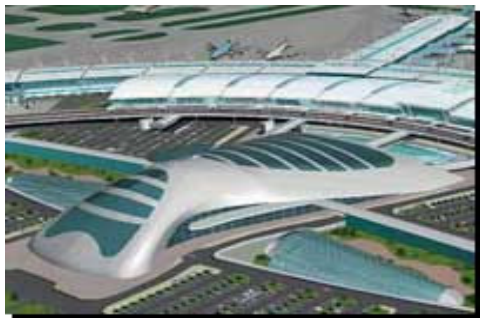


(a) ASEM convention center



(b) Incheon International Airport

KTX Chonan Station

Kwangju Worldcup Stadium

Fig. 1. Examples of the constructions made of the stainless steels in South Korea

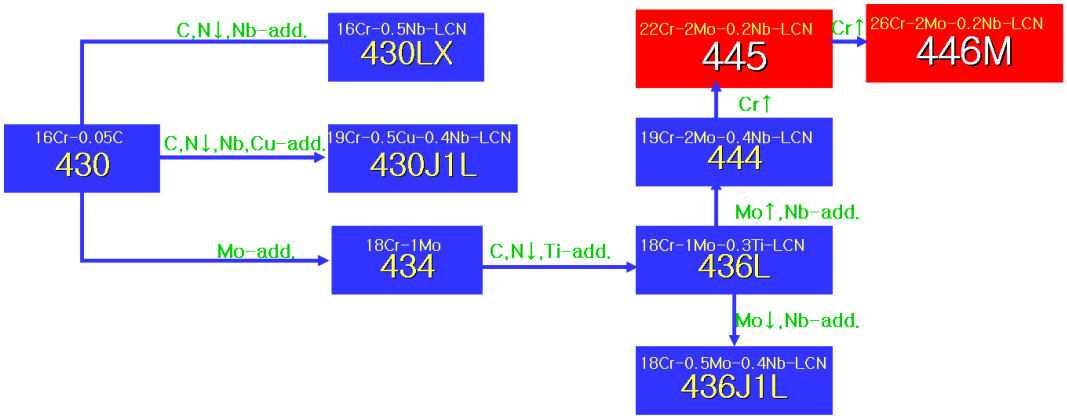


Fig. 2. Different kinds of ferritic stainless steels with nominal chemical compositions

2. Stainless steels as a building materials

It has been reported that type 304 stainless steel showed 35 times lower corrosion rate than Al and 333 times lower than Cu in marine environment.[2)] Summarizing the basic properties of typical austenitic stainless steels and high Cr-conatining ferritic stainless steels, mechanical properties of stainless steels were also better than other metallic materials such as Cu, Al, and carbon steels (Table 1). Yield strength of the stainless steels is higher than all other materials, but the elongation of the ferritic stainless steels is a little lower than Cu and carbon steel.

Table 1. Mechanical properties of stainless steels and other metallic materials.

Material		YS (MPa)	TS (MPa)	E (GPa)	n	Elongation (%)
300 (γ)	304	314	618	193	0.5	55
	316	314	578	195	0.5	54
400 (α)	445	440	540	200	0.18	28
	446M	440	550	214	-	26
Copper		133	237	117		40
Aluminum		103	108	68	-	12
Carbon Steel		231	433	200	-	41

Table 2. Physical properties of stainless steels and other materials

Material		Composition (wt%) Cr	Mo	Ni	N	PREN	Thermal Expansion (°C-1, 10-6)	Electric Resistance (Ωm, 10-3)	Thermal Conductivity (W/m° · C)
300 (γ)	304	18.4	-	8.1	0.04	18	16	72	16
	316	17.3	2.3	11	0.02	24	16	72	14
400 (α)	445	22	2	-	-	28	11	62	20
	446M	26	2	-	-	32	11	64	19
Copper		-	-	-	-	-	16	1.7	390
Aluminum		-	-	-	-	-	23	3.0	222
Carbon Steel		-	-	-	-	-	12.6	13	74.6

In Table 2, PREN means the Pitting Resistance Equivalent Number and can be calculated using the simple equation of 'wt.% of Cr + 3.3 wt.% of Mo', based on the chemical composition of the alloy).[3] Ferritic stainless steels show much lower thermal expansion coefficient than those of austenitic stainless steels and other materials. Therefore, ferritic stainless steels would be suitable for large-scale construction.

3. Corrosion properties of stainless steels

Several types of austenitic and ferritic grade stainless steels have been tested in the atmospheric environments. As shown in Fig. 3, SS 446M having 26 wt.% of Cr showed the best resistance to atmospheric corrosion in the seashore environment for two years. The rust area of this grade alloy is almost zero. This result is well consistent with the corrosion indication parameter of PREN.

To verify the excellence of SS 446M, atmospheric exposure test has been done in the rural, urban, seashore, and industrial sites. (Table 3 and 4) For the two-year exposure, SS 446M showed the outstanding resistance to the atmospheric corrosion in all environments. In rural region, three stainless steels of SS304, SS316, and SS446M did not show any big difference in corrosion properties, which meant that it could be optimum grade of the stainless steel for the different regions considering the cost.

Austenitic stainless steels were the popular grade of SS for the use as the building exterior materials because of its good corrosion resistance, formability and weldability. However, high Cr-containing ferritic grade stainless steels such as SS 445 and SS 446M have been recently used for this application field in South Korea since 2000 because of their excellent corrosion resistance.

Table 3. Metrological data of the typical sites in South Korea for the atmospheric exposure test

Type	Urban	Industrial/Marine	Rural/Marine
Site	Seoul	Pohang	Jeju
Temp.(°C)/ R.H. (%)	12.3/64	13.8/60	15.2/61
SO^2 (ppm)	0.011	0.011	0.002
NOx(ppm)	0.034	0.030	0.004
Fine particle ($\mu g/m^3$)	50	71	33*

Table 4. Comparison of the corrosion properties of SS304, SS316, and SS446M after two-year exposure at rural, urban(Seoul), seashore(Walpo), and industrial(Pohang) regions.

Stainless steel	Rust Area(%) Rural	Seoul	Pohang	Walpo
Type 304	< 0.1	11	8.0	18
Type 316	< 0.1	6	9.0	10
Type 446M	< 0.1	< 1	< 1	< 1

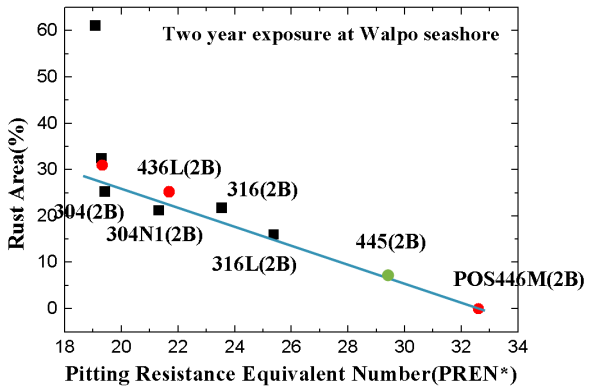


Fig. 3. Corrosion properties of the stainless steels with different PREN after two-year exposure at seashore

4. Summary

Stainless steels have many benefits as building exterior materials and have been widely applied in the construction field in South Korea. Compared to other metallic materials, its good aesthetic appearance and low maintenance cost are the major advantages for this application. Low thermal expansion property of ferritic grade stainless steel is another benefit, which makes it possible to apply the ferritic stainless steel for large-scale construction. In the field exposure test at the several regions including the seashore, SS 446M alloy showed the best resistance to the atmospheric corrosion.

References

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3. A. J. Sedriks, Corrosion of Stainless Steels, 2nd ed., p. 111, Wiley, 1996.