STAINLESS STEELS AS BUILDING EXTERIOR MATERIALS

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Keywords: Stainless Steels, Niobium, High-Cr Stainless 446, Roofing, Building Exteriors, Pitting Resistance, Mechanical Properties, Physical Properties

Abstract

Stainless steels have been widely used as the exterior materials for buildings because of their unique appearance, simple construction process, good corrosion resistance, and low maintenance cost. Recently, ferritic grades of stainless steels have been applied as roofing materials for large structures because of price advantage and low thermal expansion. POSCO has developed high-Cr ferritic stainless steels of 21 wt.%, 22 wt.%, and 26 wt.% Cr. Type 446M stainless steel with 26%Cr was used as the roofing material for the Incheon International Airport in 2002 and has maintained its good appearance for longer than ten years without rusting. For the development of 446 grade, Nb was added as a microalloying element to prevent weld decay which is a very common form of corrosion in ferritic stainless steels. Therefore, Nb-added high-Cr 446 stainless steels have been successfully developed and applied as roofing materials in large structures such as an airport, convention center, and train stations.

Application of Stainless Steels

Stainless steels (SS) have been widely used as interior/exterior panels, roofing materials, elevators, and doors. Recently, higher alloyed SS such as 26%Cr stainless steels and surface-treated products have also been widely applied in this field. For the construction of large-scale buildings, the exterior appearance has become very important for the city-scape. Therefore, the highly-functional SS is still expanding its market to airports, train stations, and convention centers, etc. These applications are demonstrated in Figure 1.

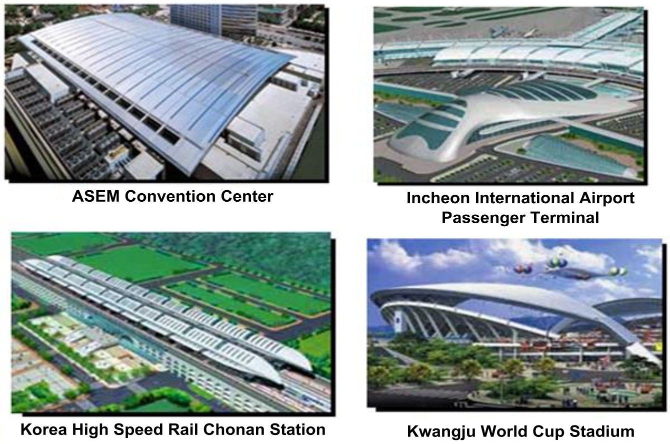

Figure 1. Large-scale constructions where highly-functional stainless steels were applied in South Korea.

Product and Development

The benefits of SS as the building exterior material are the excellent corrosion resistance, no need to paint, long life, completely recyclable, good appearance, wide range of surface finishes, and potential for high strength where required. The corrosion resistance of stainless steels can be determined by the material factors of chemical composition and surface finish, and by the environmental factors of ionic species, humidity and temperature. As shown in Figure 2, a passive layer of Cr-oxide is formed on the stainless steel and inhibits the metallic dissolution and the penetration of harmful ions into the materials. Typically, the PREN (Pitting Resistance Equivalent Number) is representative of the corrosion resistance of stainless steels and can be easily calculated based on a simple equation:

$$PREN = wt.\%Cr + 3.3 \times wt.\% Mo + 16 \times wt.\%N \quad (1)$$

Stainless steels can be classified into two groups of Ni-containing grades (austenitic and duplex) and Ni-free grades (ferritic and martensitic). For the building exterior materials, ferritic grades are commonly used. In Figure 3, highly-alloyed SS of types 445 and 446M have recently been developed for building exterior materials. Their Cr contents range from 22 to 25 wt.% with the addition of Mo and Nb. Mo can increase the 'PREN' value and improve the corrosion resistance. Nb alloying usually improves the weldability of SS which can be very helpful because high-Cr ferritic SS can be difficult to weld. Nb can enhance the fine weld microstructure and can prevent the weld corrosion by fixing the free C which can otherwise easily form chromium carbide during the weld solidification and cooling.

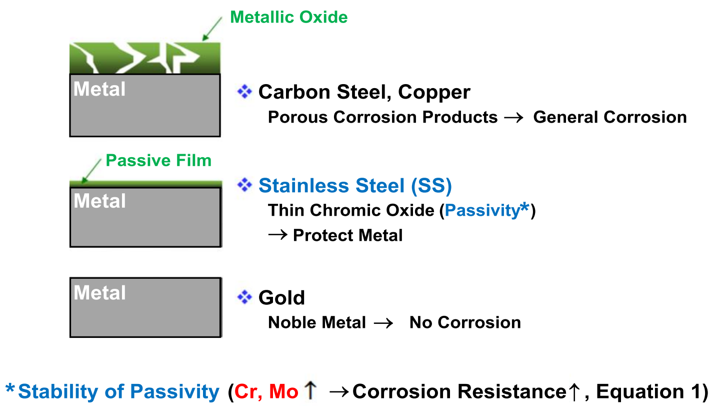

Figure 2. Schematic description of passivity of stainless steels compared to other metallic materials.

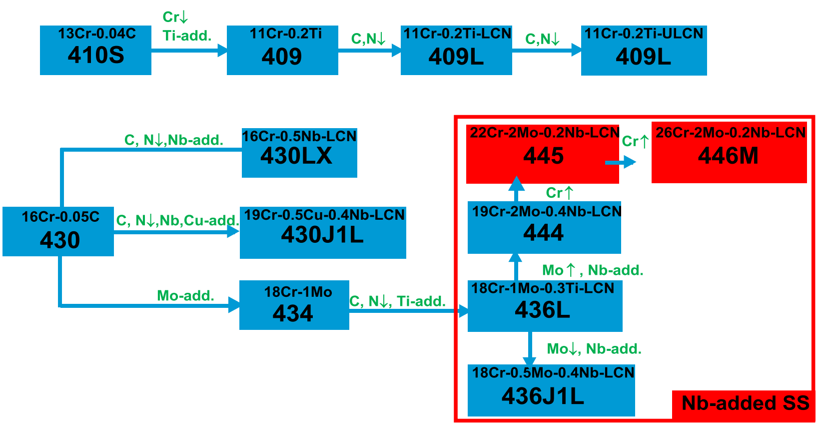

Figure 3. Various kinds of ferritic stainless steels with different chemical compositions.

In Figure 4, the atmospheric corrosion resistance of different SSs are compared after two-year exposure in seashore environments. 26%Cr SS of type 446M showed a small rust area of less than 1%, whereas conventional SS of type 304 was highly corroded. Therefore, in the case of marine application, including seashore and beach, type 446M would be the best and type 445 could be the second choice.

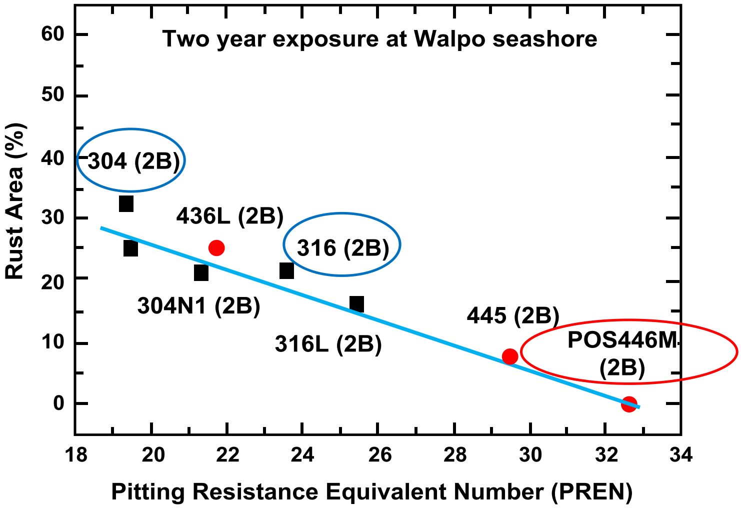

Figure 4. Atmospheric corrosion resistance of highly-alloyed ferritic stainless steels in seashore environments (austenitic comparisons in black).

Table I. Physical Properties of Stainless Steels and Other Metallic Materials

Material		**Composition (wt.%)**				**PREN**	**Thermal Expansion (°C^{-1}, 10^{-6})**	**Electric Resistance (Ωm, 10^{-8})**	**Thermal Conductivity (W/m-°C)**
		Cr	**Mo**	**Ni**	**N**				
300 (ϒ)	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
	446	26	2	-	-	32	11	64	19
Copper	-	-	-	-	-	-	16	1.7	390
Aluminium	-	-	-	-	-	-	23	3.0	222
Carbon Steel	-	-	-	-	-	-	12.6	13	74.6

In Table I, the thermal expansion coefficients of the ferritic stainless steels were the lowest, even compared to that of C steel. For large-scale construction, the thermal expansion property is very important when applied as roofing and exterior materials. Therefore, ferritic SS would be the best metallic material for large-scale construction.

Table II. Example Mechanical Properties of Stainless Steels and Other Metallic Materials

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

Ferritic SS usually shows higher yield strengths (YS) and lower tensile strengths (TS) than austenitic stainless steels, as shown in Table II. This feature implies that ferritic SS can maintain good flatness (high YS and E) and good bending and machining performance.

With the variety of positive features of ferritic SSs, the field of application could expand to almost all kinds of industrial areas as shown in Figure 5, including building exteriors, home appliances, water industry, cooking, containers and automotive exhausts.

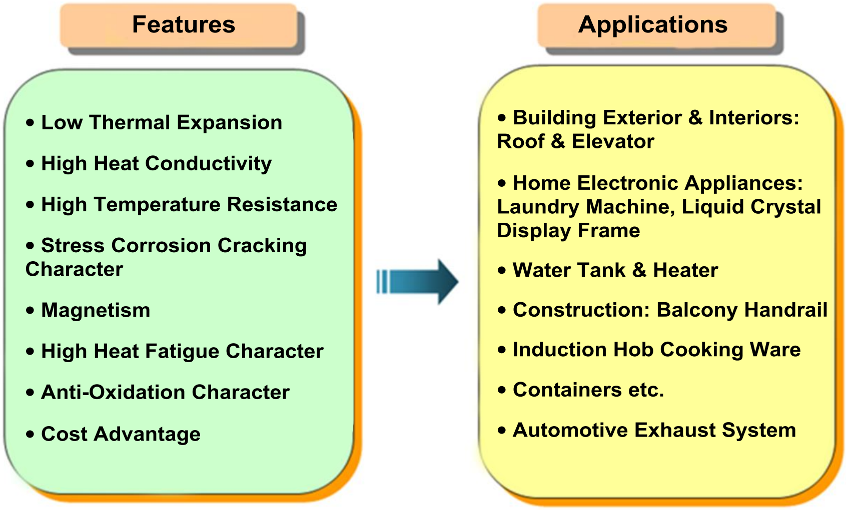

Figure 5. Features and future applications of ferritic stainless steels.

Stainless Steels as Building Exterior Materials

Building Exterior, General

Table III shows a list of recent applications of SS as building exterior materials in South Korea. Before 2000, conventional grades of 300 series SS were applied after surface treatment, such as coating and linen. Later, highly-alloyed SS of types 446M, 445, 445NF were developed and applied to large-scale constructions.

Table III. Applications of Stainless Steels as Building Exterior Materials in South Korea

Year	Name of Building	Material (Surface Finish)
1995	Samsung Hospital in Seoul	304 (Dull-Fluoride Coating)
1997	Korean Economic Press Building	304 (Embossing)
1998	Panmoonjum House of Freedom	304 (Dull)
1999	POSPLAZA (Shanghai)	316, 304 (Dull)
2000	LG Building in Kangnam	304 (Linen, Bead, HL)
2000	ASEM O/T	316 (Linen, Dull, HL)
2000	Industrial Bank Building	316 (Dull)
2000	Incheon International Airport Transportation Center	446M (Dull, Satin) 316 (Satin)
2001	Dongbu Finance Building	316 (HL)
2003	POSCO Museum	446M (Dull)
2008	Songdo Convensia	446M (Bead)
2010	KAIST Sports Complex	445 (Dull)
2011	POSCO Gymnasium	445NF, 316L (Dull-Fluoride Coating)

Roofing

Table IV. Applications of Stainless Steels as Roofing Materials in South Korea

Year	Name of Building	Material (Surface Finish)
1998	ASEM Convention Center (Roof, Ceiling)	446M (Dull) 316 (Dull)
1999	Incheon International Airport Passenger Terminal	446M (Dull)
1999	Yangyang Airport Terminal	445 (HL-Fluoride Coating)
2000	Kwangju World Cup Stadium	316 (Dull)
2000	Taegu International Airport	445 (Dull)
2000	EXCO Daegu	446M (Dull)
2002	Jeju Convention Center	446M (Dull)
2004	KTX Busan Station	446M (Dull)
2004	KTX Gwangmyoung Station	446M (Dull)
2005	Yeosu Airport Passenger Terminal	445 (Dull)
2008	Songdo Convensia	446M (Bead)
2010	KAIST Sports Complex	445 (Dull)
2011	POSCO Gymnasium	445NF, 316L (Dull-Fluoride Coating)

The roof would usually experience a more corrosive environment than other exterior applications because more contamination and accumulation of harmful elements can often occur. Therefore, more corrosion-resistant materials should be used as roofing materials rather than for general exterior materials. In Table IV, it is shown that 26%Cr SS of type 446M has been widely used as a roofing material since 1998. The anti-corrosion properties of this alloy were already proved even at the seashore. Depending on the location of the construction, typical candidates for roofing materials would be type 446M, 445, and 445NF.

Conclusions

Highly alloyed ferritic stainless steels such as types 446M and 445 have been developed and applied as building exterior materials since 1998. Because of their unique appearance and low maintenance cost-saving, these materials are often adopted as the best candidates for large-scale construction exterior materials. Depending upon location and function of the construction, there are several choices of grades of ferritic stainless steels and different surface finishes.

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