

Welding Consumables for Fire-resistant Steels

1. Introduction

Nippon Steel has commercialized fire-resistant steels for building construction (NSFR). These steel products have excellent fire resistance. Even at 600 °C, they exhibit more than two-thirds of their proof stress at room temperature. Various welding consumables having fire-resistant properties comparable to those of NSFR to meet specific welding requirements (steel product configuration and welding method) have been also developed and commercialized.

2. Welding Consumables

Table 1 lists Nippon Steel’s welding consumables that can be applied to fire-resistant steels for building construction. A wide variety of welding consumables, each being applicable to steel products whose tensile strength ranges from 400 to 590 MPa, have been commercialized. They are applicable to various welding methods used in building construction - SMAW, MAG (Ar + CO₂), CO₂, submerged arc welding (SAW) and even electro-slag welding (SESNET, SES).

Table 1 List of welding consumables for fire-resistant steels in various welding processes

Welding Process	Trade name	Specification		JIS class	Applicable FR steel				
		Wire dia. (mm)	Flux (Mesh)		400 MPa	490 MPa	520 MPa	590 MPa	
SMAW	All position	- 16FR	3.2, 4.0, 5.0, 6.0		Z 3211 D4316				
		L-50FR			Z 3212 D5016				
		L-53FR			Z 3212 D5316				
		L-60FR			Z 3212 D5816				
	Fillet	LM-40FR	5.0, 5.5,		Z 3211 D4326				
		LM-50FR	6.0, 6.4		Z 3212 D5026				
LM-53FR			Z 3212 D5326						
GMAW (Solid wire)	CO ₂	YM-40FR	1.2, 1.4, 1.6		Z 3312 YGW14				
		YM-50FR			Z 3312 YGW14				
		YM-60FR			Z 3312 YGW21				
	Ar-CO ₂	YM-40FRA			Z 3312 YGW17				
		YM-50FRA			Z 3312 YGW17				
GMAW (Flux cored wire)	CO ₂ Flux cored	SF-40FR	1.2, 1.4, 1.6		Z 3313 YFW-C430R				
		SF-50FR			Z 3313 YFW-C50DR				
	CO ₂ Metal cored	SM-50FR	1.2, 1.4, 1.6, 2.0		Z 3313 YFW-C50DM				
		SM-60FR			Z 3313 YFW-C60FM				
SAW	General use	YF-15FR × Y-D•FR	2.4, 3.2, 4.0, 4.8	12 × 150, 20 × 200 20 × D	Z 3183 S502-H				
		YF-15FR × Y-DM•FR			Z 3183 Z582-H				
	Fillet	NF-820FR × Y-D•FR	2.4, 3.2, 4.0, 4.8	12 × 150 12 × 48	Z 3183 S502-H				
		NF-820FR × Y-DM•FR			Z 3183 S581-H				
		YF-800S × Y-D•FR	4.0 ~ 6.4		Z 3183 S501-H				
		NF-900S × Y-DL•FR			Z 3183 S581-H				
	Corner joint (single pass)	NB-52FRM × Y-DL•FR	4.8, 6.4	12 × 100	Z 3183 S502-H				
		NB-60FRS × Y-DL•FR			Z 3183 S581-H				
	Corner joint (multi pass)	NB-52FRM × Y-DL•FR	4.8, 6.4	12 × 100 48 × D	Z 3183 S502-H				
		NF-1•FR × Y-D•FR	2.4 ~ 4.8		Z 3183 S502-H				
		NB-60FRM × Y-DL•FR			Z 3183 S581-H				
	ESW	SESNET	YM-40FRS × YF-15I	1.6	20 × D	-			
YM-50FRS × YF-15I			-						
YM-60FRS × YF-15I			-						
SES		Y-CM•FR × SES-15(F) × YF-15I	2.4 × 10	20 × D	-				

3. Typical Weld Metal Properties

Tables 2 to 4 show examples of the mechanical properties of weld metals for welded joints prepared using the welding consumables shown in Table 1. Table 2 concerns weld metal properties of SAW joints, Table 3 concerns those of CO₂-welded joints, and Table 4 concerns those of SESNET (Simplified ElectroSlag Non-

consumable Elevating Tip: Simplified electroslag welding with a non-consumable nozzle) joints. All the weld metals have sufficient room temperature strength compared to the base metal strength. Their yield strength (0.2% proof stress) at 600 °C is much higher than two-thirds of the base metal yield strength. They also have shown good results in a 2 mm V-notch Charpy test at 0 °C.

Table 2 Examples of weld metal properties for SAW

Flux	Wire	FR steel grade	Plate thickness (mm)	Welding condition	Pass No.	Electrode	Current (A)	Voltage (V)
NB-52FRS (12 × 100)	Y-DL•FR 6.4 mm	490MPa class	40	Single pass	1	L	1700	36
						T	1300	46
NB-52FRM (12 × 100)	Y-D•FR L; 4.8 mm T; 6.4 mm	490MPa class	70	Multi pass with underlaying of CO ₂ welding	CO ₂	L	300	33
					1 - 3	L	1100	36
						T	1000	38
					4	L	1100	38
					T	1000	44	
YF-15FR (20 × D)	Y-D•FR 4.8 mm	490MPa class	32	Multi pass with backing plate HI 5 kJ/mm	1 - 3	L	650	34
					4 - 13	L	650	34
NF-1•FR (48 × D)	Y-D•FR 4.8 mm	490MPa class	32	Multi pass with backing plate narrow gap	1	L	600	32
					2	L	650	33
					3	L	700	33
						T	650	34
					4 - 6	L	800	34
						T	700	35

Welding speed (cpm)	Heat input (kJ/mm)	Electrode spacing (mm)	RT			600			vE ₀ (average) (J) (vE ₋₂₀)
			YS (MPa)	TS (MPa)	El (%)	YS (MPa)	TS (MPa)	El (%)	
25	29.0	60	463	617	27	280	350	29	80
25	2.4	-	541	633	27	279	351	36	71
32	3.2	15							
35	3.5								
40	3.3	-	489	604	31	244	320	32	69 (vE ₋₂₀)
30	4.4		497	581	28	298	345	21	53
25	4.6	-							
	5.2								
45	6.0	15							
40	7.8								

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Table 3 Examples of weld metal properties for CO₂ welding

Category	Wire		FR steel grade	Plate thickness (mm)	Welding process	Current (A)	Voltage (V)	Welding speed (cpm)	Heat input (kJ/mm)	Ext. (mm)
	Trade name	Dia. (mm)								
Solid wire	YM-50FR	1.4	490MPa class	40	CO ₂	380	39	30.5	2.9	25
FCW (flux)	SF-50FR	1.2	490MPa class	20	CO ₂	270	29	25	1.9	20
		1.4				300	30	30	1.8	25
		1.6				350	31	35	1.9	25
FCW (metal)	SM-50FR	1.2	490MPa class	20	CO ₂	270	30	25	1.9	25
		1.4				300	29	30	1.7	25
		1.6				350	31	30	2.2	25
		2.0				450	34	40	2.3	25

Preheating temp. ()	Inter-press temp. ()	RT			600			vE ₀ (average) (J)
		YP (MPa)	TS (MPa)	EI (%)	YP (MPa)	TS (MPa)	EI (%)	
Non	250	584	660	30	446	541	18	111
Non	150	566	623	28	334	355	21	70
Non	150	564	621	27	297	337	21	59
Non	150	566	625	28	329	344	21	64
Non	150	606	662	25	319	384	31	77
Non	150	585	619	27	273	351	22	71
Non	150	604	666	26	337	366	23	86
Non	150	577	632	28	344	404	22	83

Table 4 Examples of weld metal properties for electro-slag welding (SESNET)

Wire	Flux	FR steel grade	Plate thickness (mm)		Current (A)	Voltage (V)	Welding speed (cpm)	Heat input (kJ/mm)	Groove gap (mm)	RT			600			vE ₀ (average) (J)
			Skin plate	Diaphragm						YS (MPa)	TS (MPa)	EI (%)	YS (MPa)	TS (MPa)	EI (%)	
YM-50FRS	YF-15I	490MPa class	35	35	380	48	2.4	45.6	25	460	650	30	310	380	25	120
YM-60FRS	YF-15I	590MPa class	60	60	380	52	1.3	91.2	25	487	692	30	373	450	26	138

(For further information, contact Steel Research Laboratories)