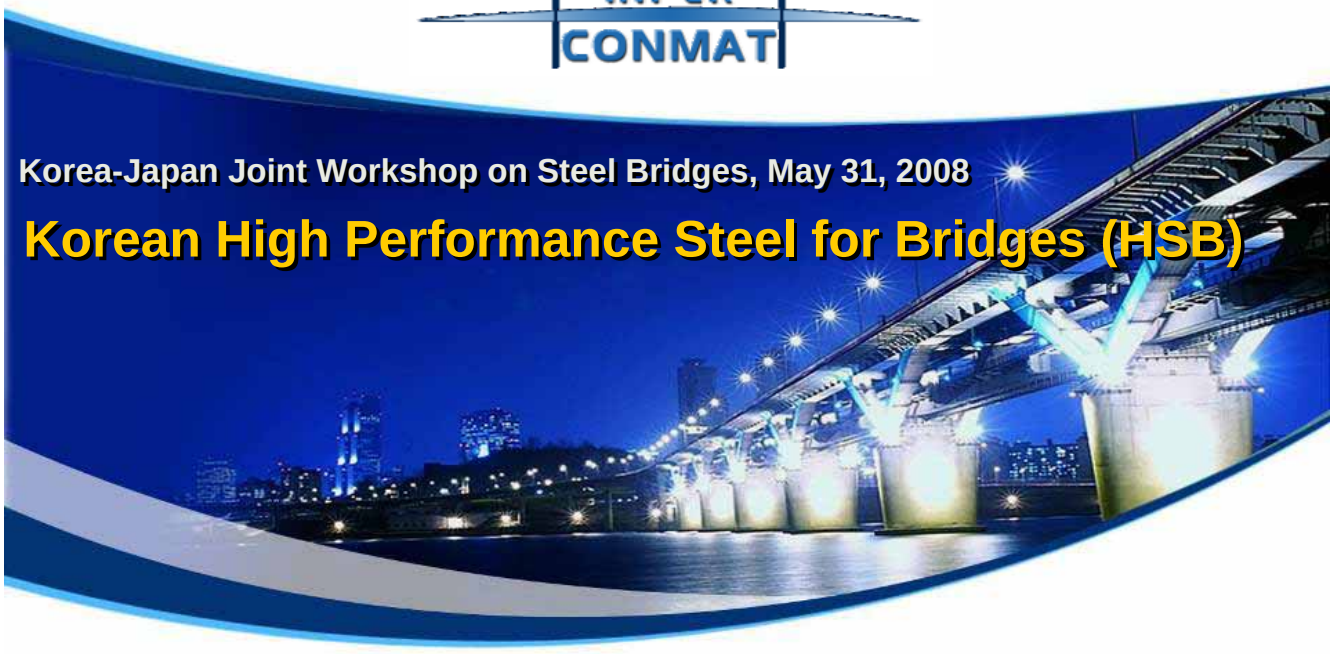


Yoon, Tae-Yang

RIST Research Institute of Industrial Science & Technology

Korean High Performance Steel for Bridges

- Development of HSB
- Material Properties
- Registration in KS (Korean Standards)
- Revision of Bridge Design Code
- Application of HSB

Development of HSB

Introduction of HSB

- HSB is Korean High Performance Steel for Bridges
- RIST was awarded the National Research center for developing high performance construction materials (Director Yoon, Tae-Yang)

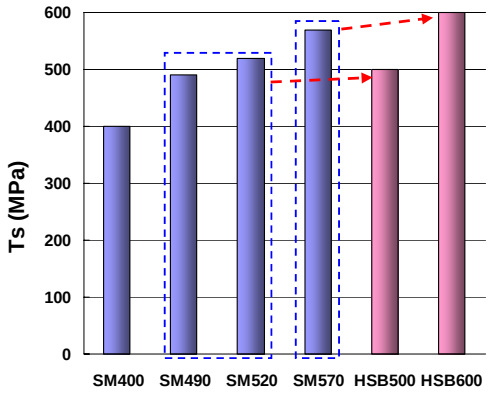
HIPER CONMAT 차세대사설콘용신재료특용기술연구단

- HSB was developed as Korean high performance steel for bridges
  - Development of 500/600MPa high performance steel for bridges
  - Develop application technology and design optimization using HSB
- Cooperative research among POSCO, Korean expressway corp., fabricators, designers and academia

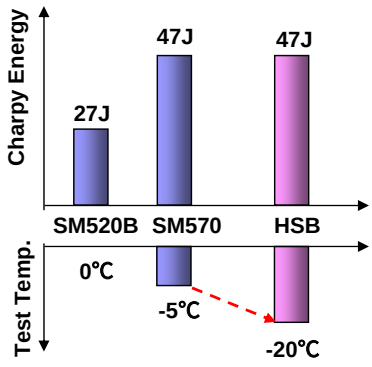
Development of HSB

Introduction of HSB

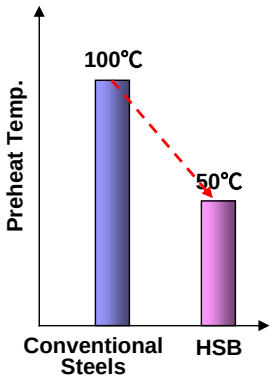
- Specifications of HSB are derived from VOC (Opinions of the steel users)
  - -Voices of various experts (designers, academia, fabricators of steel bridges)
  - -Require higher strength, higher toughness, and better weldability



< Strength >



< Toughness >



< Weldability >

- Process for Producing Steel: TMCP (Thermo-Mechanical Controlled Process)

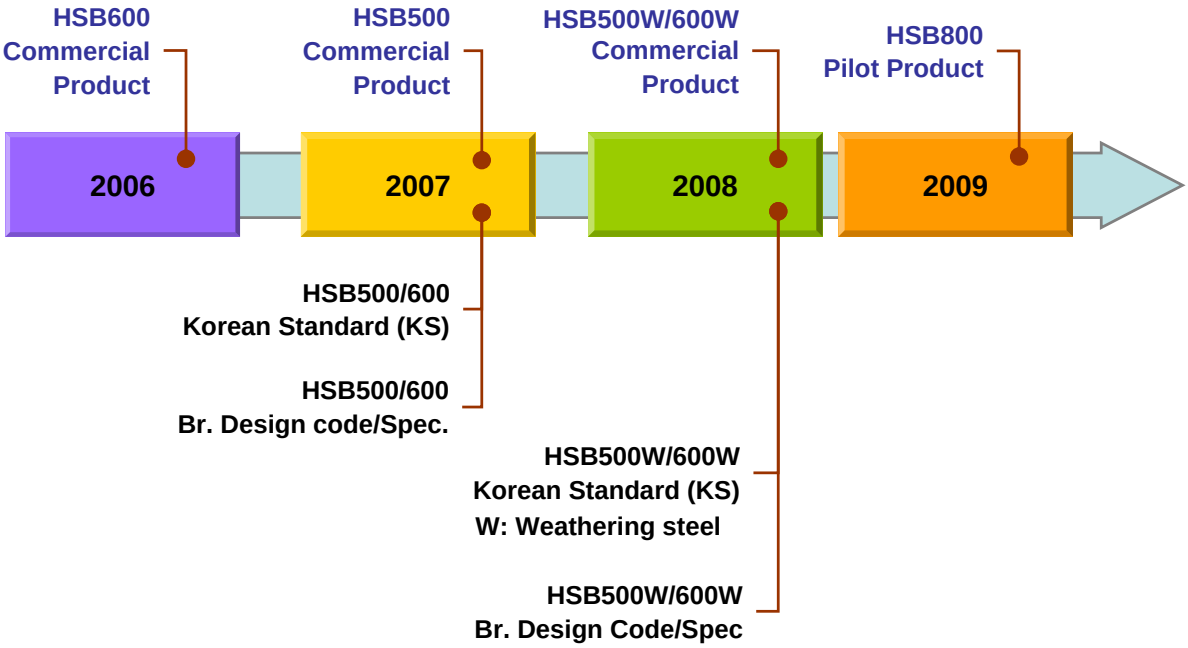
Development of HSB

Development Process

Process	Participants/Institutes				
	RIST	POSCO	Fabricator	Consultants	3rd agency
Spec. Setup	VOC survey → Required Spec.			Spec. Setup	
Pilot Product	Performance Test	Pilot Product → Weld Consumable	Korea Development Corp. Weld Tests	Verification of Test Results	Korea Testing & Research Institute Performance Certification
Mass Product		Manufacturing Spec.			
User's Guide & Code	KS Registration → Br. Design Code				

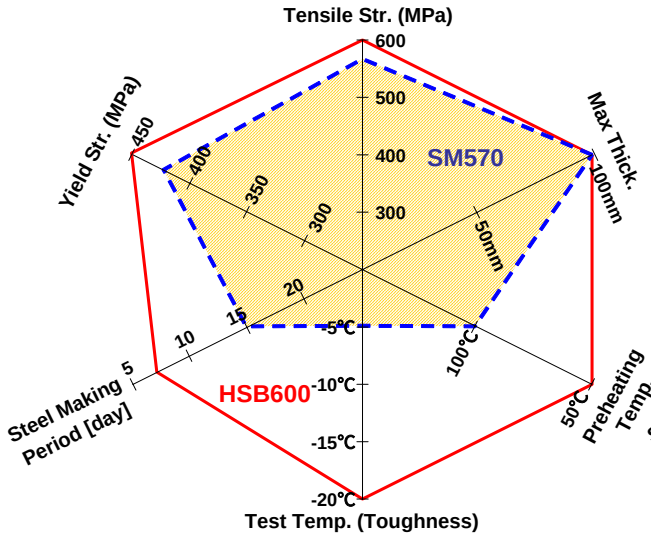
Development of HSB

HSB Development Schedule

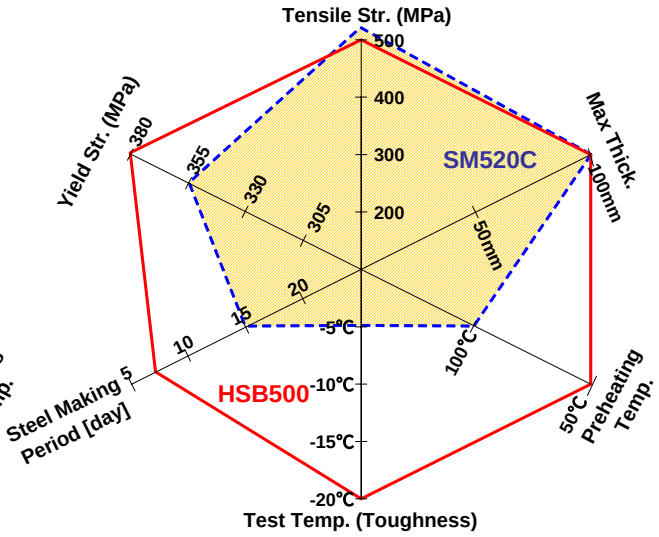


Material Properties of HSB

HSB vs Conventional Steels



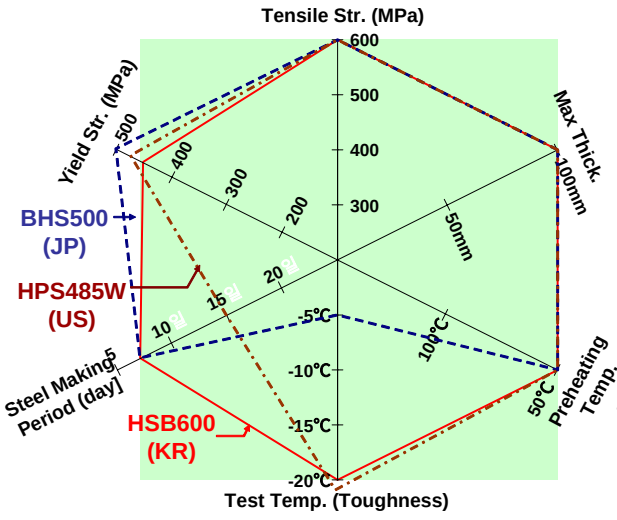
<HSB600 vs SM570>



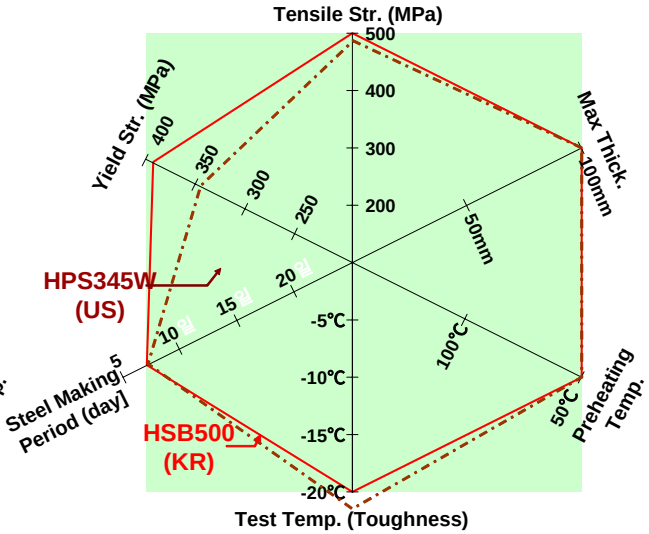
<HSB500 vs SM520C>

Material Properties of HSB

HSB vs HPS, BHS



<HSB600 vs HPS485W, BHS500>



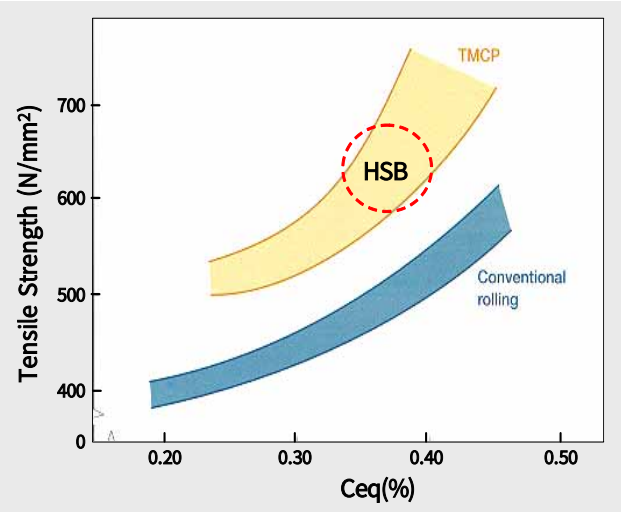
<HSB500 vs HPS345W>

Process for Producing Steel: TMCP for HSB, BHS
Q&T for HPS

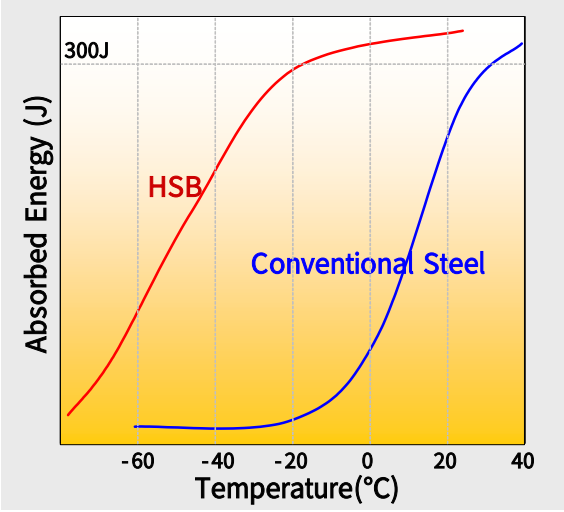
Material Properties of HSB

High Strength and High Toughness

- TMCP → High tensile strength, No reduction of strength for thick plates
- High Toughness → Reduction of brittle fracture in low temperature, Improvement of cold-formability



< C_{eq} vs Tensile strength >

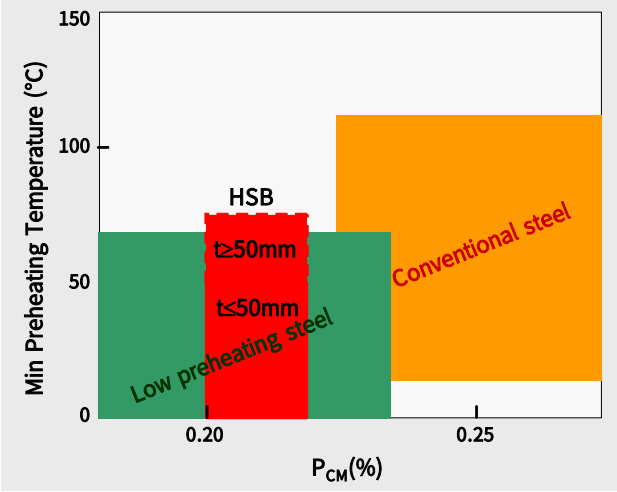


< Charpy Energy vs test temperature >

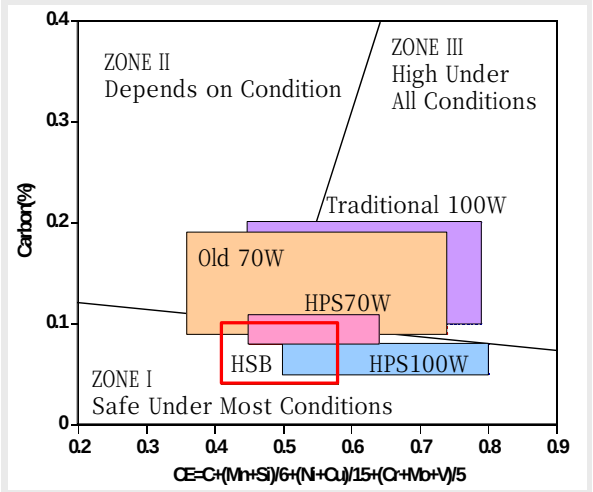
Material Properties of HSB

Weldability

- Low P_{cm} → Low preheating temperature
- Low C_{eq} → Reduction of cold cracking



< P_{cm} vs min preheating temperature >

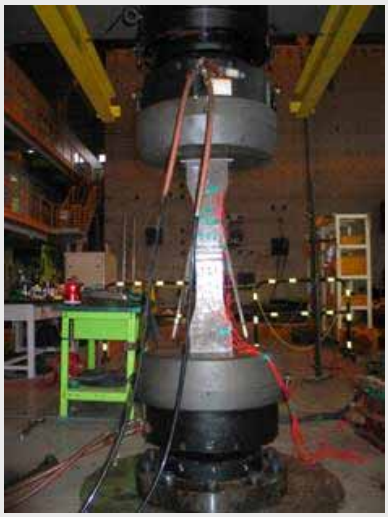


< C_{eq} vs Carbon >

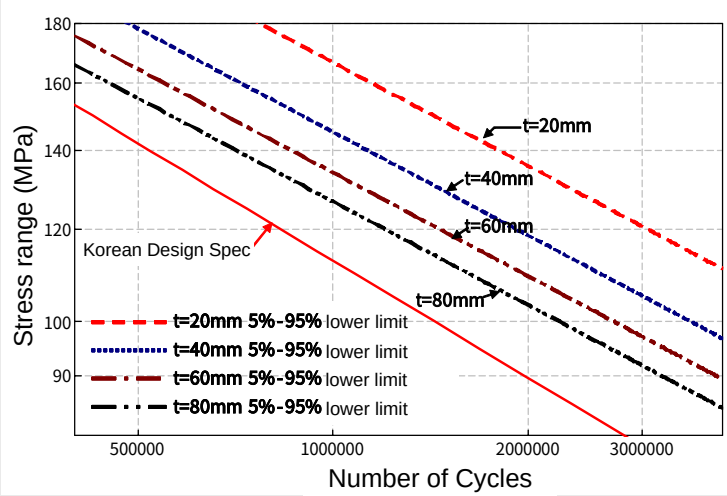
Material Properties of HSB

Fatigue Performance

- HSB satisfies the fatigue design spec. for all thickness tested



<Fatigue Test for welded plates>



< S-N curves of HSB>

Registration in KS (Korean Standards)

KS D 3868

- HSB was Registered in KS as “Rolled Steels for Bridge Structures”, Aug., 2007

Symbol of HSB

Symbol	Max Thickness	Notes
HSB500 HSB500L HSB500W	100mm	For Bridge Structures L : Low Temperature W : Weathering Resistance
HSB600 HSB600L HSB600W		

Chemical Composition of HSB

Symbol	C	Si	Mn	P	S	Cu	Cr	Ni
HSB500 HSB500L	≤ 0.18	≤ 0.55	≤ 1.80	≤ 0.020	≤ 0.006	-	-	-
HSB500W	≤ 0.18	≤ 0.65	≤ 1.80	≤ 0.020	≤ 0.006	0.10~0.50	0.45~0.75	0.05~0.80
HSB600 HSB600L	≤ 0.10	≤ 0.55	≤ 1.80	≤ 0.020	≤ 0.006	-	-	-
HSB600W	≤ 0.10	≤ 0.65	≤ 1.80	≤ 0.020	≤ 0.006	0.10~0.50	0.45~0.75	0.05~0.80

Registration in KS (Korean Standards)

C_{eq} and P_{cm}

		SM490	SM520	SM570	HSB500 HSB500L	HSB600 HSB600L	HSB500W HSB600W
C_{eq} (%)	T ≤ 50mm	≤ 0.38	≤ 0.40	≤ 0.42	≤ 0.40	≤ 0.42	≤ 0.47
	T ≤ 100mm	≤ 0.40	≤ 0.42	≤ 0.44			
P_{cm} (%)	T ≤ 50mm	≤ 0.24	≤ 0.26	≤ 0.27	≤ 0.20	≤ 0.20	≤ 0.22
	T ≤ 100mm	≤ 0.26	≤ 0.27	≤ 0.29			

Registration in KS (Korean Standards)

Mechanical Properties

Symbol	Yield Strength	Tensile Strength	Elongation		
			Thickness(mm)	%	specimen
HSB500 HSB500L HSB500W	≥ 380 MPa	≥ 500 MPa	T ≤ 16 T ≤ 40 40 < T	≥ 15 ≥ 19 ≥ 21	# 1A # 1A # 4
HSB600 HSB600L HSB600W	≥ 450 MPa	≥ 600 MPa	T ≤ 16 T ≤ 20 20 < T	≥ 19 ≥ 26 ≥ 20	# 5 # 5 # 4

Charpy Energy

Symbol	Test Temperature	Charpy Energy	Notes
HSB500 HSB600 HSB500W HSB600W	-5 ℃	≥ 47 J	For ordinary temperature
HSB500L HSB600L	-20 ℃	≥ 47 J	For low temperature

Revision of Bridge Design Code

Revision of Korean Bridge Design Code

- Currently being revised by the Ministry of Land, Transport and Maritime Affairs

Addition of HSB

- Articles for HSB500 : linear interpolation between SM520 and SM570(yield strength)
- Articles for HSB600 : same process as SM570 (due to same yield strength)
- There is No Reduction of min. yield strength of HSB w.r.t. plate thickness

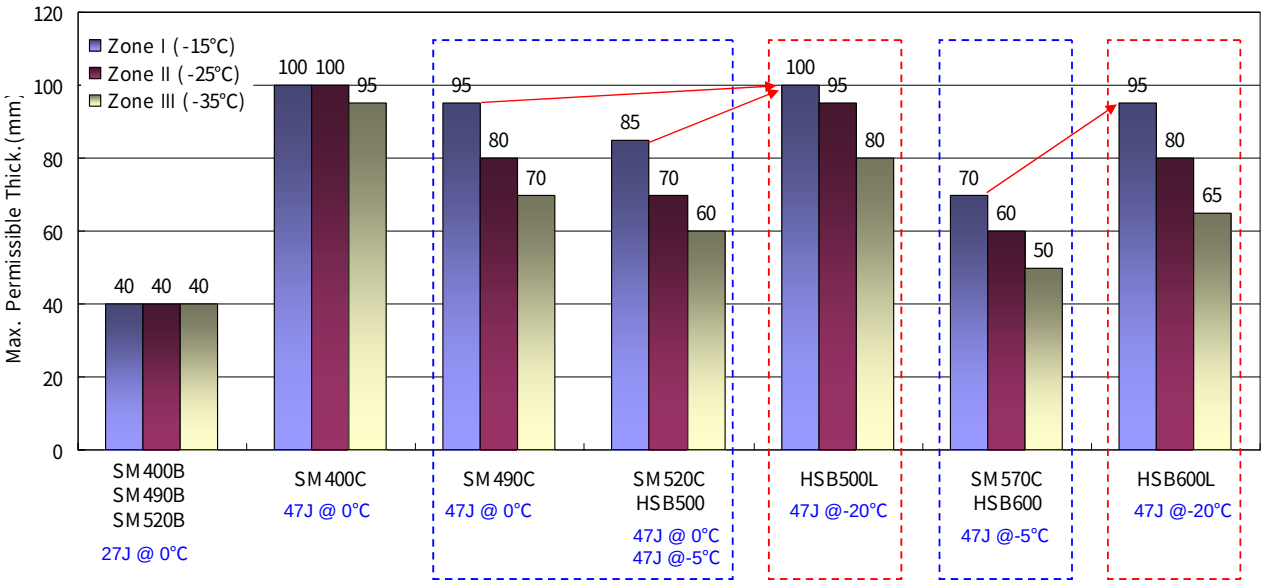
	SS400 SM400 SMA400		SM490		SM490Y SM520 SMA490			SM570 SMA570		
Thickness (mm)	≤ 40	40 < ≤ 100	≤ 40	40 < ≤ 100	≤ 40	40 < ≤ 75	75 < ≤ 100	≤ 40	40 < ≤ 75	75 < ≤ 100
Min Yp (MPa)	235	215	315	295	355	335	325	450	430	420
Ts (MPa)	400 ~ 510		490 ~ 610		490 ~ 610 (520 ~ 640 for SM520)			570 ~ 720		

	SM490C-TMC	SM520C-TMC	SM570-TMC	HSB500	HSB600
Thickness (mm)	≤ 100	≤ 100	≤ 100	≤ 100	≤ 100
Min Yp (MPa)	315	355	450	380	450
Ts (MPa)	490 ~ 610	520 ~ 640	570 ~ 720	≥ 500	≥ 600

Revision of Bridge Design Code

Toughness Requirement : Max. Allowable Thickness

- Based on temperature zone and toughness, max. allowable thickness of steel is given
- HSB-L with high toughness has better quality than conventional steels



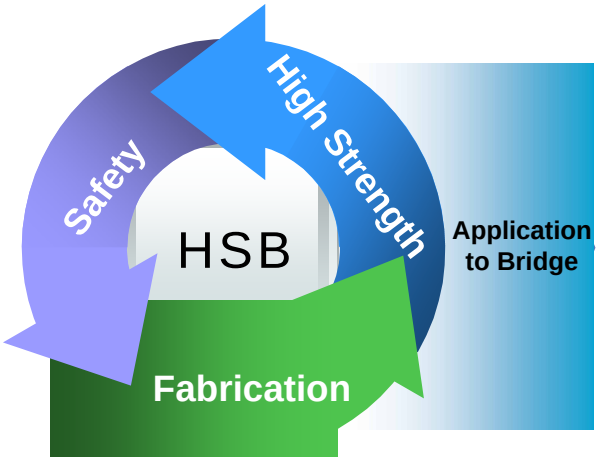
Application of HSB

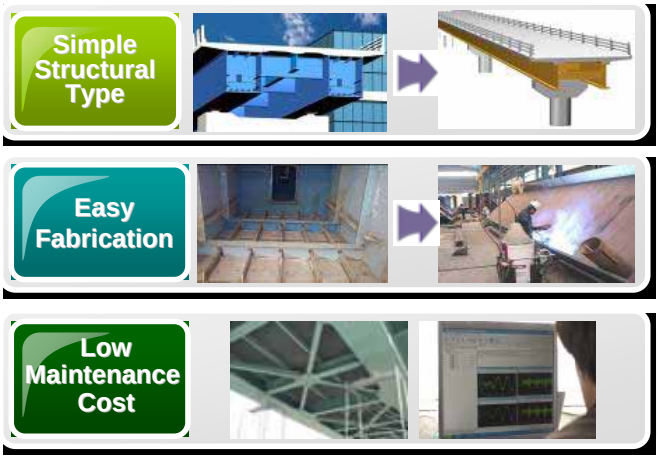
13,700 tons of HSB is supplied for bridges (Jan. 2007~ Present)

Type	Project	Supply(ton)	Procurement office	Supply Period
HSB600	Incheon Bridge	1,420	Hanjin Heavy Industries & Const.	2007.1
	Busan Subway line 3	4,362	Busan Transportation Corp.	2007.7~2008.3
	Seoul-Busan KTX (14-1)	2,445	Korea Rail Network Authority	2007.5~7
	Gyeongju City Detour	1,690	Busan MOCT	2007.6~8
	South Gumi IC Ramp	1,117	Korea Expressway Corp.	2007.5
	PCT Bridge	665	Korea Expressway Corp.	2007.1
	Iksan-Jangsu highway br.	370	Korea Expressway Corp.	2007.5
	Jinbuk Industrial Complex Br.	537	Masan City	2007.9
	Others	57	Sampyo, Sambu	-
HSB500	Suncheon Haryong-Sangsam Project	1,013	Samhyun PF	2007.12~2008.2
Total		13,676		

Application of HSB

Benefits of HSB

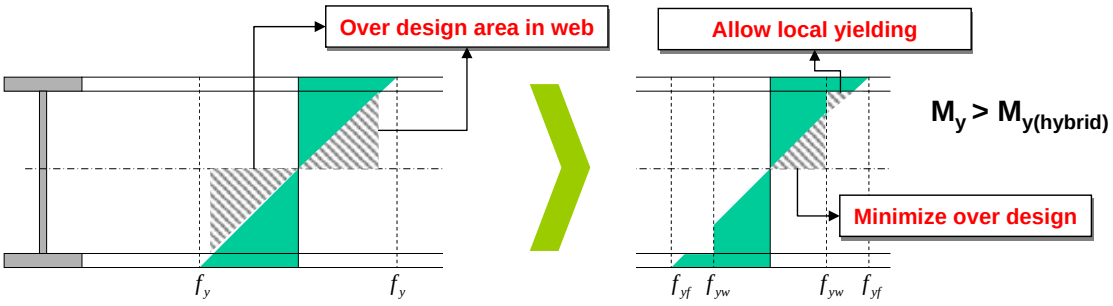




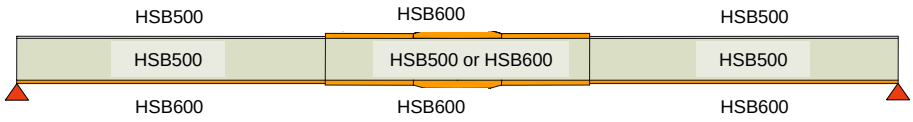
Application of HSB

Twin Hybrid Girder Bridge

- Design concept of hybrid girder bridges
  - Using different grades of steel in a section
  - Optimize design by utilizing full capacity of the section
  - Lower construction cost (10%), girder height (30%), total steel weight (15%)



Conventional Section　　Hybrid Section



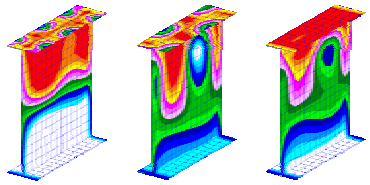
Hybrid Plate Girder

Application of HSB

Twin Hybrid Girder Bridge

- Codes / Design guide using high performance steel
- Fabrication guide for high performance steel
- Optimal Design of twin girders

Type		Weight (ton)				Total Weight (ton)	Cost (KR$ 1,000,000)
Flange	Web	SM400	SM490	HSB500	HSB600		
HSB600	HSB600				243	243 (100%)	230 (100%)
HSB600	HSB500			92	148	241 (99%)	218 (95%)
HSB600	SM490		87		152	239 (98%)	211 (92%)
HSB600	SM400	78			161	239 (98%)	207 (90%)



t_w=67mm t_f=10mm　　t_w=13mm t_f=14mm　　t_w= 8mm t_f=83mm

< Ultimate stress states >

(L=40+50+40m, H=2m, B=0.5m)

< Ilsan Bridge >

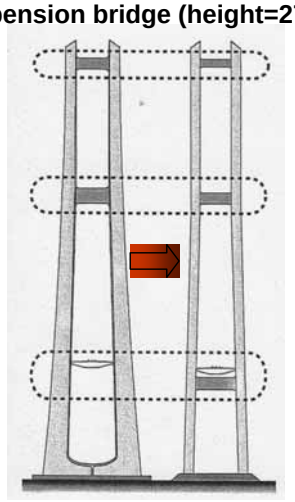
Application of HSB

Steel Towers/Pylons of Cable-Supported Bridges

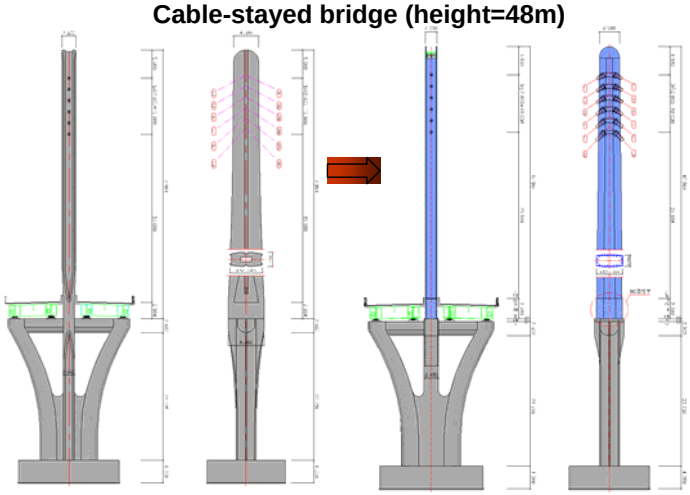
- Reduce total construction period by prefabrication
- Aesthetic (slim, colorful, complex shapes are possible)
- Better structural quality due to shop fabrication

- Design alternative from concrete to steel towers
  - Applying HSB reduces fabrication costs of towers

Suspension bridge (height=270m)



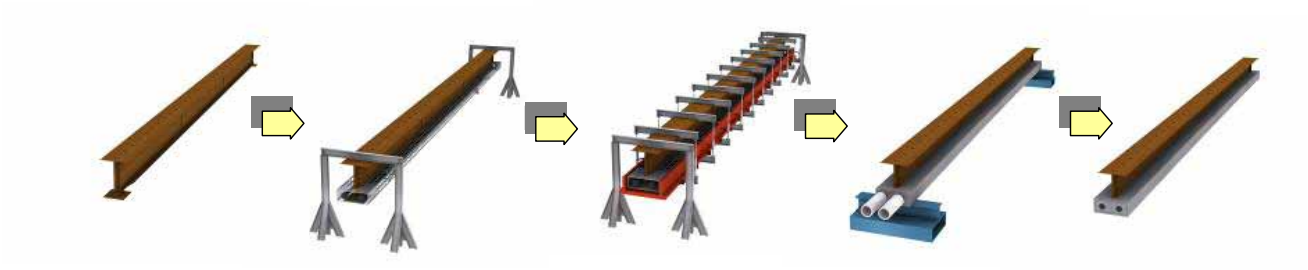
Cable-stayed bridge (height=48m)



Application of HSB

PRECOM: Prestressed Composite Girder

- Steel girders take the self-weight of concrete before composite action



Application of HSB

TUrn-over Girder

- Preflexing or prestressing steel girders by using the self-weight of girder