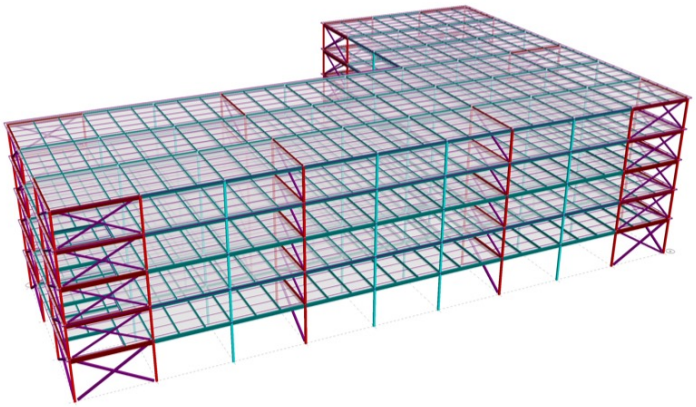
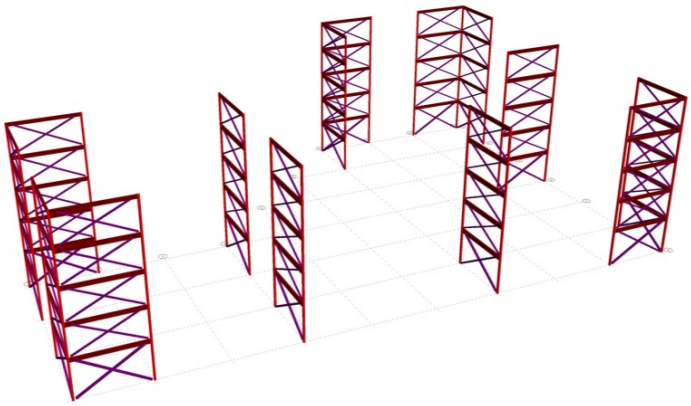
STEEL TUBE INSTITUTE

HSS AND WF COMPARATIVE CASE STUDY

The Steel Tube Institute (STI) conducted a comprehensive case study comparing Hollow Structural Section (HSS) and Wide Flange (WF) use in the design of a 5-story commercial office building located in the Midwest region of the United States. The study focused on key factors such as tonnage, material and fabrication costs, surface area, fireproofing requirements, connection design, and environmental impact (Global Warming Potential, or GWP). Below, we present the findings, showcasing how HSS is a highly efficient choice for columns and braces in modern steel construction.

5-STORY COMMERCIAL STRUCTURE IN LEWISTON, MI





- **Project Type:** 5-story commercial structure
- **Square Footage:** ~22,500 SF
- **Design Codes:** ASCE 7-16, AISC 360-16
- **Superimposed Dead Load:** 10 psf at all levels
- **Live Loads:** 50 psf typical
  100 psf at corridors
  35 psf snow roof load
- **Wind Loads:** Exp B, Wind Speed = 115 mph
- **Roof Framing:** Non-composite wide-flange beams with 3" metal deck
- **Floor Framing:** Composite wide-flange beams with 3-1/4" lightweight concrete over 2" metal deck
- **Lateral System:** Braced frames in both directions
- **Structural Design:** FORSE Consulting
- **Steel Pricing and Fabrication Input:** Three anonymous fabricators
- **Fireproofing Input:** Nettles Construction Solutions, Luke Fischer, Reg Sales Mgr

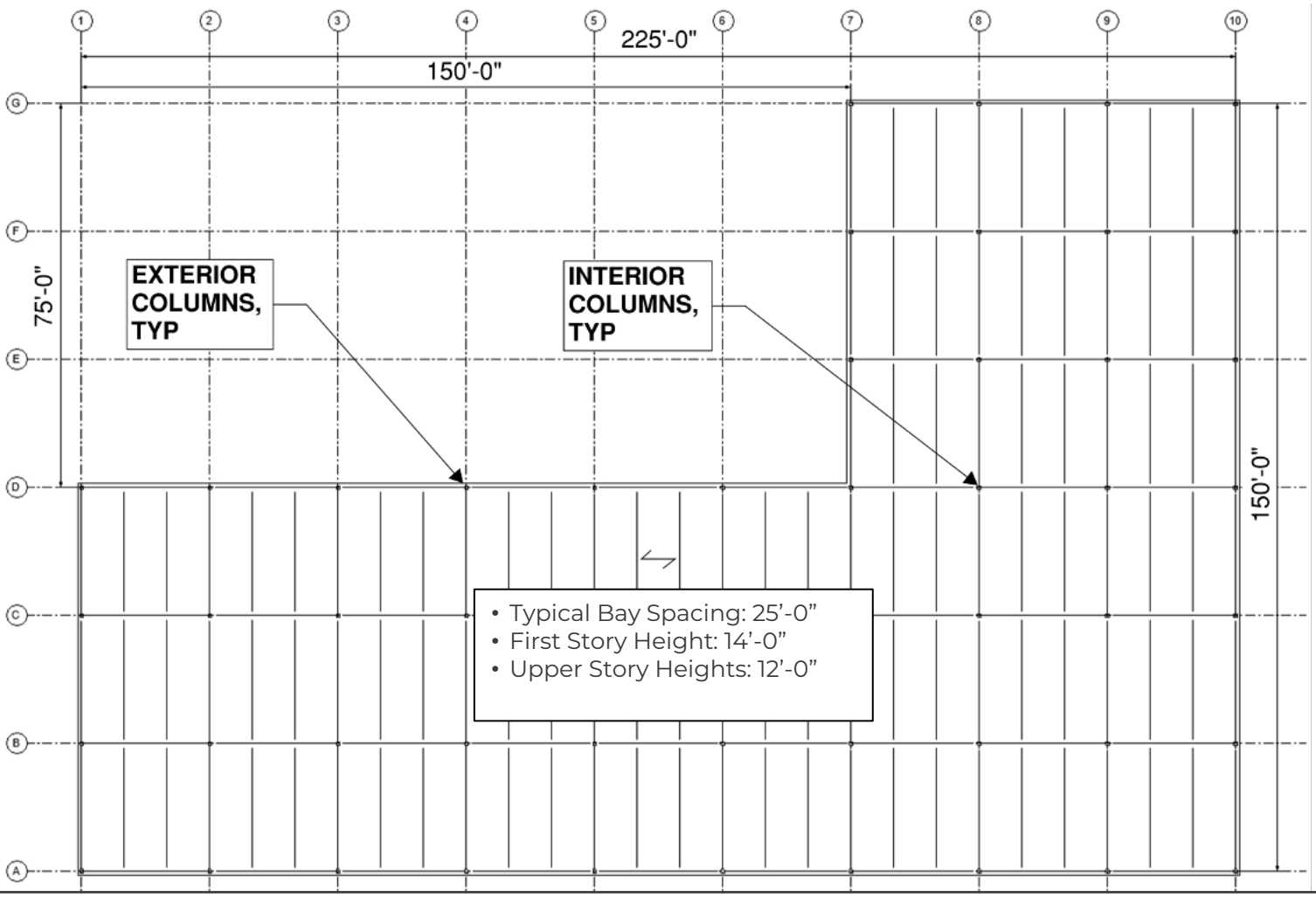
DISCUSSION OF METHODOLOGY

- Two scenarios were considered:

HSS SCENARIO	WF SCENARIO
HSS columns, HSS braces, WF beams	WF columns, WF and 2L braces, WF beams

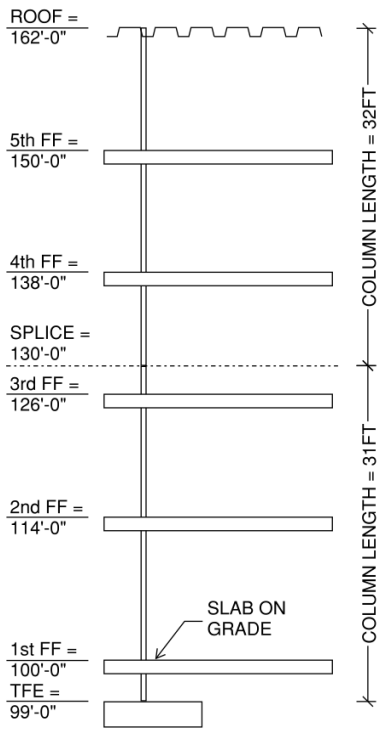
- Column and brace sections were selected that are readily available and commonly used.
- Utilization values were targeted to be similar for each scenario.
- Often-overlooked impacts of connections and surface area were included.

TYPICAL FLOOR PLAN

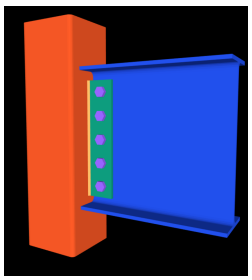


TYPICAL ELEVATIONS

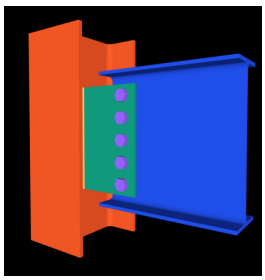
- Columns are spliced above the 2nd story
- Lower Column Length: 31'-0"
- Upper Column Length: 32'-0"



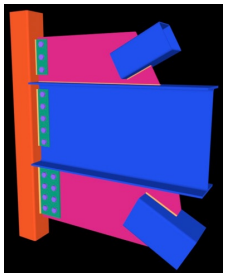
TYPICAL CONNECTION TYPES



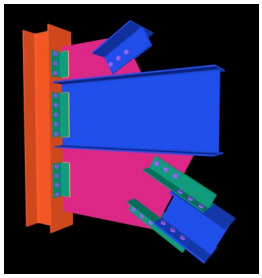
- Single plate to HSS wall or WF flange



- Extended single plate to WF web



- HSS braces with HSS column



- WF and 2L braces with WF column

DESIGN SUMMARY

- There are a total of 52 columns in the structure. Lower stories have two column sizes. Upper stories have one.
- There are 28 braces per story for a total of 140 braces. The first story braces are heavier.
- Beam sizes range from W12x14 to W21x48 and were the same for both scenarios.
- Thus, the focus of this case study's comparison is on column members and brace members.

MEMBER	MEMBER EXTENTS	QTY	LENGTH (FT)	TOTAL LENGTH (FT)	MAX UTIL RATIO HSS	MIN UTIL RATIO HSS	MAX UTIL RATIO WF	MIN UTIL RATIO WF
LOWER EXTERIOR COLUMN	T/Fndn to 4' Above L3	29	31	899	0.89	0.40	0.93	0.34
LOWER INTERIOR COLUMN	T/Fndn to 4' Above L3	23	31	713	0.93	0.62	0.72	0.47
UPPER COLUMN	4' Above L3 to Roof	52	32	1,664	0.75	0.15	0.57	0.10
LOWER BRACE	L1	28	29	812	0.55	0.31	0.76	0.33
UPPER BRACE	L2 to Roof	112	28	3,136	0.60	0.06	0.55	0.04

MEMBER TONNAGE AND COST COMPARISON: COLUMNS AND BRACES

	HSS SCENARIO						WF SCENARIO					
MEMBER	SECTION	WT. (PLF)	MEMBER WEIGHT (TONS)	TONS	$/TON	MEMBER COST	SECTION	WT. (PLF)	MEMBER WEIGHT (TONS)	TONS	$/TON	MEMBER COST
LOWER COL	HSS 8x8x5/16	31.8	14.3				W12x45	45.0	20.2			
LOWER COL	HSS 8x8x3/8	37.7	13.4				W12x53	53.0	18.9			
UPPER COL	HSS 8x8x1/4	25.8	21.5				W12x40	40.0	33.3			
LOWER BRACE	HSS 8x8x1/4	25.8	10.5				W10x49	49.0	19.9			
	ALL HSS 8x8			59.7	$1,050	$62,685	All WF			92.3	$1,315	$121,375
UPPER BRACE	HSS 6x6x1/4	19.0	29.8				2L 6x6x3/8	29.8	46.7			
	ALL HSS 6x6			29.8	$1,030	$30,694	All Angles			46.7	$1,145	$53,472
	HSS TOTALS		TONS	89.5	COST	$93,379	WF TOTALS		TONS	139.0	COST	$174,847
							WF INCREASES		TONS	+49.5 +55.3%	COST	+$81,468 +87.2%

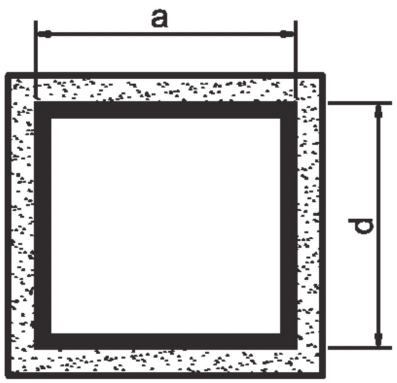
- Tonnages are based on center-to-center member dimensions and do not include miscellaneous steel.
- Material costs reflect pricing from American Metal Markets as of August 2024 with a small addition for delivery.
- At the time of this case study, the "pound-for-pound" price of HSS was lower than WF. Even if HSS prices increase in the future, the reduced tonnage required for HSS often leads to a cost advantage.

TONNAGE AND COST FINDINGS

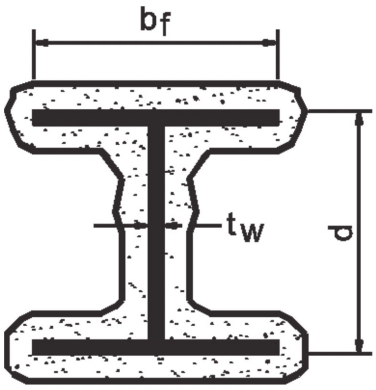
The HSS scenario resulted in lower material tonnage and cost.

- HSS deliver higher compressive capacity per pound of steel compared to WF sections.
- The decreased tonnage of HSS also translates to reduced shipping needs, requiring fewer trucks to transport material to the site.

PERIMETER AND FIREPROOFING COMPARISON: COLUMNS AND BRACES



$D=2(a+d)$



$D=4b_f + 2d - 2t_w$

	HSS SCENARIO					WF SCENARIO				
MEMBER	SECTION	SECTION PERI-METER (IN)	TOTAL PERI-METER SURFACE AREA (IN²)	FIRE-PROOF-ING THICK-NESS (IN)	FIRE-PROOFING MATERIAL & LABOR COST	SECTION	SECTION PERI-METER (IN)	TOTAL PERI-METER SURFACE AREA (IN²)	FIRE-PROOF-ING THICK-NESS (IN)	FIRE-PROOFING MATERIAL & LABOR COST
LOWER COL	HSS 8x8x5/16	31.0	334,428	1/2		W12x45	55.7	601,215	5/8	
LOWER COL	HSS 8x8x3/8	30.8	263,525	7/16		W12x53	63.5	543,392	9/16	
UPPER COL	HSS 8x8x1/4	31.2	623,002	11/16		W12x40	55.3	1,103,232	5/8	
LOWER BRACE	HSS 8x8x1/4	31.2	304,013	11/16		W10x49	59.3	578,014	9/16	
UPPER BRACE	HSS 6x6x1/4	23.2	873,062	11/16		2L 6x6x3/8	25.5	959,616	5/8	
	HSS TOTALS		2,398,030		$22,000	WF TOTALS		3,785,469		$30,000
						WF SURFACE AREA INCREASES		+1,387,439 +57.9%		+$8,000 +36.4%

- Fireproofing estimates were provided by Luke Fischer at Nettles Construction Solutions based on 1 hr cementitious fireproofing in February 2024 and include materials and labor.

PERIMETER NOTES

- All materials applied to a structural frame, including fireproofing, enclosures, paint, and weld metal contribute to the overall cost and environmental impact of a structure.
- A smaller perimeter / surface area results in a reduction in painting material, weld metal, fireproofing material, and surface preparation (i.e. chemical cleaning, abrasive blasting, etc.)

PERIMETER AND FIREPROOFING FINDINGS

The HSS scenario resulted in lower fireproofing volume and cost.

- HSS shapes have approximately 2/3 the perimeter of an open section of comparable capacity, which is a direct factor in calculating surface area.

GLOBAL WARMING POTENTIAL (GWP) COMPARISON: COLUMNS AND BRACES

HSS SCENARIO

MEMBER	SECTION	TOTAL WEIGHT (LBS)	TOTAL WEIGHT (METRIC TONS)	STEEL GWP ($kgCO_2e$)	SECTION PERIMETER (IN)	TOTAL SECTION LENGTH (FT)	FIRE-PROOFING THICKNESS FOR 1-HR RATING (IN)	FIRE-PROOFING GWP ($kgCO_2e$)	TOTAL GWP ($kgCO_2e$)
LOWER COL	HSS 8x8x5/16	28,624	13.0	25,838	31.0	899	1/2	2,327	28,165
LOWER COL	HSS 8x8x3/8	26,873	12.2	24,257	30.8	708	7/16	1,604	25,861
UPPER COL	HSS 8x8x1/4	42,965	19.5	38,782	31.2	1622	11/16	5,961	44,743
LOWER BRACE	HSS 8x8x1/4	20,966	9.5	18,925	31.2	874	11/16	2,909	62,193
UPPER BRACE	HSS 6x6x1/4	59,647	27.1	53,840	23.2	2598	11/16	8,353	21,834
	HSS GWP TOTALS			161,642				21,154	182,796

WF SCENARIO

MEMBER	SECTION	TOTAL WEIGHT (LBS)	TOTAL WEIGHT (METRIC TONS)	STEEL GWP ($kgCO_2e$)	SECTION PERIMETER (IN)	TOTAL SECTION LENGTH (FT)	FIRE-PROOFING THICKNESS FOR 1-HR RATING (IN)	FIRE-PROOFING GWP ($kgCO_2e$)	TOTAL GWP ($kgCO_2e$)
LOWER COL	W12x45	40,455	18.4	22,387	55.73	1616	5/8	5,229	
LOWER COL	W12x53	37,789	17.1	20,912	63.51	1461	9/16	4,254	
UPPER COL	W12x40	66,560	30.2	36,833	55.25	2873	5/8	9,596	
LOWER BRACE	W10x49	39,788	18.1	22,018	25.50	1661	9/16	4,525	
UPPER BRACE	2L 6x6x3/8	93,453	42.4	51,715	59.32	2856	5/8	8,347	
	WF GWP TOTALS			153,865				31,951	185,816
	WF GWP RELATIVE TO HSS			-7,777 -4.8%				+10,797 +51.0%	+3,020 +1.7%

GLOBAL WARMING POTENTIAL (GWP) NOTES

- Steel GWP calculations were based on industry-average fabricated Environmental Product Declarations (EPDs).
- GWP for WF = 1220 $kgCO_2e$ / MT
- GWP for HSS = 1990 $kgCO_2e$ / MT
- GWP for Cementitious Fireproofing (FP) = 0.167 $kgCO_2e$ / inch FP thickness / inch perimeter / ft length
- Sample steel GWP calculation of HSS 8x8x5/16: $25663\ lb\left(\frac{1\ MT}{2204.62\ lbs}\right)\left(1990\frac{kgCO_2e}{MT}\right) = 23165\ kgCO_2e$

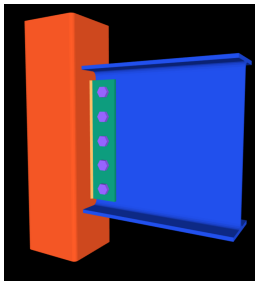
GLOBAL WARMING POTENTIAL (GWP) FINDINGS

The HSS scenario resulted in lower overall GWP values.

- Functional equivalency is imperative to consider when comparing GWP of HSS and WF.
- When adding both the steel GWP and cementitious fireproofing GWP, the total GWP value was lower for the HSS scenario when compared to the WF scenario.

SHEAR CONNECTIONS – GLOBAL WARMING POTENTIAL (GWP) AND WEIGHT COMPARISON

A



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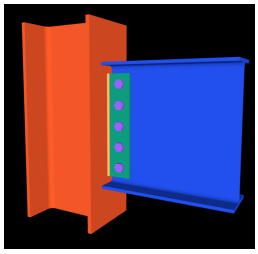

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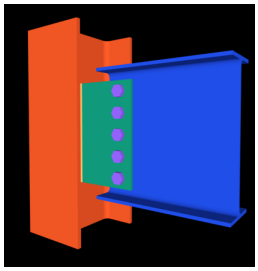


HSS SCENARIO						
CONNECTION TYPE FOR W18x35 GIRDER	COLUMN SIZE	SHEAR BOLTS	PLATE WEIGHT PER CONN (LB)	NO. OF SIMILAR CONNS	TOTAL PLATE WEIGHT FOR ALL SIMILAR CONNS (LB)	TOTAL PLATE GWP FOR ALL SIMILAR CONNS ($kgCO_2e$)
A – Shear Plate to HSS Face	HSS 8x8	¾"Ø A325	5.6	176	986	546
HSS WEIGHT AND GWP TOTALS					986	546

WF SCENARIO						
CONNECTION TYPE FOR W18x35 GIRDER	COLUMN SIZE	SHEAR BOLTS	PLATE WEIGHT PER CONN (LB)	NO. OF SIMILAR CONNS	TOTAL PLATE WEIGHT FOR ALL SIMILAR CONNS (LB)	TOTAL PLATE GWP FOR ALL SIMILAR CONNS ($kgCO_2e$)
B – Shear Plate to WF Flange	W12x	¾"Ø A325	5.6	16	90	50
C – Shear Plate to WF Web	W12x	1"Ø A490	14.9	160	2,384	1,319
WF WEIGHT AND GWP TOTALS					2,474	1,369
WF WEIGHT AND GWP INCREASES					+1,488 +151%	+823 +151%

SHEAR CONNECTIONS NOTES

- Typical W18x35 gravity girder connections were designed for a maximum factored shear of 42k.
- Single plate connections to the faces of HSS or the flanges of WF are identical, requiring a 3/8"x3.5"x15" plate and (5) 3/4" A325 SC bolts.
- Single plate connections to the webs of WF require an extended plate, which increases eccentricity, resulting in more plate material – 3/8"x9"x15", and requiring larger, stronger bolts – (5) 1" A490 SC.
- Weight and GWP comparisons above consider only the W18x shear plate size differences, but additional WF scenario increases will be seen due to the larger bolts.
- W14x and W16x girders exist in the project and would have similar comparisons.
- GWP for plate = 1220 kgCO2e / MT
- The HSS column wall thicknesses were chosen up-front to be adequate to resist all imparted loads from the shear connections.

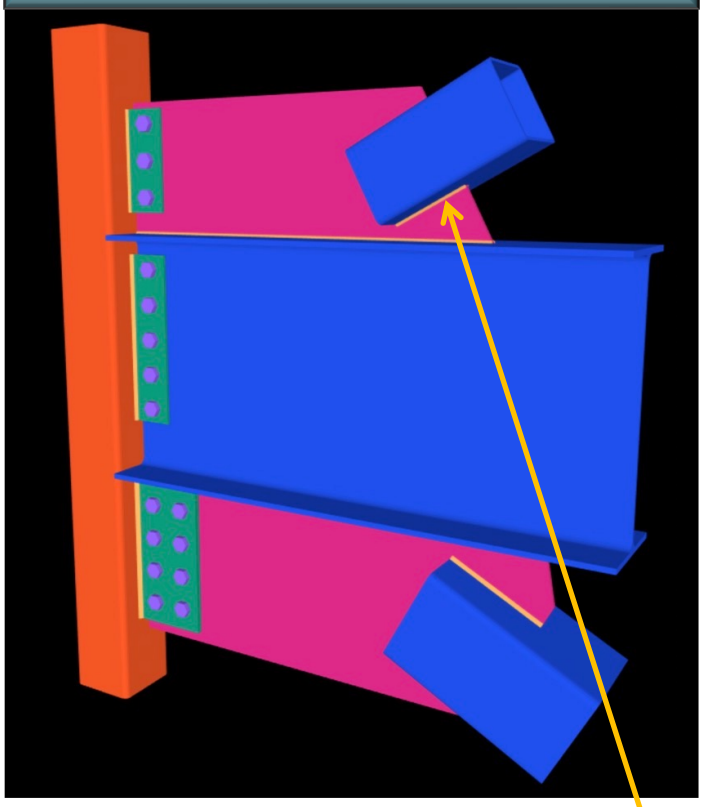
SHEAR CONNECTIONS FINDINGS

The HSS scenario resulted in less shear plate material, lighter bolts, and lower GWP.

- Having one standard connection in the HSS scenario to both faces of the HSS also increases efficiency of construction.

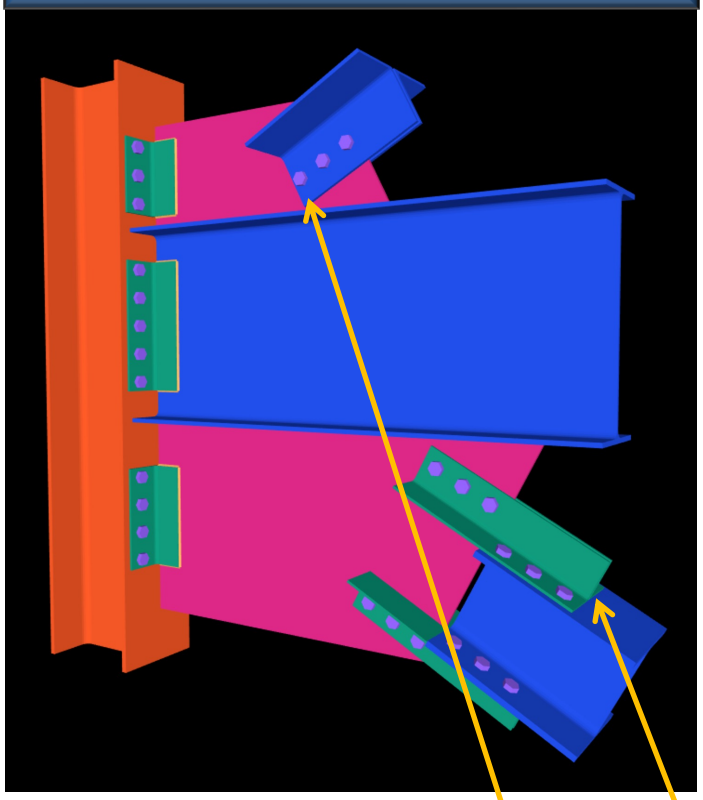
BRACING CONNECTIONS – GENERAL COMPARISON

HSS SCENARIO



- Slotted HSS welded to gusset, typ
- Fewer connecting elements – will require one erection bolt per HSS brace
- This sample connection shows HSS 6x6 above, HSS 8x8 below, W21x48 beam

WF SCENARIO



- Double angle bolted to gusset
- Wide flange with claw angles bolted to gusset
- More connecting elements – bolts and claw angles
- This sample connection shows 2L 6x6 above, W10x49 below, W21x48 beam

BRACING CONNECTIONS NOTES

- Brace lengths, gusset plate sizes, and weld sizes were comparable between the two scenarios.
- HSS bracing connections are slotted and welded to the gusset plate with one erection bolt.
- WF and 2L bracing connections require additional connecting elements, such as claw angles and structural bolts.
- The HSS braces are narrower than the WF braces, easing coordination with architectural openings and minimizing gusset sizes.
- The HSS column wall thicknesses were chosen up-front to be adequate to resist all imparted loads from the transfer / pass-through forces.

BRACING CONNECTIONS FINDINGS

The HSS scenario resulted in less bracing material and bracing fabrication costs (see following pages for quoted values)

- It is important to consider all aspects of a diagonal brace including length of brace, gusset plate size, number of pieces, number of bolts, and length of weld.

TOTAL STRUCTURE COMPARISON – INCLUDING BEAMS AND FABRICATION

- Thus far, the focus of this case study's comparison has been on column members and brace members, which is where HSS and WF sections are most often interchanged.
- WF beams are the same for both scenarios and are the obvious and efficient choice.
- Adding in the WF beams and total structure fabrication costs allows for a more complete comparison.

FABRICATION LABOR COMPARISON: TOTAL STRUCTURE

HSS SCENARIO			WF SCENARIO		
COMPONENT	FABRICATOR'S QUOTED MATERIAL TONNAGE	FABRICATOR'S QUOTED LABOR COST	COMPONENT	FABRICATOR'S QUOTED MATERIAL TONNAGE	FABRICATOR'S QUOTED LABOR COST
Columns, Base Plates, Splices	53	$48,334	Columns, Base Plates, Splices	76	$69,962
Braces, Brace Connections	54	$53,539	Braces, Brace Connections	75	$78,973
WF Beams, WF Beam Connections	258	$257,041	WF Beams, WF Beam Connections	259	$262,358
HSS TOTALS	365	$358,914	WF TOTALS	410	$411,293
			WF TONNAGE INCREASES	+45 +12.3%	+$52,379 +14.6%

- Fabrication costs were estimated in August 2024 by an anonymous fabricator.

FABRICATION LABOR NOTES

- The HSS column wall thicknesses were chosen up-front to be adequate to resist all imparted loads from the shear connections. Thus, no reinforcement of the HSS walls was expected during fabrication.
- The fabrication estimate confirmed that no HSS wall reinforcement had been required.

FABRICATION LABOR FINDINGS

The HSS scenario resulted in lower fabrication labor cost.

- The higher WF scenario fabrication costs can be attributed in part to:
  - Larger base plates and longer welds due to larger footprint of W12x columns vs. HSS 8x8 columns
  - More connecting materials (angles and bolts) at WF braces and 2L braces than at slot welds to HSS braces
  - Higher quantities of bolt holes and larger welds at extended shear plate connections to WF webs
- Reinforcing HSS walls was not necessary, therefore, no additional fabrication costs were incurred.

This demonstrates that with proper design, the misconception that HSS structures are more costly to fabricate is unfounded.

GLOBAL WARMING POTENTIAL (GWP) COMPARISON: TOTAL STRUCTURE

HSS SCENARIO						WF SCENARIO					
COMPO-NENT	TONS	STEEL GWP ($kgCO_2e$)	FP GWP ($kgCO_2e$)	SHIPPING GWP ($kgCO_2e$)	TOTAL GWP ($kgCO_2e$)	COMPONENT	TONS	STEEL GWP ($kgCO_2e$)	FP GWP ($kgCO_2e$)	SHIPPING GWP ($kgCO_2e$	TOTAL GWP ($kgCO_2e$)
Columns	49.2	88,876	9,892	1,992	100,760	Columns	72.4	80,132	19,079	2,929	102,140
Braces	40.3	72,765	11,262	1,631	85,658	Braces	66.6	73,733	12,871	2,696	89,300
WF Beams	256.8	284,162	82,950	10,388	377,500	WF Beams	256.8	284,162	82,950	10,388	377,500
HSS GWP TOTALS		445,803	104,104	14,011	563,918	WF GWP TOTALS		438,027	114,900	16,013	568,940
						WF GWP RELATIVE TO HSS		-7,776 -1.7%	+10,796 +10.4%	+2,002 +14.3%	+5,022 +0.9%

- Tonnages are based on center-to-center member dimensions and do not include miscellaneous steel.
- GWP based on Industry-Average Fabricated EPDs as noted previously and GWP for Shipping to Site (45 miles assumed) = 44.6 kgCO2e / MT

The HSS scenario resulted in <1% difference in overall GWP when considering steel, fireproofing, and shipping GWP, with the HSS GWP being lower.

FABRICATED COST COMPARISON: TOTAL STRUCTURE

HSS SCENARIO				WF SCENARIO			
COMPONENT	FABRICATOR'S QUOTED MATERIAL COST	FABRICATOR'S QUOTED LABOR COST	FABRICATOR'S QUOTED TOTAL COST	COMPONENT	FABRICATOR'S QUOTED MATERIAL COST	FABRICATOR'S QUOTED LABOR COST	FABRICATOR'S QUOTED TOTAL COST
Columns, Base Plates, Splices	$100,966	$48,334	$149,300	Columns, Base Plates, Splices	$132,700	$69,962	$202,662
Braces, Brace Connections	$84,995	$53,539	$138,534	Braces, Brace Connections	$117,595	$78,973	$196,568
WF Beams, WF Beam Connections	$468,686	$257,041	$725,727	WF Beams, WF Beam Connections	$470,799	$262,358	$733,157
Fireproofing			$22,000	Fireproofing			$30,000
HSS TOTAL	$654,647	$358,914	$1,035,561	WF TOTAL	$721,094	$411,293	$1,162,387
				WF COST INCREASES	+$66,447 +10.2%	+$52,379 +14.6%	+$126,826 +12.2%

- Shipping costs to the job site are not shown here, however, the wide flange scenario would incur higher shipping costs due to increased tonnage.
- Note that the material costs quoted here reflect the price from the fabricator, which includes a fabricator markup. This figure may differ from the direct pricing available from HSS producers.

The HSS scenario resulted in a lower overall fabricated cost for both materials and labor.

CONCLUSIONS

This HSS office building scenario resulted in:

- ❖ Lower tonnage and material cost
- ❖ Lower global warming potential (GWP)
- ❖ Lower overall fabricated cost

HSS offers a compelling design choice due to the advantages of:

- ✓ Reduced tonnage
- ✓ Lower embodied carbon emissions
- ✓ Cost savings

The results of this case study confirm the advantages of using HSS in multi-story commercial structures, alongside their proven effectiveness in applications such as warehouses, data centers, and big box retail.

ADDITIONAL NOTES

- HSS sections with comparable axial capacity to WF sections are lighter and have a smaller steel section perimeter.
- Functional equivalency is important to consider when comparing HSS and WF shapes – do not simply compare "pound for pound" costs or Global Warming Potential (GWP).
- The recommended approach for designing cost-effective and sustainable structures is to prioritize member optimization and minimize material usage for your loading condition (i.e. use HSS for columns, braces, trusses, girts, etc.)
- Consider all aspects of a structural design for total cost and GWP, including structural material, fireproofing, and connections.
- Additional considerations that were not included in this case study, but provide additional benefit when selecting HSS for your structure, are:
  - Perimeter reduction also results in less paint and less weld material to a base plate
  - Depth reduction results in potential for smaller architectural column enclosures.
  - Tonnage reduction results in the potential for lighter foundations.

ABOUT THE STEEL TUBE INSTITUTE

The Steel Tube Institute was formed in 1930 when a group of manufacturers joined forces to advance the steel tube industry. Today it is the leading technical resource in North America for steel tube products. STI is dedicated to advancing the growth and competitiveness of North America's steel tubular products. Our strength is bringing together resources to move the industry forward through active collaboration. We accomplish this by effective promotion, education, and problem solving; targeting all trades from engineers and architects to fabricators and field installers.

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