How does HFMI affect bridge design ?

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Master thesis 2024

Supervised by COWI
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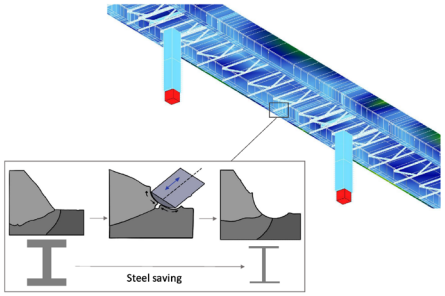

Composite bridge design optimisation using HFMI-treatment

Design and optimisation of composite bridges using high-frequency mechanical impact (HFMI) treatment

Master's thesis in Master program Structural engineering and building technology

CECILIA ENGLUND
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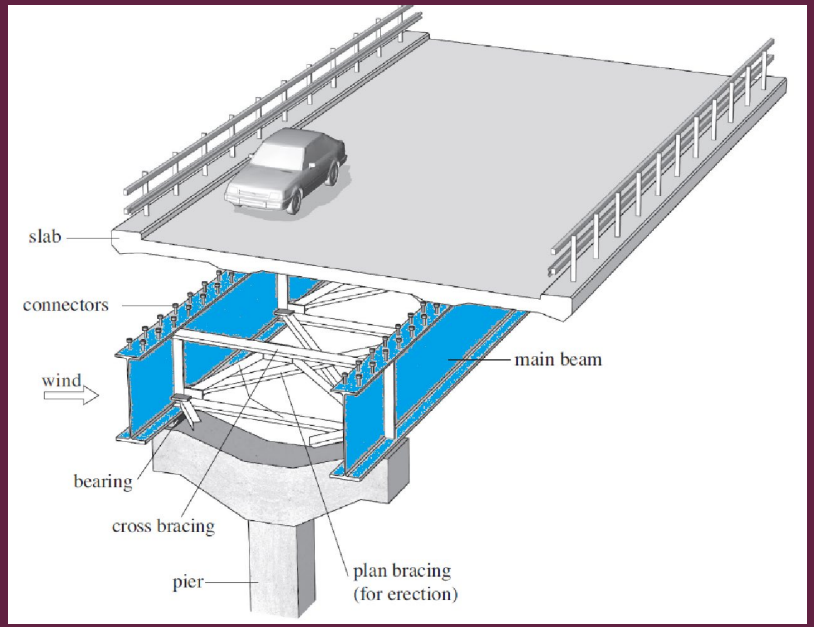
CHALMERS UNIVERSITY OF TECHNOLOGY
Master's thesis ACEX30
Gothenburg, Sweden 2024

Composite bridge

Composite bridge & road traffic



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Fatigue in steel

- Progressive
- Localized
- Permanent

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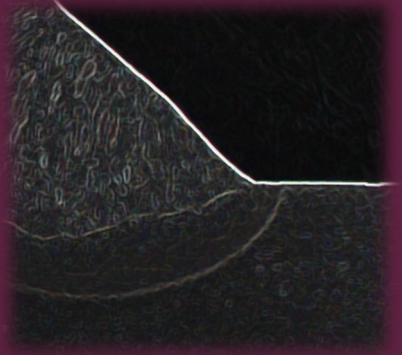
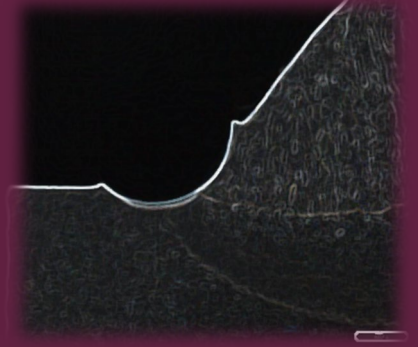
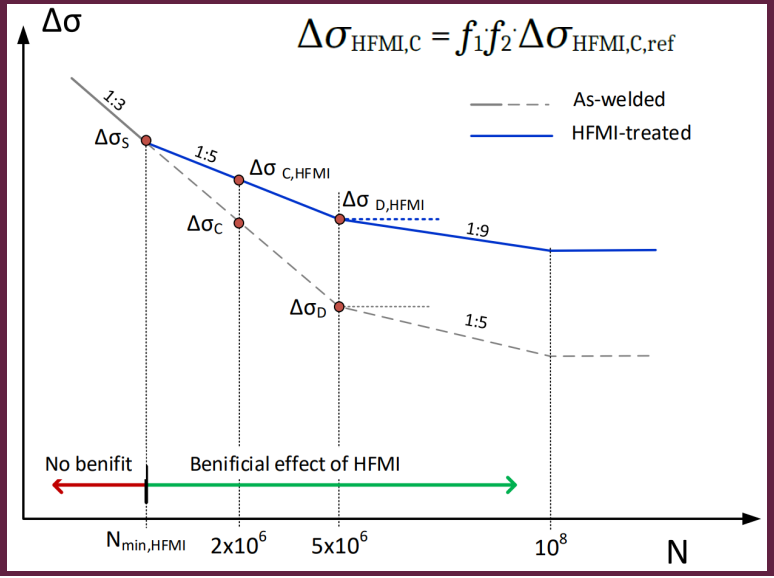
HFMI





Increased fatigue strength
Dependant on

- Steel grade
- Loading condition
  1. Mean stress effect
  2. Maximum stresses



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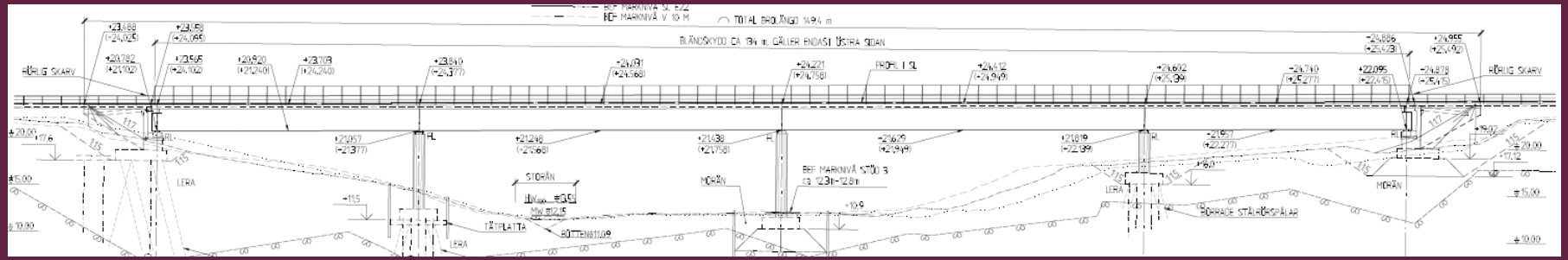
Bridge design

Example bridge



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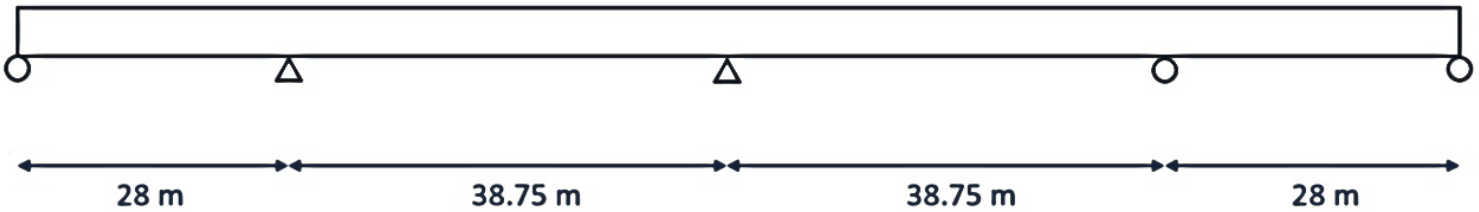
Bridge design

Simplified model



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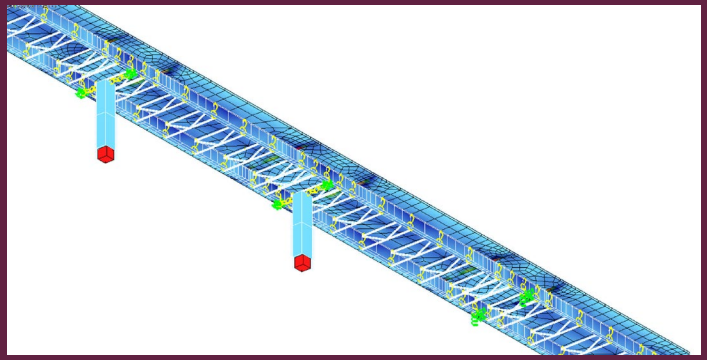
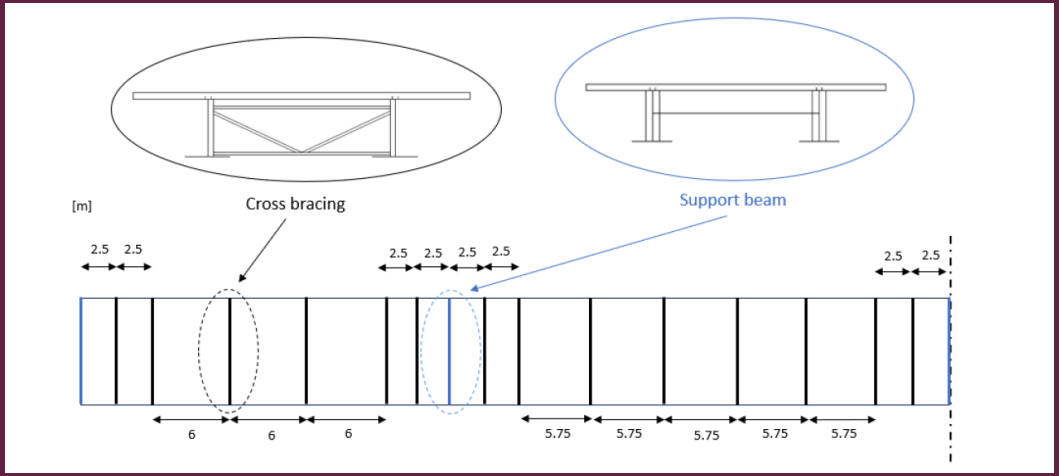
Bridge design



FE-model (SOFiSTiK)
Hand verifications



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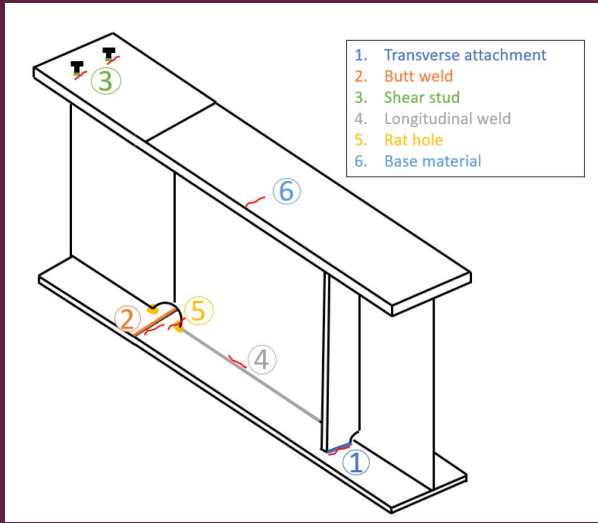
Bridge design

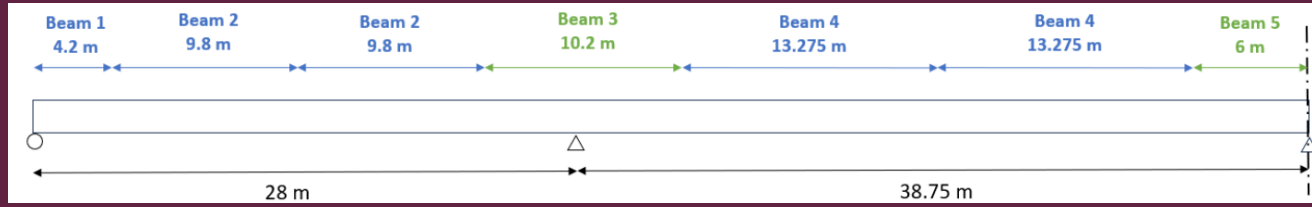
Details subjected to normal stresses:	$\Delta\sigma_c$ [MPa]	$\Delta\sigma_{c,HFMI,ref}$ [MPa]
1. Transverse attachment	80	140
2. Butt-weld	112	160
4. Longitudinal weld	112	-
5. Rat-hole	71	100
6. Base metal	160	-
Details subjected to shear stresses:	$\Delta\tau_c$ [MPa]	$\Delta\tau_{c,HFMI,ref}$ [MPa]
3. Shear stud	90	-

Local fatigue details



Bridge design

"Original design"



						h=L/20 = 1937.5 mm			h=L/30 = 1291.7 mm		
Beam	Nr of beams	L [m]	t_{tf} [mm]	b_{tf} [mm]	t_w [mm]	h_w [mm]	t_{bf} [mm]	b_{bf} [mm]	h_w [mm]	t_{bf} [mm]	b_{bf} [mm]
1	2	4.2	35	700	18	1862.5	40	800	1206.7	50	1100
2	4	9.8	35	700	18	1862.5	38	780	1206.7	55	1000
3	2	10.2	35	800	20	1862.5	50	1100	1206.7	60	1250
4	4	13.3	35	725	18	1862.5	40	1250	1206.7	60	1050
5	2	6	35	800	20	1862.5	50	1100	1206.7	60	1250

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Bridge design

“Original design”

Fy [MPa]	Umax ULS	Umax SLS	Umax FLS-AW	Umax ULS	Umax SLS	Umax FLS-AW
355	97.8	24.7	98.7	97.5	31.2	93.7
460	76.7	24.7	98.7	76.7	31.2	93.7
690	48.9	24.7	98.7	50.8	31.2	93.7

Bridge design

"Original design"

Fy [MPa]	Umax ULS	Umax SLS	Umax FLS-AW	Umax FLS-HFMI	Umax ULS	Umax SLS	Umax FLS-AW	Umax FLS-HFMI
355	97.8	24.7	98.7	84	97.5	31.2	93.7	81.2
460	76.7	24.7	98.7	78.1	76.7	31.2	93.7	78
690	48.9	24.7	98.7	67.8	50.8	31.2	93.7	67.7

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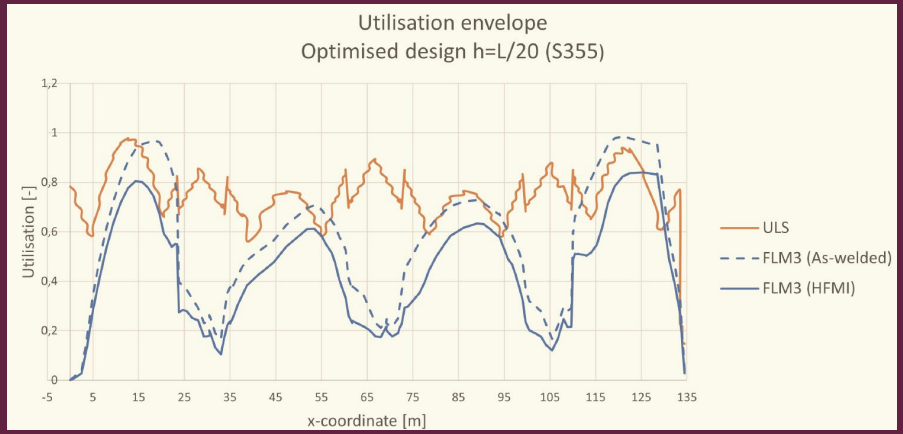
Bridge design

“Original design”



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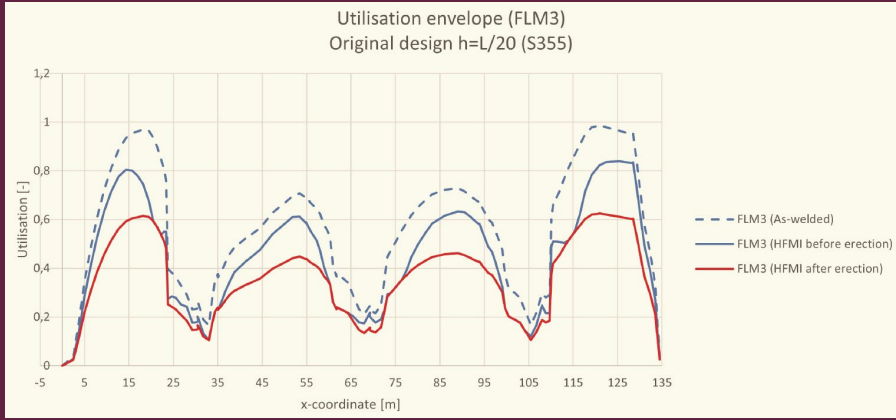
Bridge design

“Original design”



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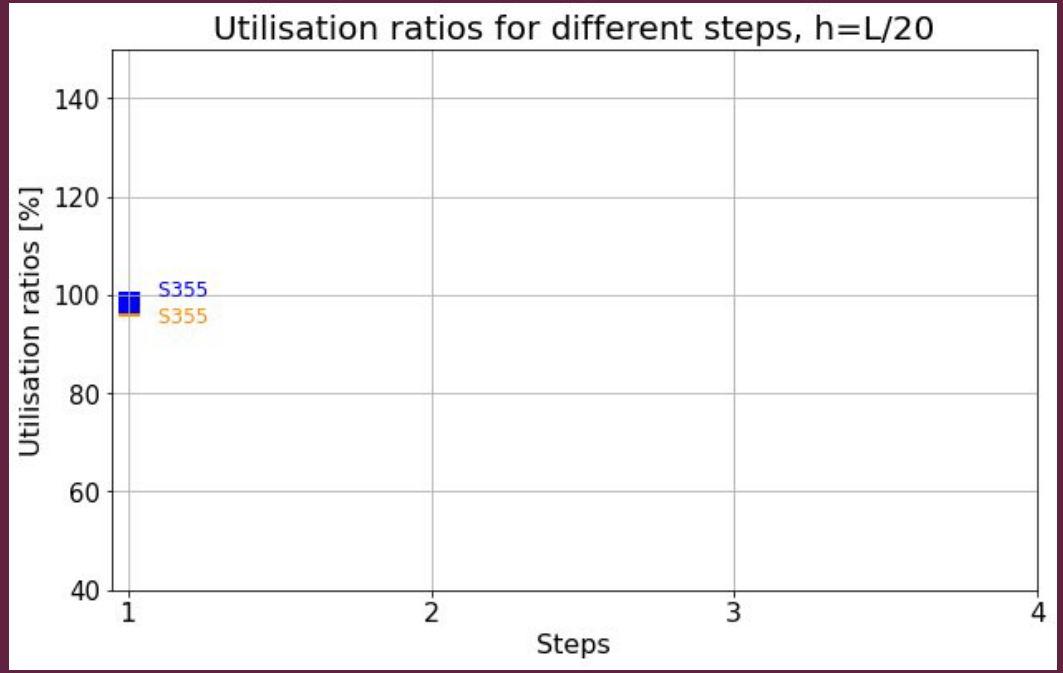
Bridge design

"optimization via HSS and HFMI"

Description of steps:	
1	Original design (S355, AW)
2	Increasing steel strength (AW)
3	Implementation of HFMI
4	Optimisation of geometry



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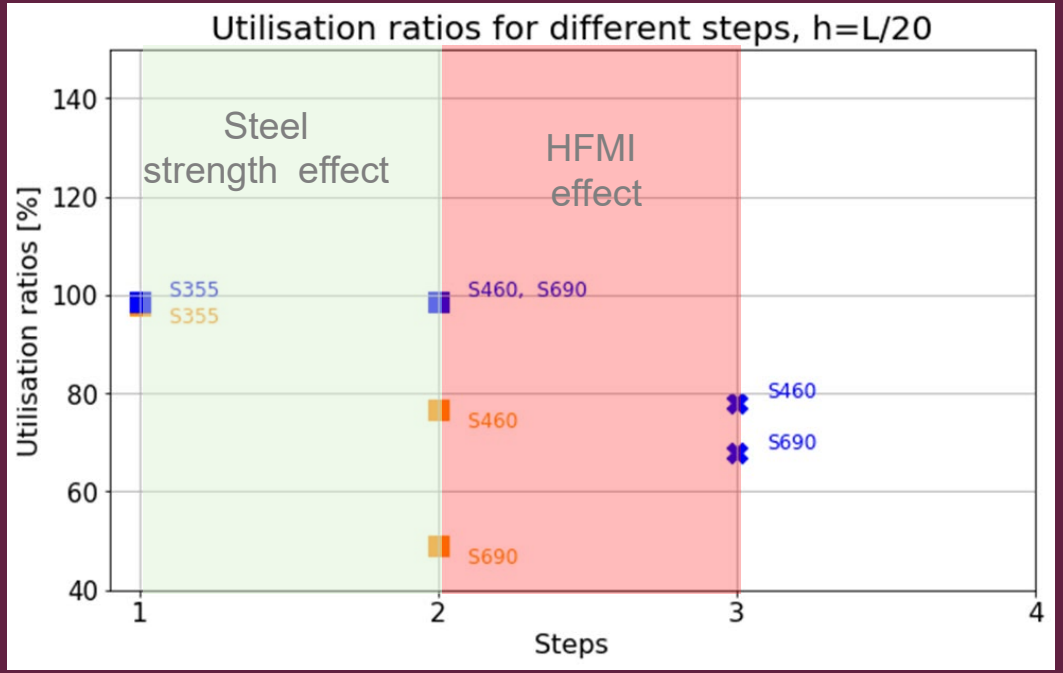

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Optimization

"optimization via HSS and HFMI"

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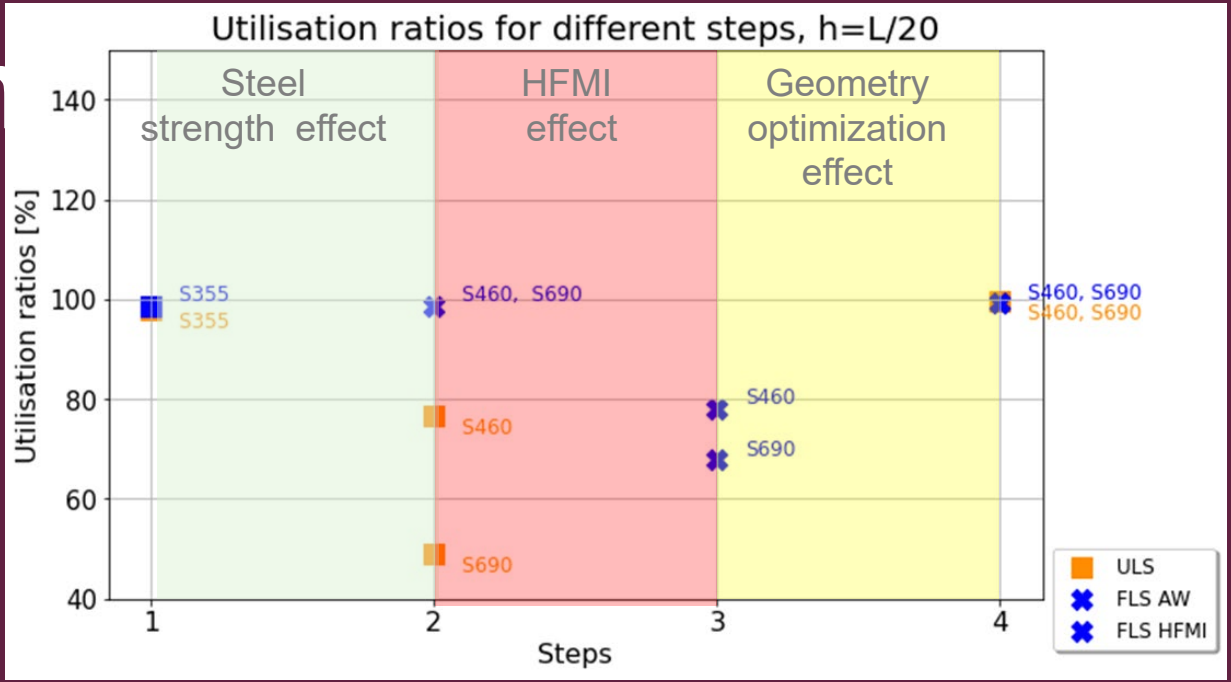
4	Optimisation of geometry



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Optimization

Original design is the reference

Design	Steel usage [tone]	Steel saving [%]	Cost [MSEK]	Cost difference [%]
	HFMI at workshop h=L/20 = 1937.5 mm / h=L/30 1291.7 mm			
Original design (AW) (S355)	225.6 / 239.7	-	2.26 / 2.40	-
Optimised design (HFMI) (S460)	126.1 /126.1	44.1 / 27.7	1.46 / 1.97	35.5 / 17.9
Optimised design (HFMI) (S690)	111.5 / 136.8	50.6 / 42.9	2.24 / 2.72	0.9 / 13.6
	HFMI on-site h=L/20 = 1937.5 mm / h=L/30 1291.7 mm			
Original design (AW) (S355)	225.6 / 239.7	-	2.26 / 2.40	-
Optimised design (HFMI) (S460)	118.5 / 167.4	47.5 / 30.2	1.37 / 1.90	39.1 / 20.6
Optimised design (HFMI) (S690)	111.5 / 112.0	50.6 / 53.3	2.24 / 2.25	0.9 / 6.3

Conclusions

- Material saving => easier transportation and less emission
- Shorter girders => more flexible for design
- Excellent tool=> When FLS is governing

Thank you