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### Exercise #4: Interaction Curves

The single storey steel industrial building shown in Figure 1 consists of I-shape S355 steel columns ( $f_y = 355\text{MPa}$ ,  $E = 200\text{GPa}$ ), which are connected to a roof truss system at the top. The cross-section sizes are shown in Figure 1. The roof truss has a flexural stiffness that is significantly greater than that of the columns in the direction where the columns bend about their strong axis (assumed as fixed at the base). The roof truss has negligible flexural stiffness in the direction where the columns are bending about their weak axis (assumed as pinned at the base). In the two perimeter frames in the East-West (EW) loading direction, X-braces made of 75mm diameter circular steel rods made of S355 ( $f_y = 355\text{MPa}$ ,  $E = 200\text{GPa}$ ), are installed in three bays to create a non-sway frame as shown in Figure 1. The steel rods have a negligible compressive resistance (i.e., tension only bracing system). Axial struts are used to brace laterally the columns in the EW loading direction as shown in Figure 1. The total dead load acting on the roof of the structure is equal to 5.0kPa.

1. Compute the buckling resistance of the HEB500 columns in the perimeter moment-resisting frames. Show explicitly your assumptions and calculations.
2. Sketch the first order bending and shear diagrams only for the columns of the perimeter moment-resisting frames in the North-South loading direction due to the lateral load,  $F_l$ .
3. Compute the bending and shear diagrams only for the columns of the perimeter moment-resisting frames in the North-South (NS) loading direction due to the lateral load,  $F_l$ , by considering the influence of compressive axial loads on the steel columns. In this case, you should to think how the frames with X-braces may affect the HEB500 steel columns.
4. Check the interaction of compressive axial load and bending moment demands for the HEB500 column in one of the perimeter moment-resisting frames. In your calculations, assume that lateral torsional buckling is not critical for these members.

NOTE for Figure 1:  $F_l=1800\text{kN}$  and  $F_2=15,000\text{kN}$

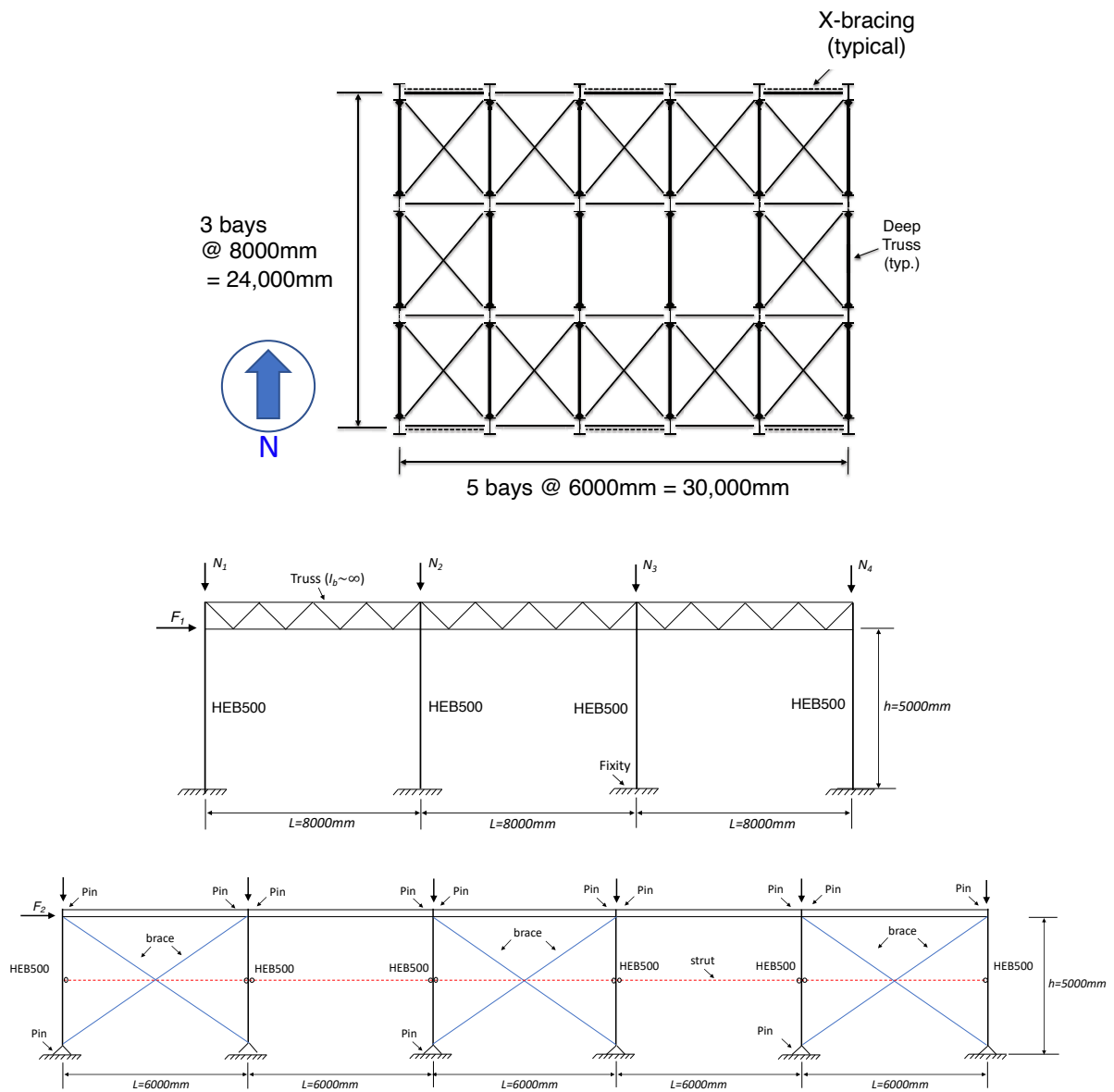
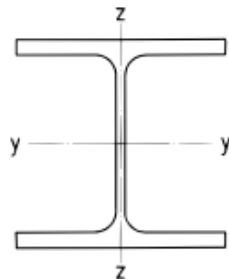


Figure 1. Single-storey industrial building – plan and elevation views

# HEB

## Breitflanschträger HEB

## Profils à larges ailes HEB



$$A_v = A - 2bt_f + (t_w + 2r) t_f$$

$$A_w = (h - t_f) \cdot t_w$$

$$S_y = \frac{1}{2} W_{ply}$$

$$S_z = \frac{1}{2} W_{plz}$$

$$W_{ely} = \frac{I_y}{h/2}$$

$$\bar{W}_y = \frac{I_y}{(h - t_f)/2}$$

$$W_{elz} = \frac{I_z}{b/2}$$

Maximale Lagerlängen /  
Longueurs maximales en stock:  
 $h \leq 180$  18 m  
 $h \geq 200$  24 m

EURONORM 53 – 62, DIN 1025/2

Andere Bezeichnungen }  
Autres désignations } DIN, IPB

\* Auch in S355J0 oder S355J2  
ab Schweizer Lager erhältlich

\* Livrable en S355J0 ou S355J2  
du stock suisse

HEB	m kg/m	Statische Werte / Valeurs statiques												
		A mm <sup>2</sup>	A <sub>v</sub> mm <sup>2</sup>	A <sub>w</sub> mm <sup>2</sup>	I <sub>y</sub> mm <sup>4</sup>	W <sub>ely</sub> mm <sup>3</sup>	$\overline{W}_y$ mm <sup>3</sup>	W <sub>ply</sub> mm <sup>3</sup>	i <sub>y</sub> mm	I <sub>z</sub> mm <sup>4</sup>	W <sub>elz</sub> mm <sup>3</sup>	W <sub>plz</sub> mm <sup>3</sup>	i <sub>z</sub> mm	K = I <sub>x</sub> mm <sup>4</sup>
					x 10 <sup>6</sup>	x 10 <sup>3</sup>	x 10 <sup>3</sup>	x 10 <sup>3</sup>		x 10 <sup>6</sup>	x 10 <sup>3</sup>	x 10 <sup>3</sup>		x 10 <sup>6</sup>
100*	20,4	2600	904	540	4,50	89,9	100	104	41,6	1,67	33,5	51,4	25,3	0,0931
120*	26,7	3400	1096	708	8,64	144	158	165	50,4	3,18	52,9	81,0	30,6	0,139
140*	33,7	4300	1308	896	15,1	216	236	245	59,3	5,50	78,5	120	35,8	0,202
160*	42,6	5430	1759	1180	24,9	311	339	354	67,8	8,89	111	170	40,5	0,312
180*	51,2	6530	2024	1410	38,3	426	461	481	76,6	13,6	151	231	45,7	0,422
200*	61,3	7810	2483	1660	57,0	570	616	643	85,4	20,0	200	306	50,7	0,596
220*	71,5	9100	2792	1940	80,9	736	793	827	94,3	28,4	258	394	55,9	0,770
240*	83,2	10600	3323	2230	112,6	938	1010	1050	103	39,2	327	498	60,8	1,04
260*	93,0	11800	3759	2420	149,2	1150	1230	1280	112	51,3	395	602	65,8	1,26
280*	103	13100	4109	2750	192,7	1380	1470	1530	121	65,9	471	718	70,9	1,45
300*	117	14900	4743	3090	251,7	1680	1790	1870	130	85,6	571	870	75,8	1,87
320*	127	16100	5177	3440	308,2	1930	2060	2150	138	92,4	616	939	75,7	2,29
340*	134	17100	5609	3820	366,6	2160	2300	2410	146	96,9	646	986	75,3	2,62
360*	142	18100	6060	4220	431,9	2400	2560	2680	155	101	676	1030	74,9	2,98
400*	155	19800	6998	5080	576,8	2880	3070	3230	171	108	721	1100	74,0	3,61
450*	171	21800	7966	5940	798,9	3550	3770	3980	191	117	781	1200	73,3	4,49
500	187	23900	8982	6840	1072	4290	4540	4820	212	126	842	1290	72,7	5,50
550	199	25400	10010	7820	1367	4970	5250	5590	232	131	872	1340	71,7	6,12
600	212	27000	11080	8840	1710	5700	6000	6420	252	135	902	1390	70,8	6,80
650	225	28600	12200	9900	2106	6480	6800	7320	271	140	932	1440	69,9	7,52
700	241	30600	13710	11400	2569	7340	7690	8330	290	144	963	1490	68,7	8,42
800	262	33400	16180	13400	3591	8980	9360	10230	328	149	994	1550	66,8	9,62
900	291	37100	18880	16000	4941	10980	11400	12580	365	158	1050	1660	65,3	11,5
1000	314	40000	21250	18300	6447	12890	13400	14860	401	163	1090	1720	63,8	12,7

Anstelle des nicht mehr gewalzten Profils HEB 1100 können HL-Profile verwendet werden, siehe Seiten 40/41.

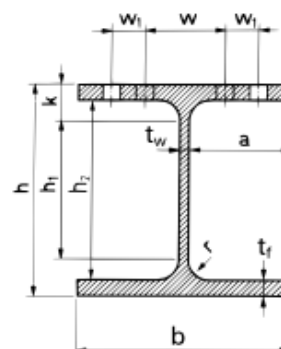
$w_1$  mit  $\varnothing_{\max}$  nur für versetzte Schrauben.

Walttoleranzen siehe Seite 116

Au lieu du profilé HEB 1100 qui n'est plus laminé, on utilisera des profilés HL (voir pages 40/41).

$w_1$  avec  $\varnothing_{\max}$  seulement pour boulons décalés.

Tolérances de laminage voir page 116



HEB	m kg/m	Profilmasse Dimensions de la section					Konstruktionsmasse Dimensions de construction							Oberfläche Surface		HEB
		h mm	b mm	t <sub>w</sub> mm	t <sub>f</sub> mm	r mm	h <sub>1</sub> mm	k mm	a mm	h <sub>2</sub> mm	w mm	w <sub>1</sub> mm	∅ <sub>max</sub>	U <sub>m</sub> m <sup>2</sup> /m	U <sub>t</sub> m <sup>2</sup> /t	
100	20,4	100	100	6	10	12	56	22	47	80	56		M12	0,567	27,8	100
120	26,7	120	120	6,5	11	12	74	23	56	98	66		M16	0,686	25,7	120
140	33,7	140	140	7	12	12	92	24	66	116	76		M20	0,805	23,9	140
160	42,6	160	160	8	13	15	104	28	76	134	86		M20	0,918	21,5	160
180	51,2	180	180	8,5	14	15	122	29	85	152	100		M24	1,04	20,3	180
200	61,3	200	200	9	15	18	134	33	95	170	110		M24	1,15	18,8	200
220	71,5	220	220	9,5	16	18	152	34	105	188	120		M24	1,27	17,8	220
240	83,2	240	240	10	17	21	164	38	115	206	96	35	M24	1,38	16,6	240
260	93,0	260	260	10	17,5	21	178	42	125	222	100	40	M24	1,50	16,1	260
280	103	280	280	10,5	18	21	192	46	135	238	100	40	M24	1,62	15,7	280
300	117	300	300	11	19	27	208	46	144	262	120	45	M27	1,73	14,8	300
320	127	320	300	11,5	20,5	27	224	48	144	279	120	45	M27	1,77	13,9	320
340	134	340	300	12	21,5	27	242	49	144	297	120	45	M27	1,81	13,5	340
360	142	360	300	12,5	22,5	27	260	50	143	315	120	45	M27	1,85	13,0	360
400	155	400	300	13,5	24	27	298	51	143	352	120	45	M27	1,93	12,4	400
450	171	450	300	14	26	27	344	53	143	398	120	45	M27	2,03	11,9	450
500	187	500	300	14,5	28	27	390	55	142	444	120	45	M27	2,12	11,3	500
550	199	550	300	15	29	27	438	56	142	492	120	45	M27	2,22	11,2	550
600	212	600	300	15,5	30	27	486	57	142	540	120	45	M27	2,32	11,0	600
650	225	650	300	16	31	27	534	58	142	588	120	45	M27	2,42	10,8	650
700	241	700	300	17	32	27	582	59	141	636	126	45	M27	2,52	10,5	700
800	262	800	300	17,5	33	30	674	63	141	734	130	40	M27	2,71	10,4	800
900	291	900	300	18,5	35	30	770	65	140	830	130	40	M27	2,91	10,0	900
1000	314	1000	300	19	36	30	868	66	140	928	130	40	M27	3,11	9,9	1000