Metal Structures

Lecture VIII

Forming of steel structures

Contents

Philosophy of design

Philosophy of design is the result of three factors:

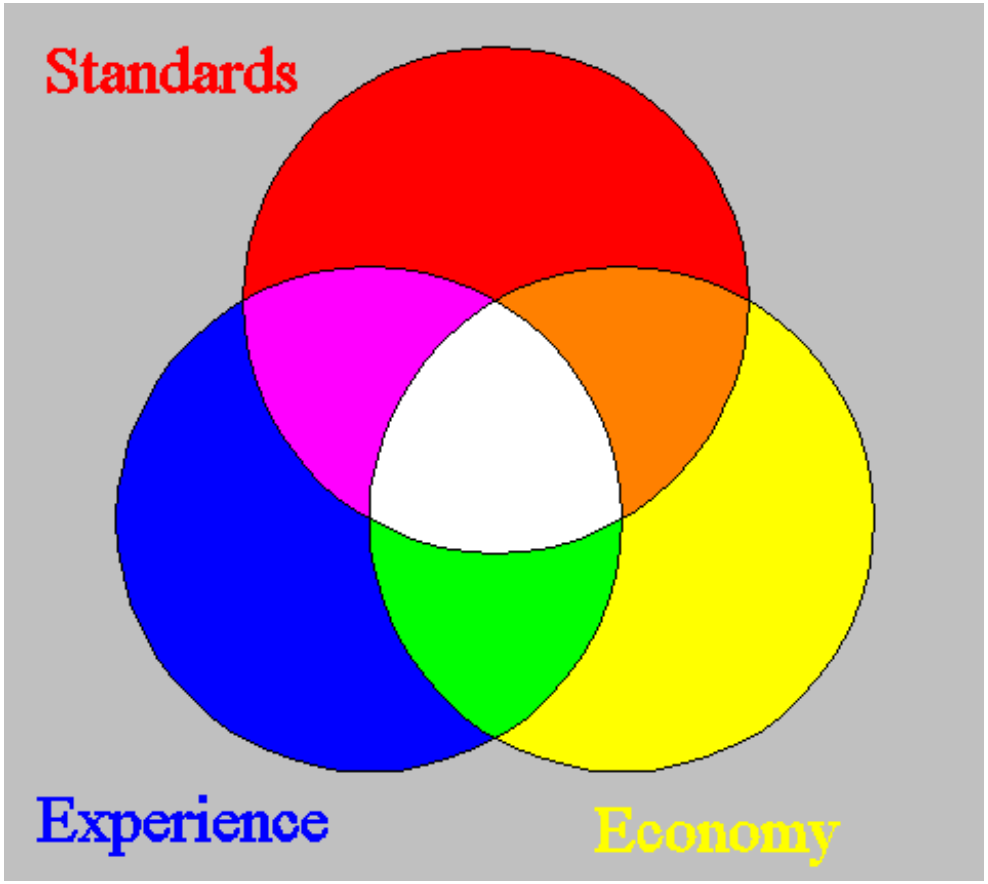


Photo: Author

Standards

What is acceptable by standards?

Ist design project: $E / R \leq 1{,}0$ for members, each plates, bolts and welds;

Economy

What is the cheapest?

Ist design project: minimalization of cross-sections;

Experience

What is the most useful / the simplest?

Ist design project: initial assumption geometry of truss;

The standard requirements change over time with the development of science and technology

Date	Standard	Notices
before 1980	Old Polish Standards PN – B / 03200 older version	• Permissible Stress Design (one common safety factor);
1980 – 2005/10	Old Polish Standards PN – B / 03200	• Limit States Metod; • Partial safety factors (for material and actions); • Division between Ist and IInd order methods;
from 2005/10	Eurocodes	• Extensive consideration of the impact of imperfection; • Analysis of stiffness of joints; • Detailed analysis of the resistance of joints; • Increase, due to technological progress, design strength of welds; • Taking into account the cooperation of housing and structure; • Diversification of the degree of structural responsibility by CC; • The obligation to use numerical models for shell structures CC3;

Types of structures

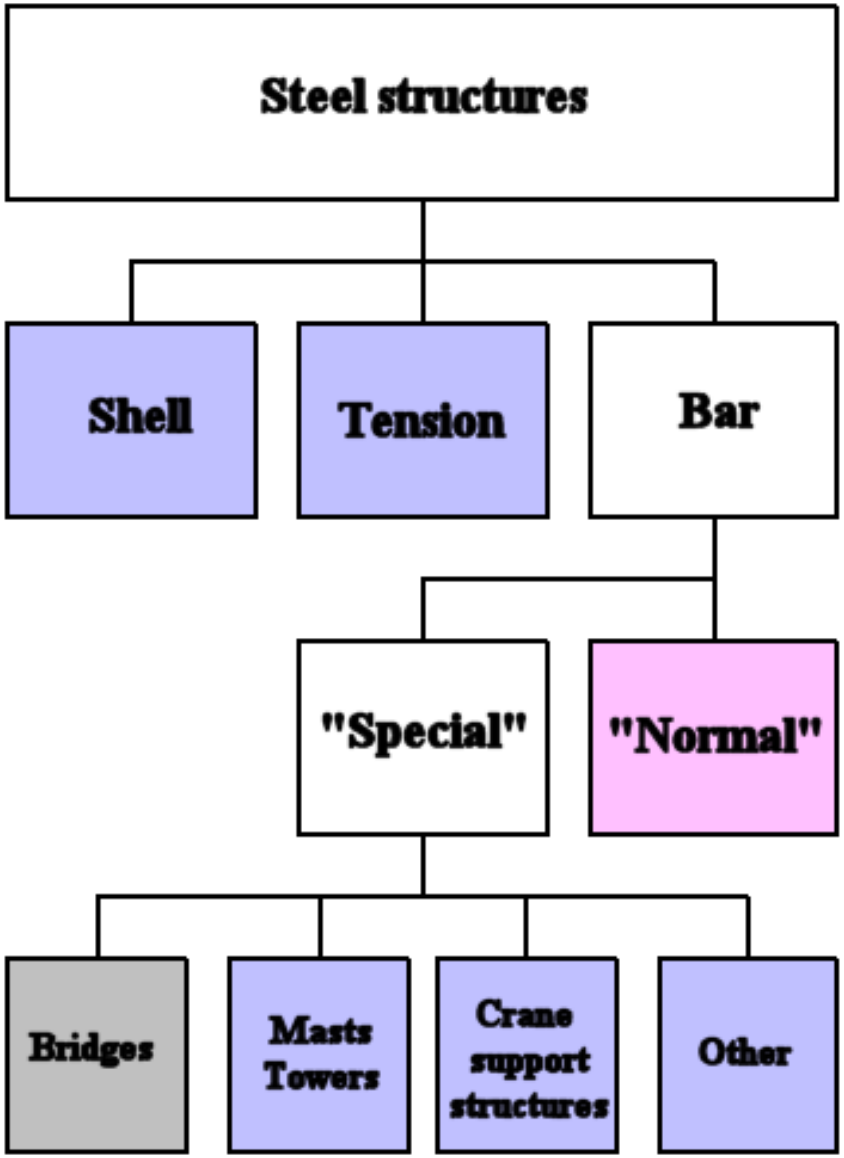


Photo: Author

Shell structures

EN 1993-1-6
EN 1993-3-2
EN 1993-4-1
EN 1993-4-2
EN 1993-4-3

Photo: carrasquilloassociates.com

Photo: wakro.com.pl

Photo: kbpomorze.pl

Photo: iniekt-system.pl

Photo: us.archello.com

Tension structures
EN 1993-1-11

Masts and towers
EN 1993-3-1

Photo: wikipedia

Photo: wikipedia

Photo:promag.pl

Crane supporting structures

EN 1993-3-6

Photo:galeria.plock24.pl

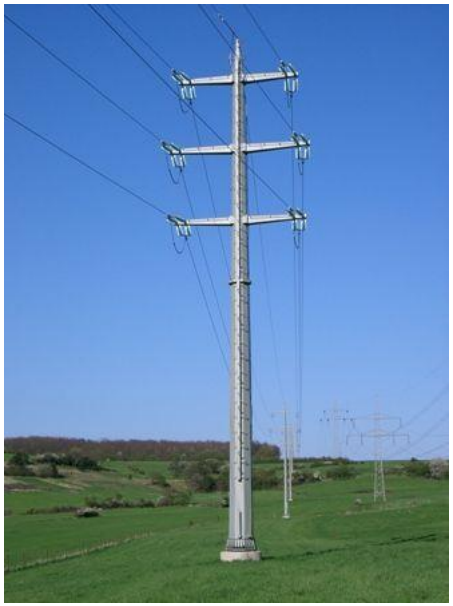


Photo: inzynieria.com

Electro-energetic towers
EN 50341-1

Piling
EN 1993-5

"Normal" steel structures
(frame and skeleton)
EN 1993-1-1
EN 1993-1-5
EN 1993-1-8

Photo: metroland.com.au

Photo: hale.info

Photo: weldon.pl

Hall: the most often type of steel structure

Steel hall: repetitive arrangement of flat steel frames, interrelated by purlins, roof bracings, walls bracings and wall girts

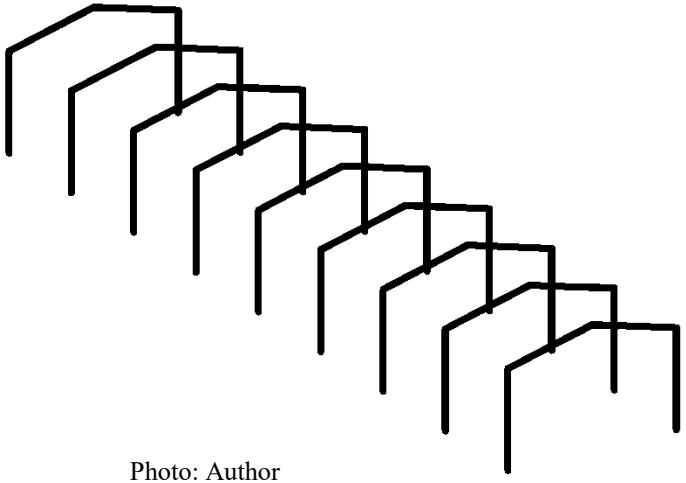


Photo: Author

Photo: traskostal.pl

Photo: weldon.pl

Photo: wallsviews.co

Steel skeletons are preferred to few-storeys offices buildings. Small number of bracings is applicated thanks to big stiffness of joint and – in horizontal direction – floors.

Photo: ekbud.lublin.pl

Photo: rccconcrete.com

Parts of structure

Photo: Author

Each steel structure can be divided into three parts:

- members
- connections
- joints

Members

→ #3 / 78

Photo: Author

Bars, beams, purlins, rafters, girders, columns, bracings - calculations according to level of cross-section or level of element.

Photo: civildigital.com

Example from Ist design project: resistance and stability of truss bars.

(~ 40% of calculation's conditions)

Welds and shank of bolts - calculation according to level of point (for welds) or cross-section (shearing resistance or tension resistance of shank of bolts)

Example from Ist design project: σ_{HMH} for welds.

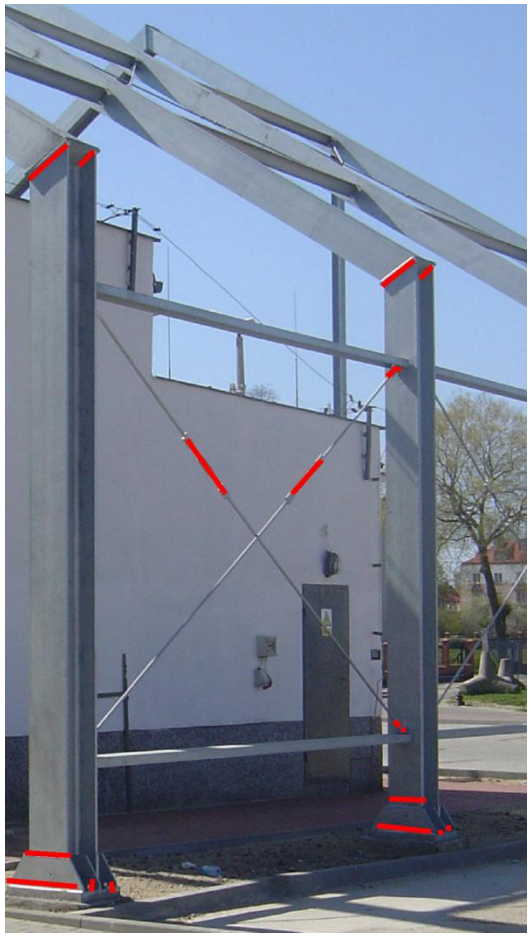


Photo: Author

Photo: ceprofs.civil.tamu.edu

Photo: researchgate.net

(~ 10% of calculation's conditions)

Joints

→ #3 / 80

Small parts of members, where are contact between two or more members. There are many specific phenomenons on these short part of beams, columns, etc. Calculation according to level of cross-section and level of element.

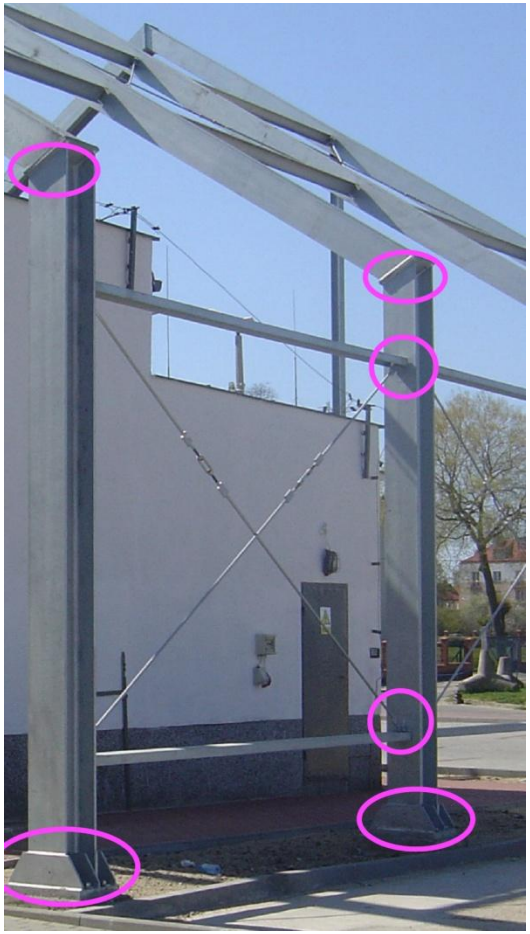


Photo: Author

Example from Ist design project: resistance of truss joints.

Photo: scielo.br

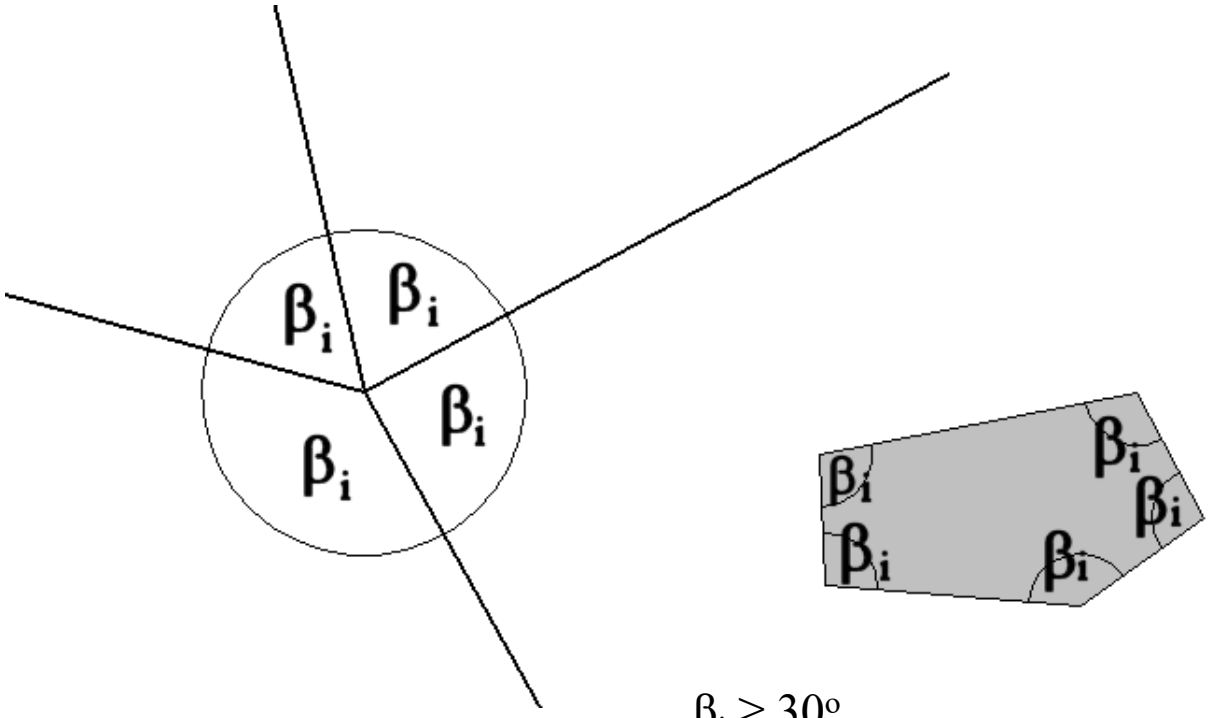
Photo: ascelibrary.org

Photo: osha.gov

(~ 60% of calculation's conditions)

General requirement:

angles between axis of members and internal angles for plates can't be too small (EN 1090-2)

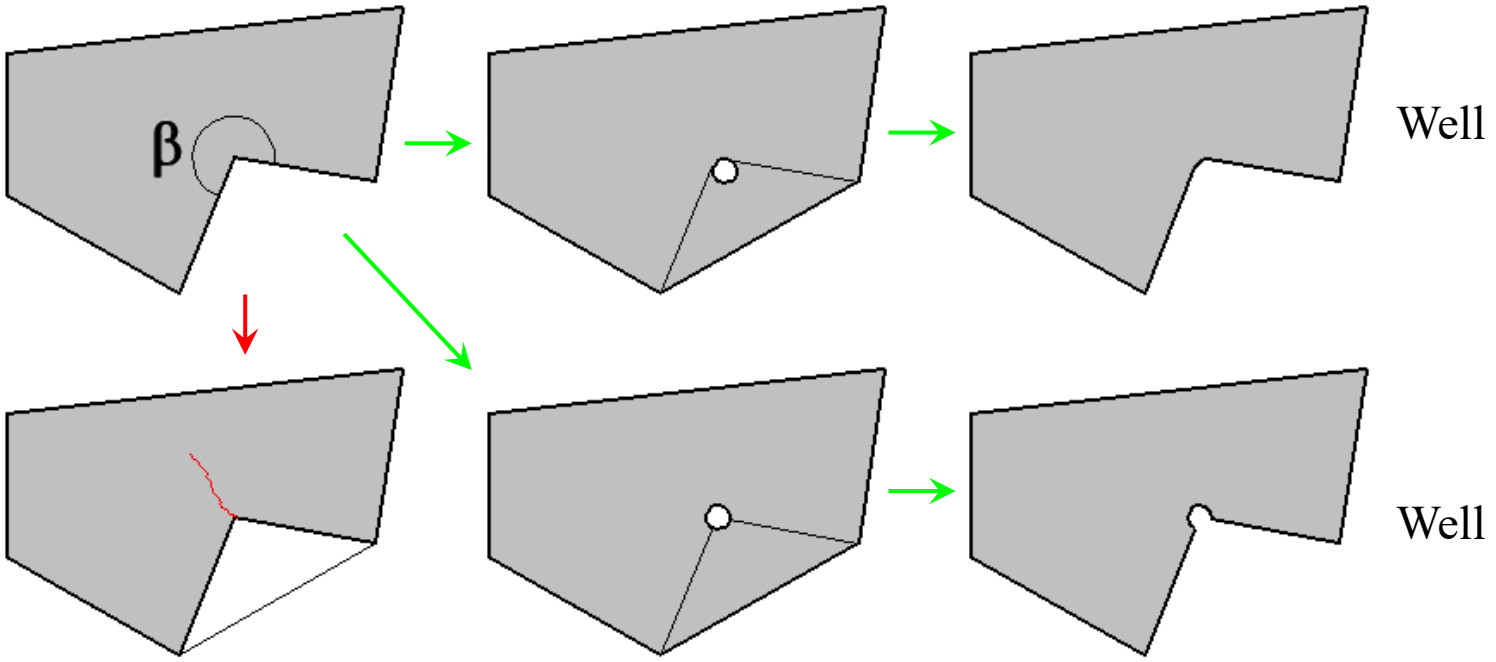


$\beta_i \geq 30^o$

Photo: Author

Reflex angles in plates we must make in special way to avoid cracking (EN 1090-2).

$\beta > 180^{o}$



Wrong

Photo: Author

Generally, structures analysed on Ist step of study (halls and skeletons), can be divided into different parts, which play different roles:

- roofing and housing → #t / 20 - 27
- purlins → #t / 28 - 41
- wall girts → #t / 42 - 47
- bracings → #t / 48
- truss → #t / 49
- beams, girders, columns → #t / 50 - 55
- joints → #t / 56 - 75

Roofing and housing

Modern solutions: sandwich panels, cladding panels, corrugated sheets, prefabricated glass fasades; steel or aluminum

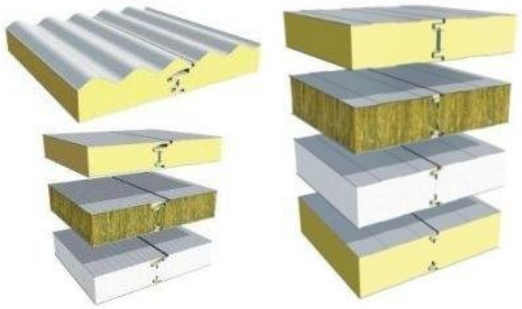


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Photo: pruszynski.com.pl

Photo: elewacje-stalowe.pl

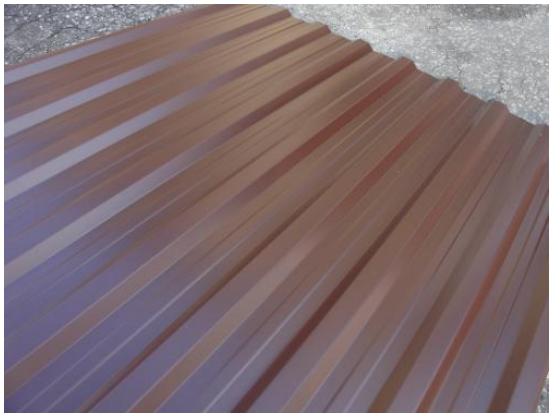
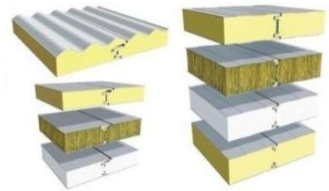
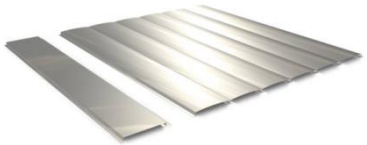


Photo: amarodachy.pl

Photo: building.co.uk

	Thermal isolation	Factory-made connecting latch	Anti-buckling protection for purlins according to EN
 Photo: steelprofil.pl	☺	☺	☹
 Photo: pruszynski.com.pl	☹	☺	☹
 Photo: amarodachy.pl	☹	☹	☺ (per 5 - 10 years from erection)
 Photo: building.co.uk	Separated problems (generally: responsible of manufacturer)		

Roofing and housing can be calculated as one of three levels of accuracy:

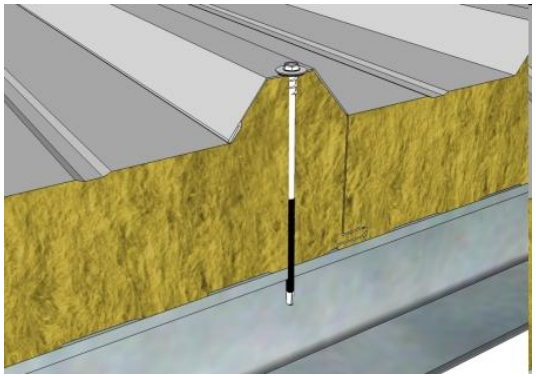
Accuracy of calculations	Comments
Dead weight only	The simples and most popular way of calculations (each type)
Dead weight + anti-buckling protection	According to EN 1993-1-3 (corrugated sheet only ; → Lecture #10) or FEM calculations according to results of tests and experiments (sandwich panels, cladding panels)
Dead weight + anti-buckling protection + cooperation with structure in bearing of loads	FEM calculations according to results of tests and experiments (each type);

Calculations of roofing (and housing) - we must choose from table thickness of sandwich
or
thickness of sheet and high of waves for value of loads and distance between purlins.

Grubość rdzenia	Obc. ze względu na	Maksymalne obciążenia, daN/m² przy rozpiętości przęsła, m														
		2,1	2,4	2,7	3,0	3,3	3,6	3,9	4,2	4,5	4,8	5,1	5,4	5,7	6,0	6,3
50	nośność	139	107	84	68	57										
	sztywność	100	78	61	48	38										
75	nośność	211	162	128	103	86	72	61	53	46	40	36				
	sztywność	183	148	121	99	82	68	57	48	40	34	29				
100	nośność		283	223	181	149	126	107	93	80	71	63	56	50	45	41
	sztywność		199	166	141	120	102	88	76	66	57	50	44	39	34	30
125	nośność		355	281	227	188	158	134	116	101	89	78	70	63	57	51
	sztywność		265	224	193	166	144	125	109	96	85	75	66	58	52	46
150	nośność			338	274	226	190	162	140	122	107	95	85	76	68	62
	sztywność			284	244	212	186	164	144	128	113	101	90	81	73	65
200	nośność				365	302	254	216	186	163	143	127	113	102	92	83
	sztywność				351	308	273	242	217	194	174	157	142	129	117	107
250	nośność				458	379	318	271	234	203	179	158	141	127	114	104
	sztywność				459	406	361	323	290	263	238	216	197	179	164	151

Photo: concretescrews.org

Photo: pruszynski.com.pl



For joints between roofing / housing and structure we use special self-tapping screw.

Photo: plyty-abo.pl

Photo: elbet.pl

Modern type of roofing - sandwich panels - very light.

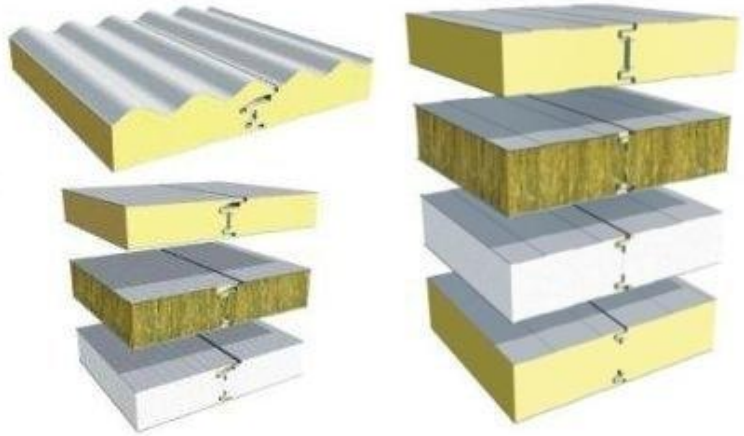


Photo: steelprofil.pl

Photo: fdbogucin.pl

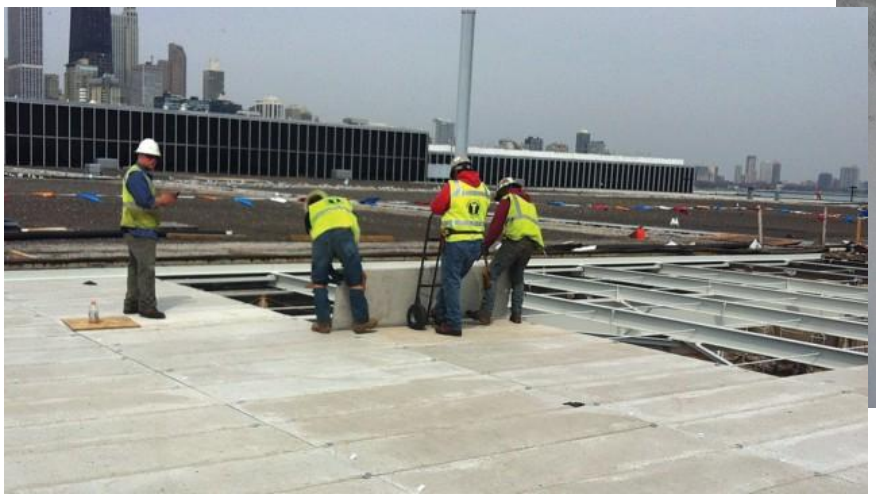


Photo: r3.forconstructionpros.com

Old type of roofing - concrete channel slab - very heavy.

Example - comparison of loads:

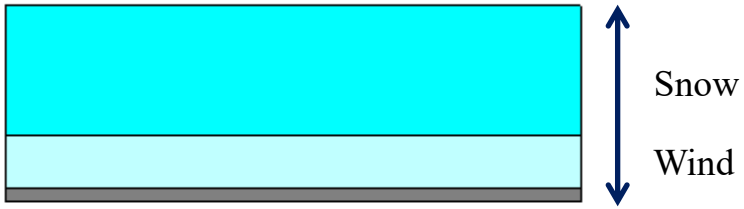
Load	Old type	Modern type
Roofing (sandwich panels or channel slab + additional layers)	~ 3,70 kN / m^2	~ 0,15 kN / m^2
Snow	~ 1,44 kN / m^2	~ 1,44 kN / m^2
Wind	~ 0,60 kN / m^2	~ 0,60 kN / m^2
Sum	~ 5,74 kN / m^2	~ 2,19 kN / m^2

Of course, modern roofing is much more lighter, so dead weight will be smaller and structure will be cheaper.

But...

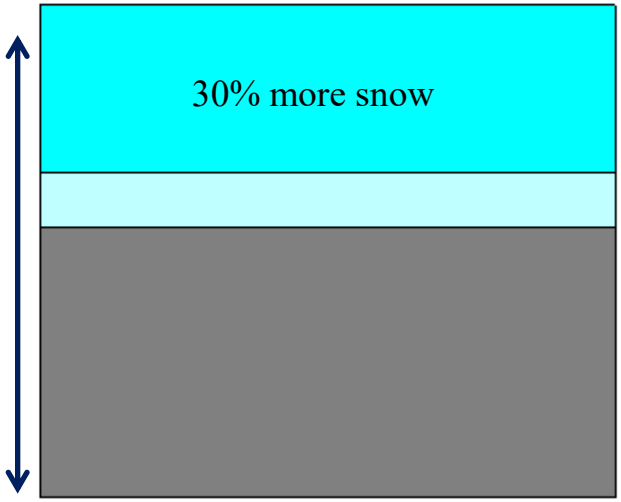
Snow it is climatic load; there is possible, that its value can be much more greater than according to standard.
For example: unforseen 30% more snow.

Load	Old type	Modern type
Roofing (sandwich panels or channel slab + additional layers)	~ 3,70 kN / m^2	~ 0,15 kN / m^2
Snow + 30%	~ 1,87 kN / m^2	~ 1,87 kN / m^2
Wind	~ 0,60 kN / m^2	~ 0,60 kN / m^2
Sum	~ 6,17 kN / m^2	~ 2,62 kN / m^2



Old type roof is less sensitible to unforseen overloading

7% more total



20% more total

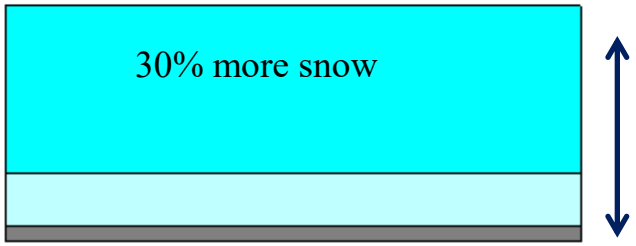


Photo: Author

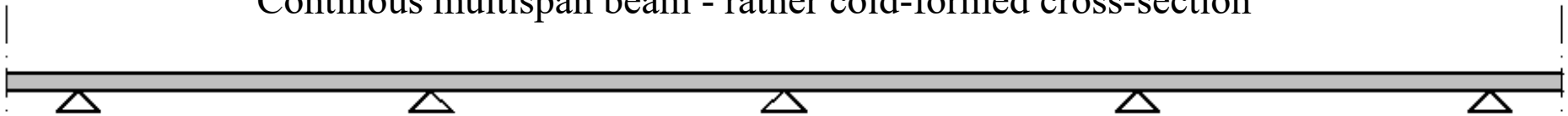
Purlins

Loads:

- Dead weight of roofing
- Dead weight of purlin
- Snow
- Wind
- Imposed loads
- Thermal actions
- Accidental actions
- Actions durin execution

Static schemes of purlins:

Continous multispan beam - rather cold-formed cross-section



One-span beam - rather hot-rolled cross-section (recommended IPE)

Photo: Author

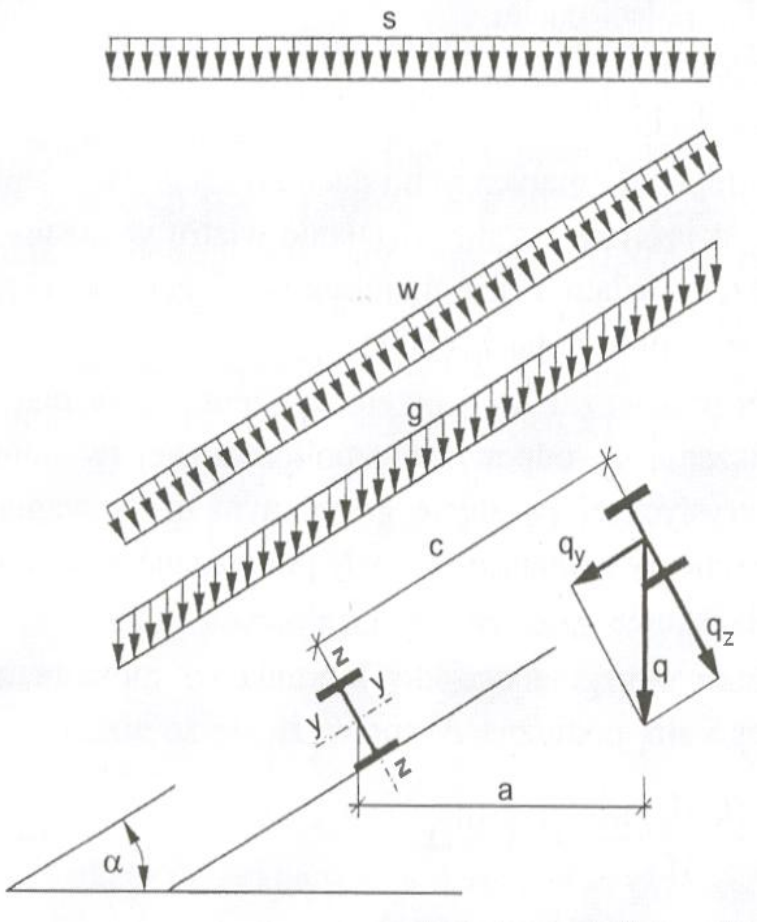


Photo: M. Łubiński, W. Żółtowski, Konstrukcje Metalowe t. II, Arkady, Warszawa 2004

Reminder from Introduction to Construction Design:

Three types of loads act on purlins:

- s - vertical related to the horizontal plane ([kN / m^2]; snow);
- g - vertical related to the plane of roof ([kN / m^2]; dead weight of roofing and imposed load);
- w - perpendicular to plane of roof ([kN / m^2]; wind).

"Normal" multispan purlin - in both direction the same length ($l_y = l_z = l$)

$$M_{Ed,\,y} \approx q_z\, l^2 \qquad M_{Ed,\,z} \approx q_y\, l^2$$

$$q_z < q_y \rightarrow M_{Ed,\,z} < M_{Ed,\,y} \quad \text{but}$$

$$J_z << J_y \rightarrow W_z << W_y \rightarrow M_{Rd,\,z} << M_{Rd,\,y}$$

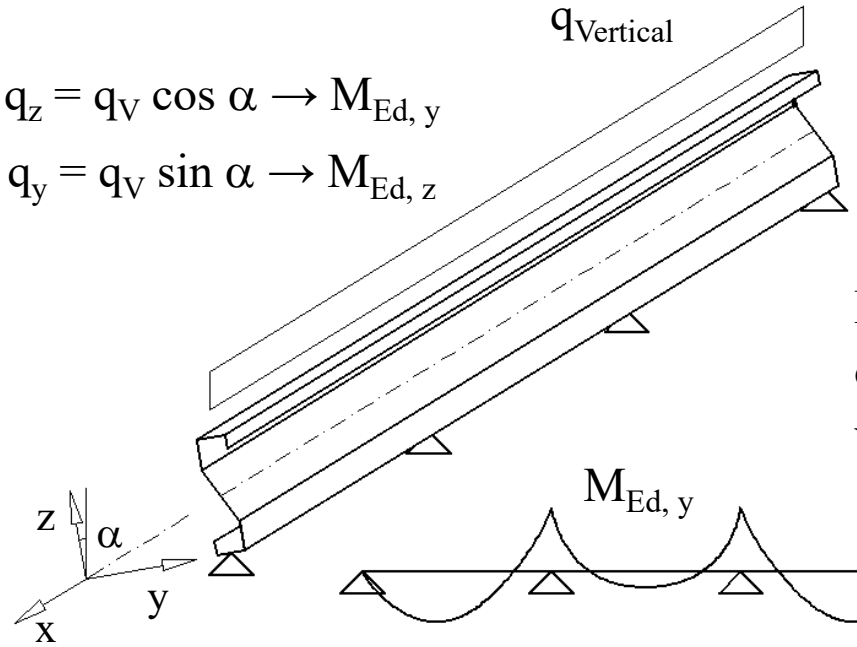
there is possible, that $M_{Ed,\,z} / M_{Rd,\,z} > M_{Ed,\,y} / M_{Rd,\,y}$

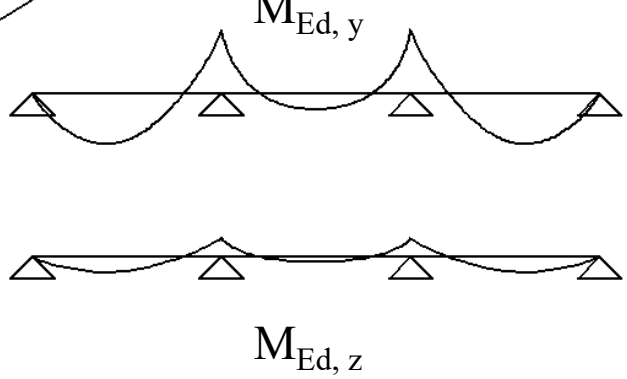
$$f_y \approx q_y\, l^4 / EJ_z \approx f_z \approx q_z\, l^4 / EJ_y$$

Big efforts in both directions, big deflections in both directions. Is possible, that cross-section must be very massive because of problems with weak axis.

$q_z = q_V \cos \alpha \rightarrow M_{Ed,\,y}$

$q_y = q_V \sin \alpha \rightarrow M_{Ed,\,z}$





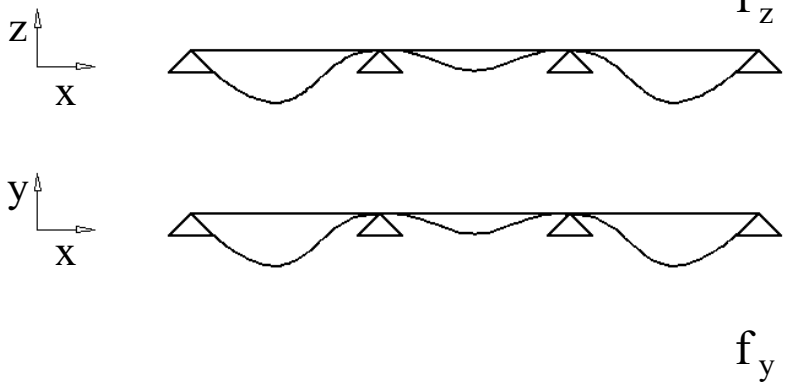
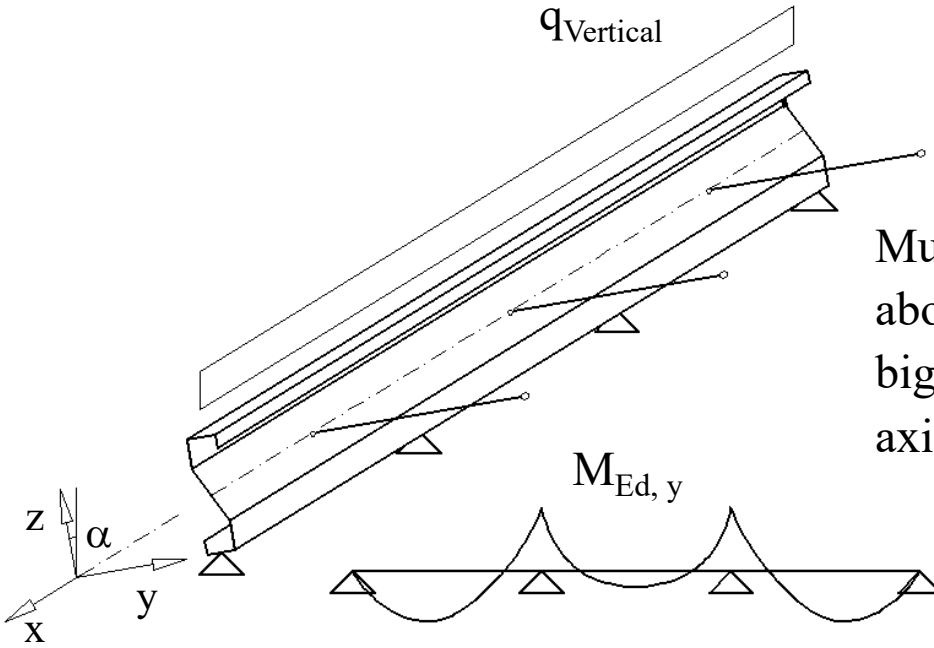


Photo: Author

Suspended purlin: hangers = additional support on y-direction (weak axis is supported).



At now, for weak axis $l_1 = l / 2$

$$M_{Ed,\,y1} \approx q_z\, l_1^2 = q_z\, l^2 / 4 = M_{Ed,\,y} / 4$$

$$f_{y1} \approx q_y\, l_1^4 / EJ_z = q_y\, l^4 / EJ_z / 16 = f_y / 16$$

Much smaller bending moments and deflections about weal axis. Very economical design projec: big effort for strong axis, small effort for weak axis.

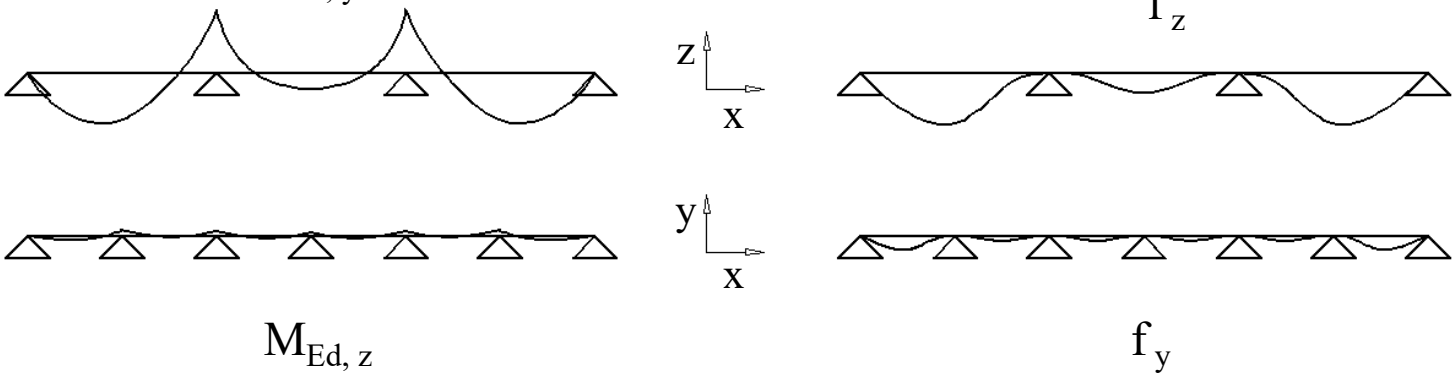


Photo: Author

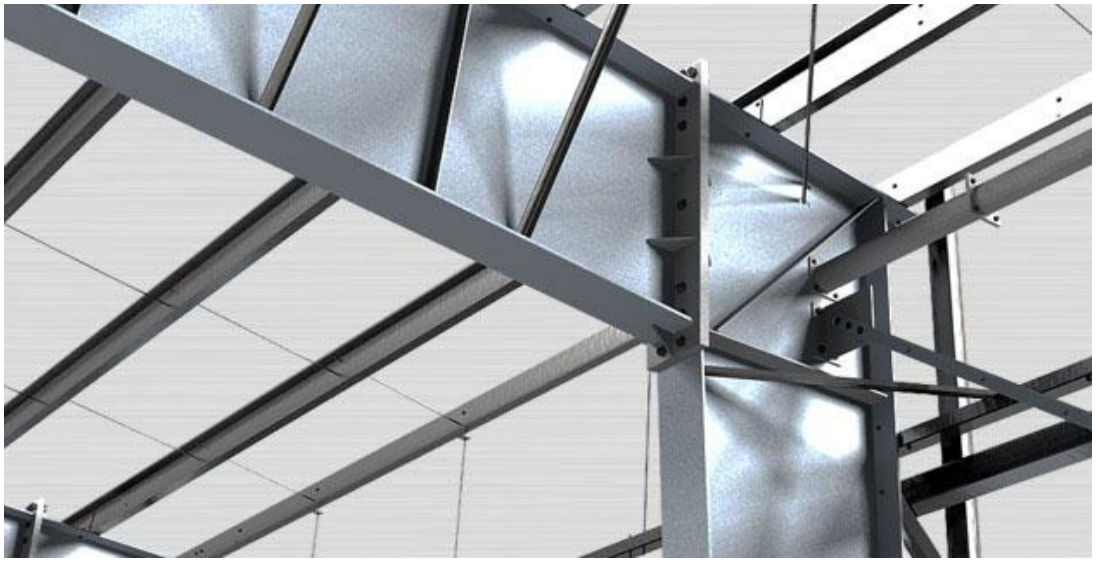
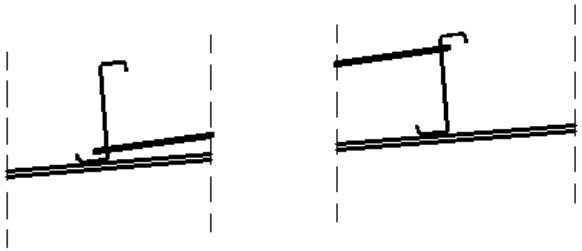


Photo: smodiinfrasteel.com



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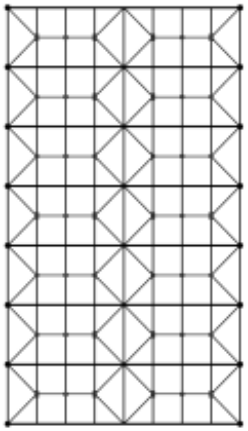
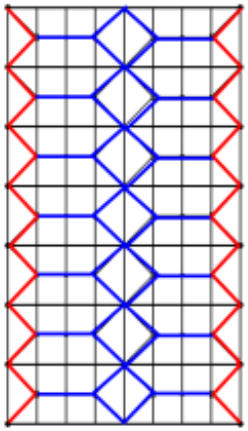
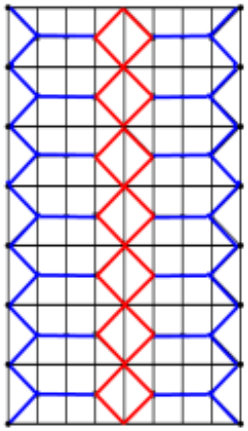
Compression and tension in hangers for:







wind pressure wind suction

There is possible compression in part of hangers. There will be permanently deformations as the effect of buckling.

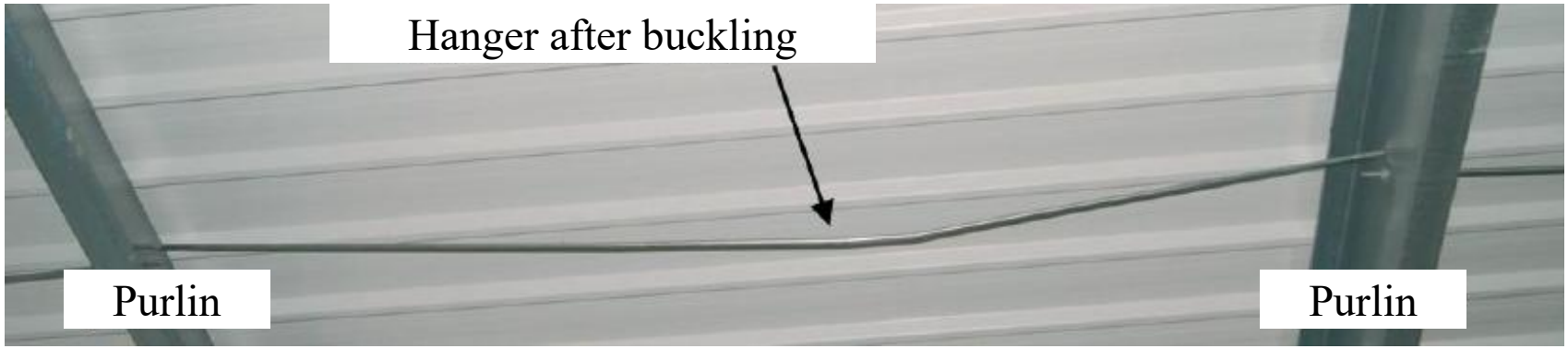
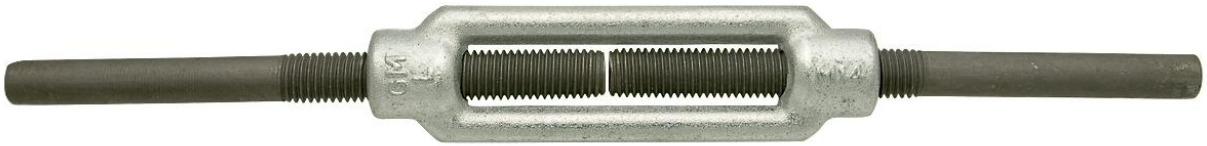


Photo: A. Biegus, Przyczyny przedawaryjnego stanu technicznego płatwi hali stalowej, Budownictwo i Architektura 12 / 2013, 173-180

Photo: dromet.pl



We need rigging screws to repair hangers.

Castellated beam

Photo: gunungsteel.com

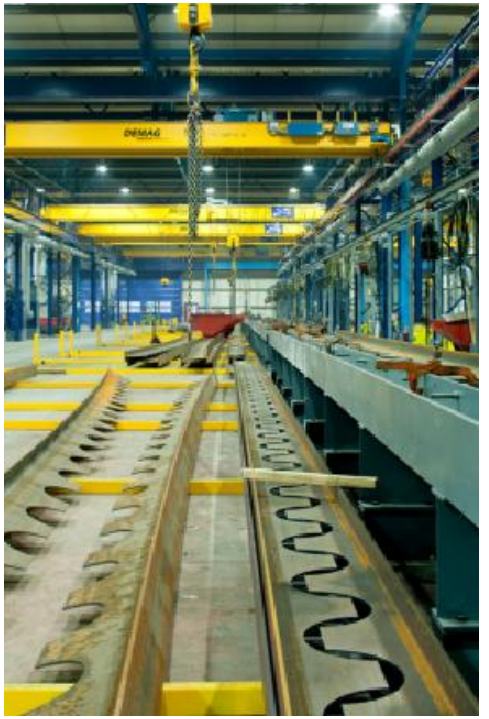


Photo: steelconstruction.info

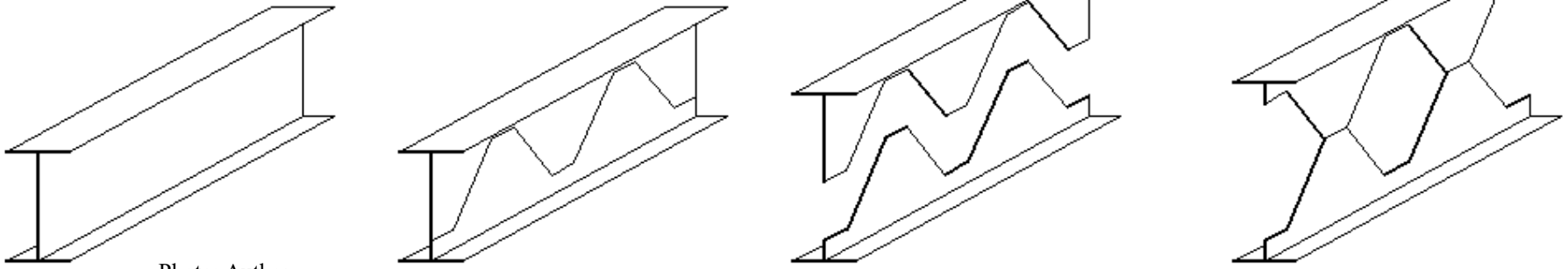


Photo: Author

The same dead weight; much greater moment of inertia and sectional modulus about strong axis; no change about weak axis.

Truss purlin

"Normal" truss - forces are applied in nodes; there are axial forces in chords and cross-bars only.

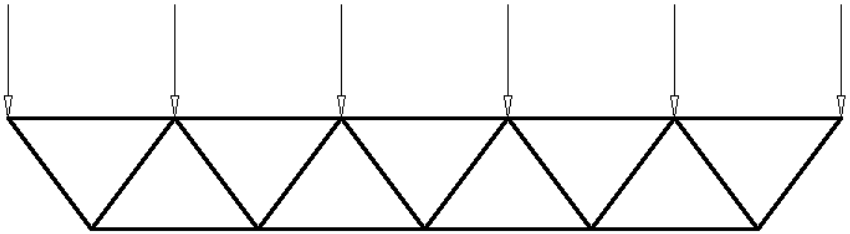


Photo: construdare.com

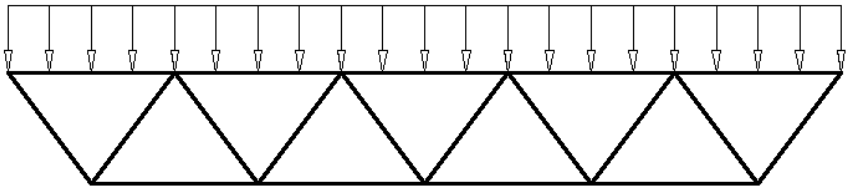
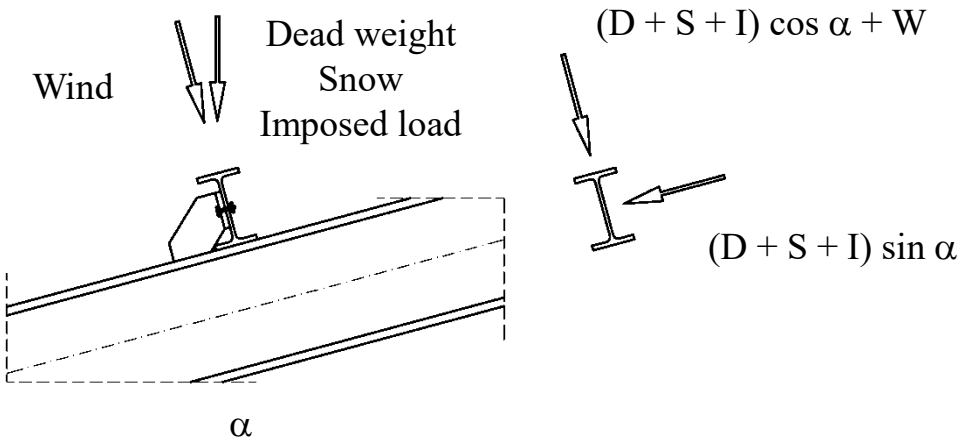


Photo: Author

Truss purlin - continuous load from roofing; there are axial forces in chords and cross-bars; in addition top chord is bending.



I-beam purlin: bi-axial bending.

Truss purlin: horizontal force

$$W \sin \alpha$$

has very small value and can be neglected (acts on roofing, not purlins). All loads act in plane of truss. There is need wedge to install truss purlin in vertical position.

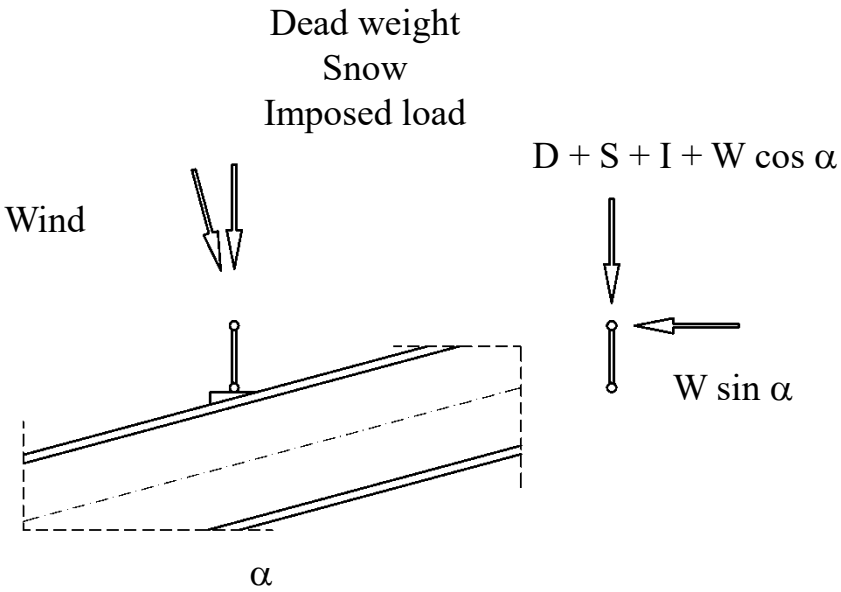


Photo: Author

Recommended types of purlins for different length of span (distance betwen supports):

Lenght [m]	Continous, cold-formed	Continous, suspended, cold formed	One-span, hot-rolled	One-span, castellated	One-span, truss
< 3					
3 – 4					
4 – 6					
6 – 8					
8 – 12					
12 – 18					
> 18	Special solutions: suspension roofs, spatial trusses (IInd step of study)				

Support for purlins

Photo: Author

Hot-rolled

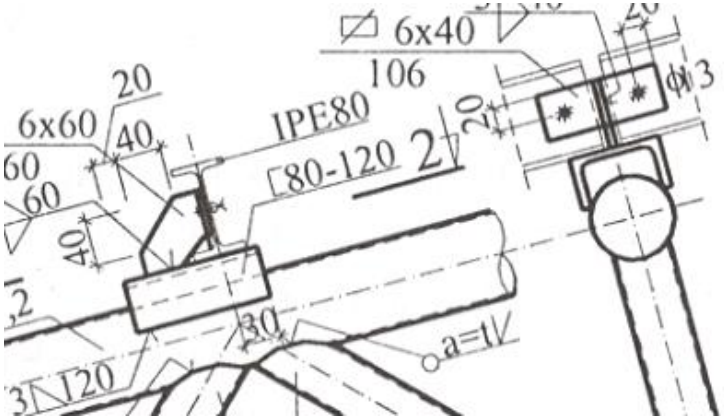
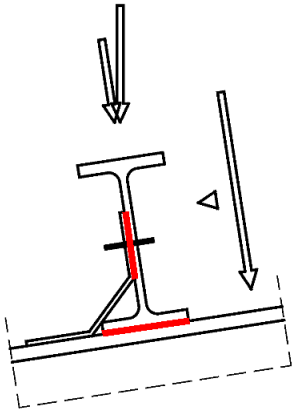
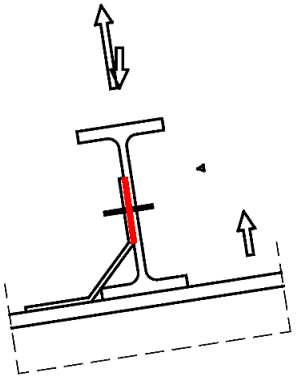


Photo: M. Gwóźdź, M. Maślak, Przykłady projektowania wybranych stalowych konstrukcji prętowych, Politechnika Krakowska 2003

Snow + dead-weight + wind pressure: by contact between bottom flange and girder; web and support plate





Wind suction bigger than dead-weight: by contact between web and support plate; shear of bolt

Photo: Author

Cold-formed purlins are fixed above top surface of girder, with a small gap. This avoids local deformation of purlins when pressed against girder. Cold-formed purlin is thin-walled section. Even small deformations could significantly change its cross-section and reduce bending resistance.

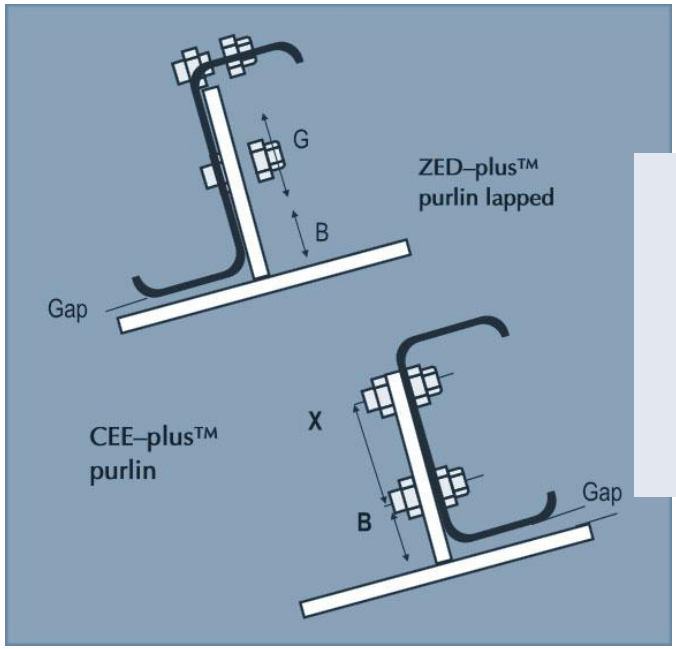


Photo: gscpl.net

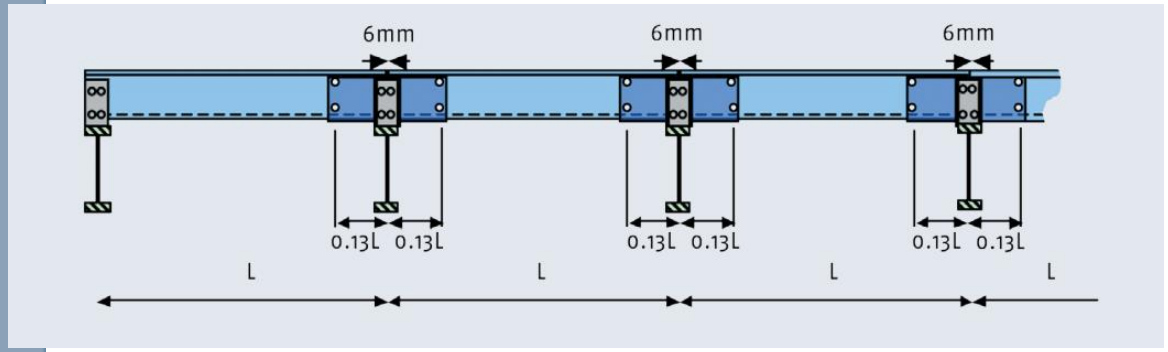


Photo: ruuki.com

Photo: steel.ie

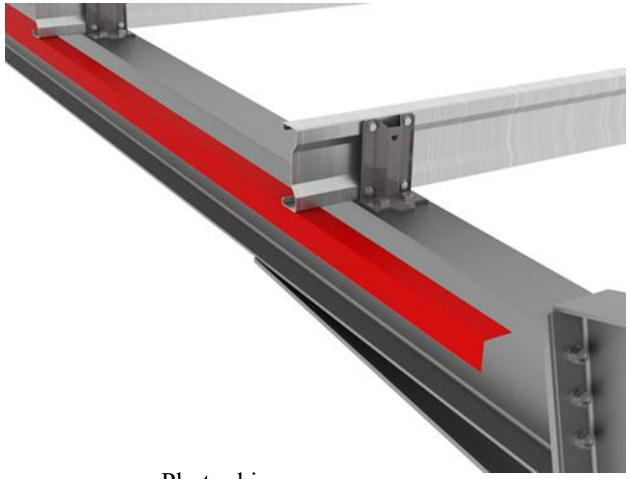
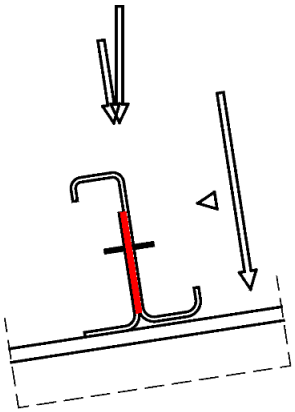


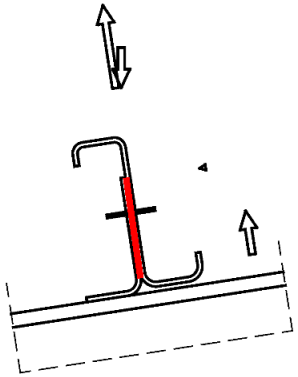
Photo: kingspan.com

Support for purlins

Cold-formed

Snow + dead-weight + wind pressure: by contact between bottom flange and girder; web and support plate





Wind suction bigger than dead-weight: by contact between web and support plate; shear of bolt

Photo: Author

Wall girts

Loads:

- Dead weight of housing
- Dead weight of girt
- Wind
- Imposed loads
- Thermal actions
- Accidental actions
- Actions durin execution

Photo: cobouw.pl

There is no snow load for girts; cross-sections of girts is much more lighter than for purlins.

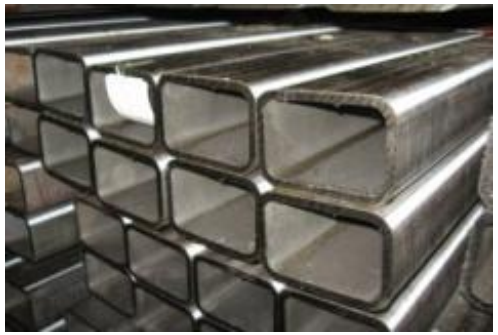
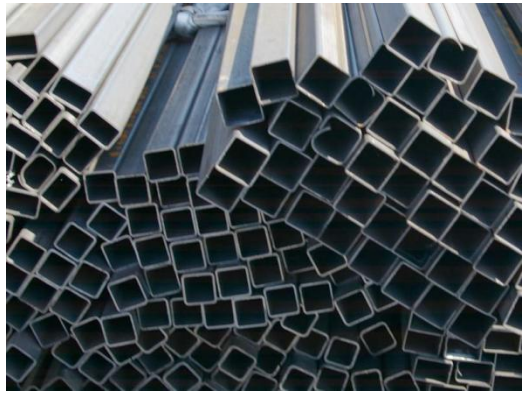
	Photo: newsteelconstruction.com	Photo: everfaithsteel.cn	Photo: calgor.com.pl
Horizontal elements			
Vertical elements (for example additional columns)			
	Photo: wggstal.pl	Photo: wistal.pl	

Photo: steelconstruction.info

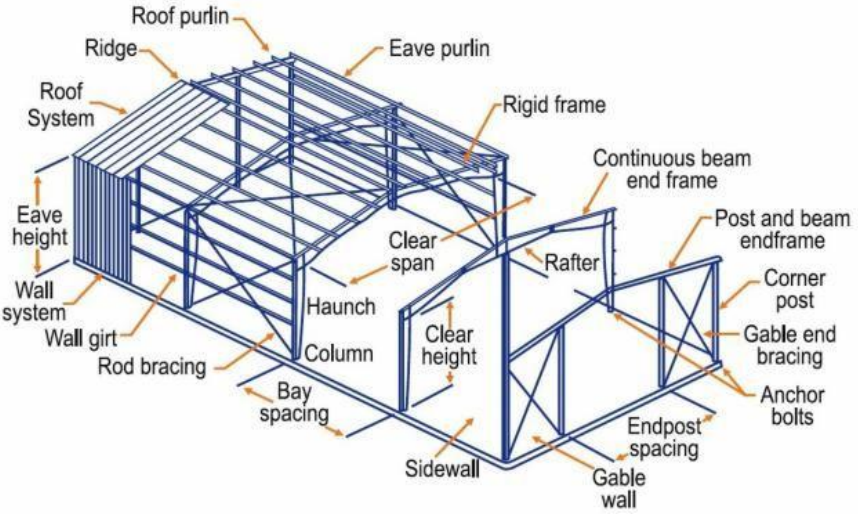
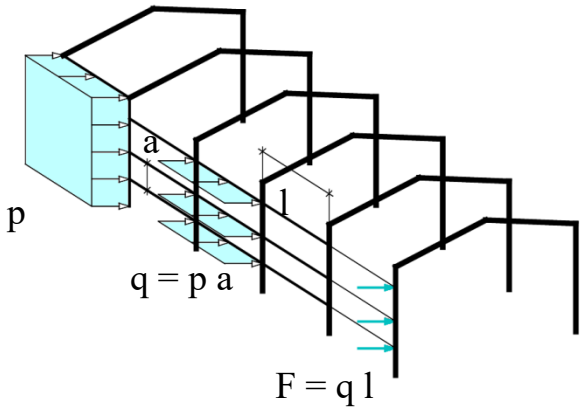


Photo: greenterrahomes.com

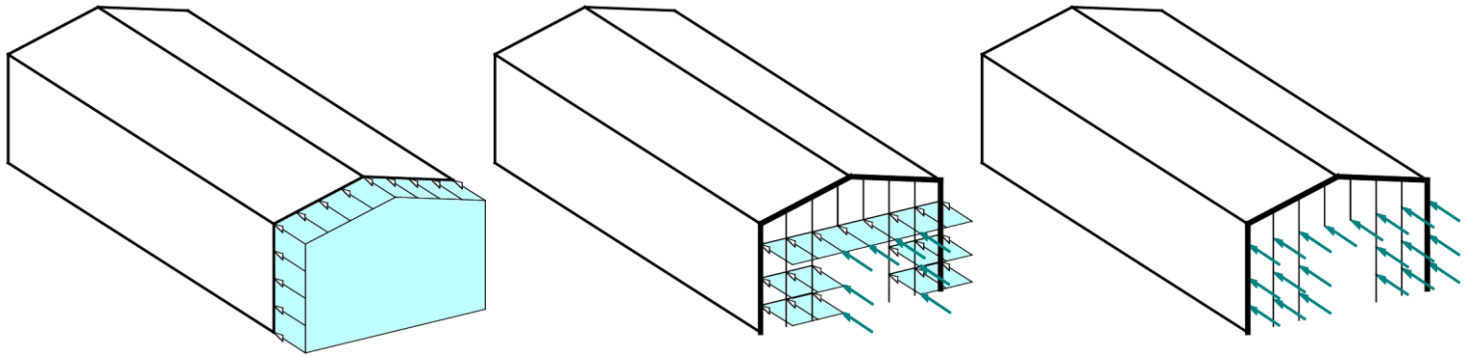
Wall girts, purlins, roof bracings and side wall bracings make specific system for wind action. Front wall housing columns must be connected with purlins and roof bracings at one point. The same, girts on front and side walls.

Photo: Author



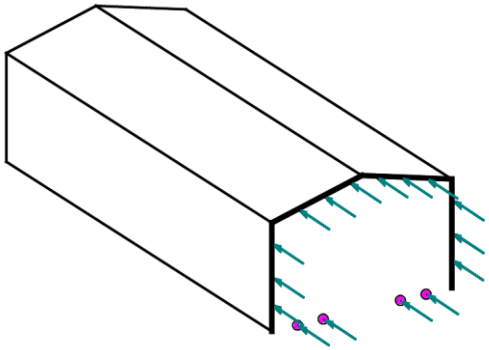
Wind acts on housing (p, [kN / m^2]). Housing is support on wall girts; loads from housing act on girts as continous loads (q, kN / m). Girts are under bending (mono- or bi-axial). Loads from girts act on main frames as forces, applied in points of connection girts - main columns.

Photo: Author



Wind acts on front wall: the same way of recalculation p → q → F. Forces are applied to main frames (perpendiculary to theirs plane) and to housing columns. In case of doors (in front / side wall), wind action from door is applied to girts and housing columns around doors.

Photo: Author



Loads from housing columns finally act on bases of housing column and main frames (main columns, roof girders), perpendiculary to theirs planes. It potentially makes bi-axial bending in main frames.

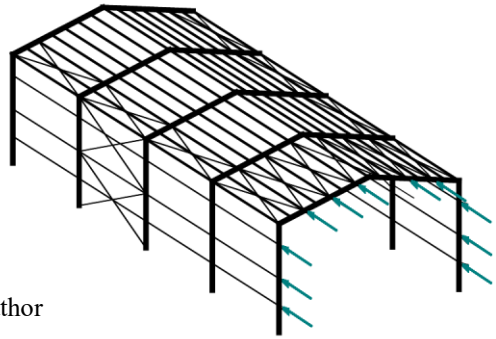
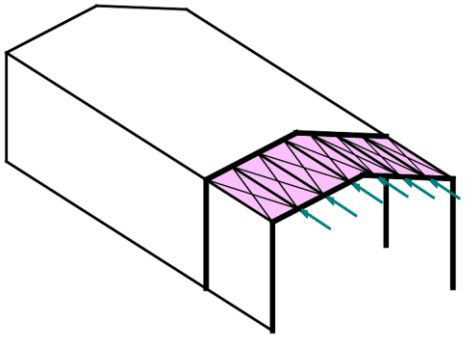


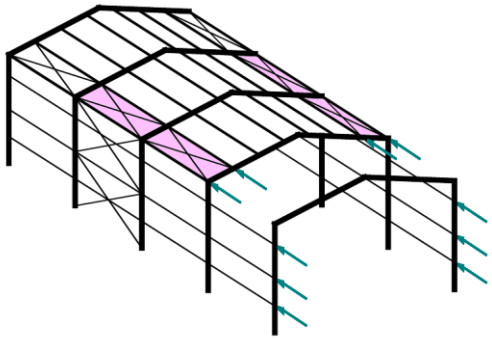
Photo: Author

Main frames are supported in perpendicular direction by bracings, purlins and side wall girts. It prevent from bi-axial bending.



Roof bracings and purlins make horizontal truss. Roof girders are chords of truss. The effect is, that loads perpendicular to main frames make additional axial forces in roof girders. Additionally, there are axial forces in purlins.

Photo: Author



Roof: loads are transported through longitudinal roof bracings.

Wall: loads are transported by side wall girts.

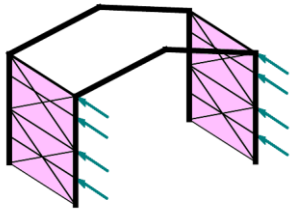


Photo: Author

Finally, loads act on vertical bracings on side walls: vertical trusses. Main columns are chords of truss.

Bracings - recommended cross-sections (→ Lec # 10)

Photo: calgor.com.pl

Photo: rafstal-inox.pl

Photo: rafstal-inox.pl

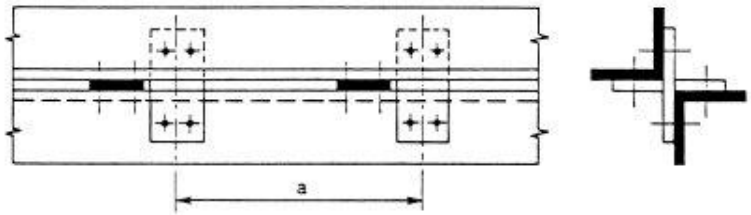


Photo: EN 1993-1-1 fig. 6.13

Photo: stalhart.pl

Modern trusses

(→ Lec # 9)

Chords : hot-rolled I-beams or pipes

Truss bracing: pipes

Each element at Ist or IInd classs of cross-section

Photo: wikipedia

Beams, girders and columns

(→ Lec # 11-13)

Photo: metroland.com.au

Photo: traskostal.pl

Hot rolled:

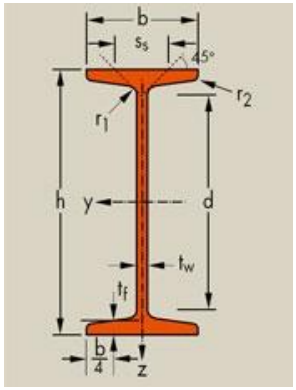
→ Lab #1 / 8

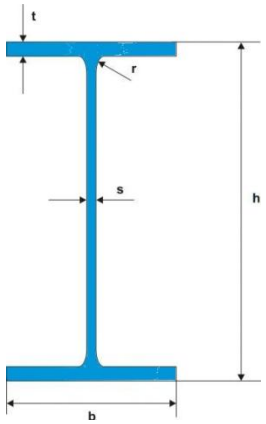
I H

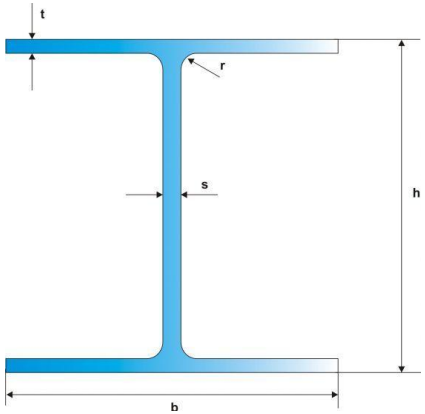
IP

HE

Photo: optimax.pl







IPN

IPE, IPE-A, IPE-AA IPE-O

HEB, HEA, HEAA, HEM

Photo: hmsteel.pl

Photo: hmsteel.pl

Proportion of cross-sections

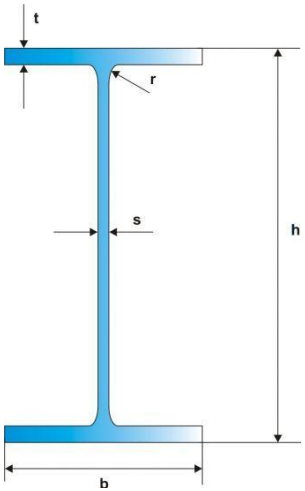
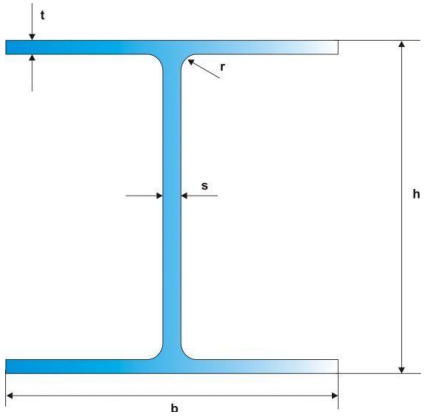


Photo: hmsteel.pl



Cross-sections	J_z / J_y	
	100 - 300	> 300
IP	~ 1 / 13	~ 1 / 13 - 1 / 30
HE	~ 1 / 3	~ 1 / 3 - 1 / 40

For which type of loads are recommended different types of cross-sections:

	IP	HE
N_{Ed}		👍
$M_{y, Ed}$	👍	
$M_{z, Ed}$	👎	
$M_{y, Ed} + M_{z, Ed}$	👍	👍
$N_{Ed} + M_{y, Ed}$	👍	👍
$N_{Ed} + M_{z, Ed}$	👎	👍
$N_{Ed} + M_{y, Ed} + M_{z, Ed}$		👍

Frames for steel halls

Photo: setrometalgroup.com

Photo: traskostal.pl

L < 25 - 30 m → hot rolled I-beam IP

L > 25 - 30 m → welded I-beam IK

Steel skeletons (3d frames)

Photo: metroland.com.au

Beams, girders → hot rolled IP, welded IK

Colums → hot rolled IP, HE, welded IK, HK

Joints

For joints important is their stifness (relationship M–ϕ)

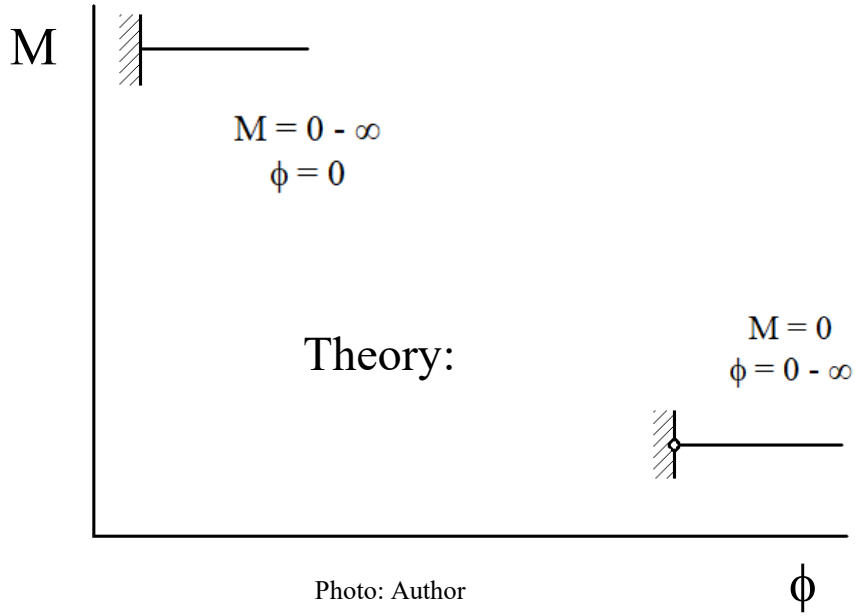


Photo: Author

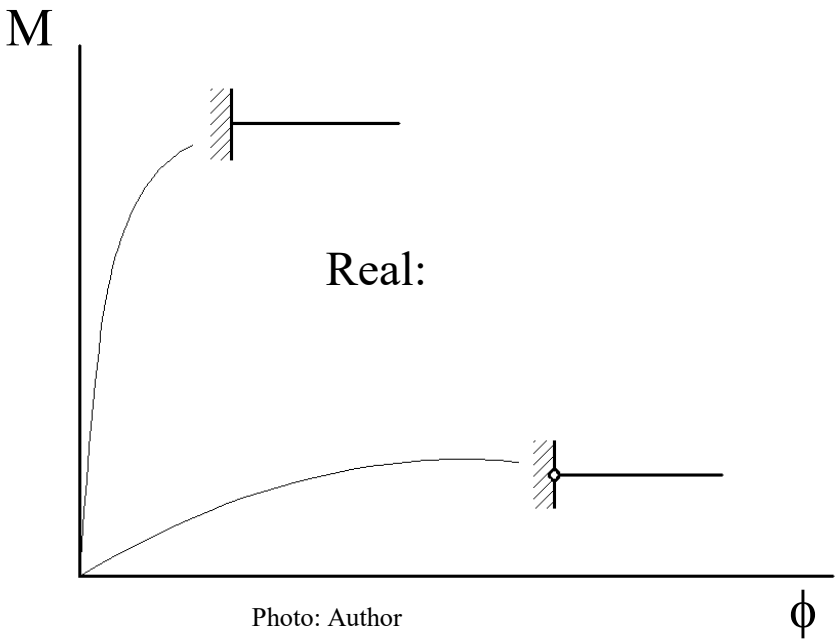


Photo: Author

Calculations (→ Lec # 14, 15):

What are limits 1-2 and 2-3?

What is stiffness of analysed joint?

What about comparison between limits and stiffness?

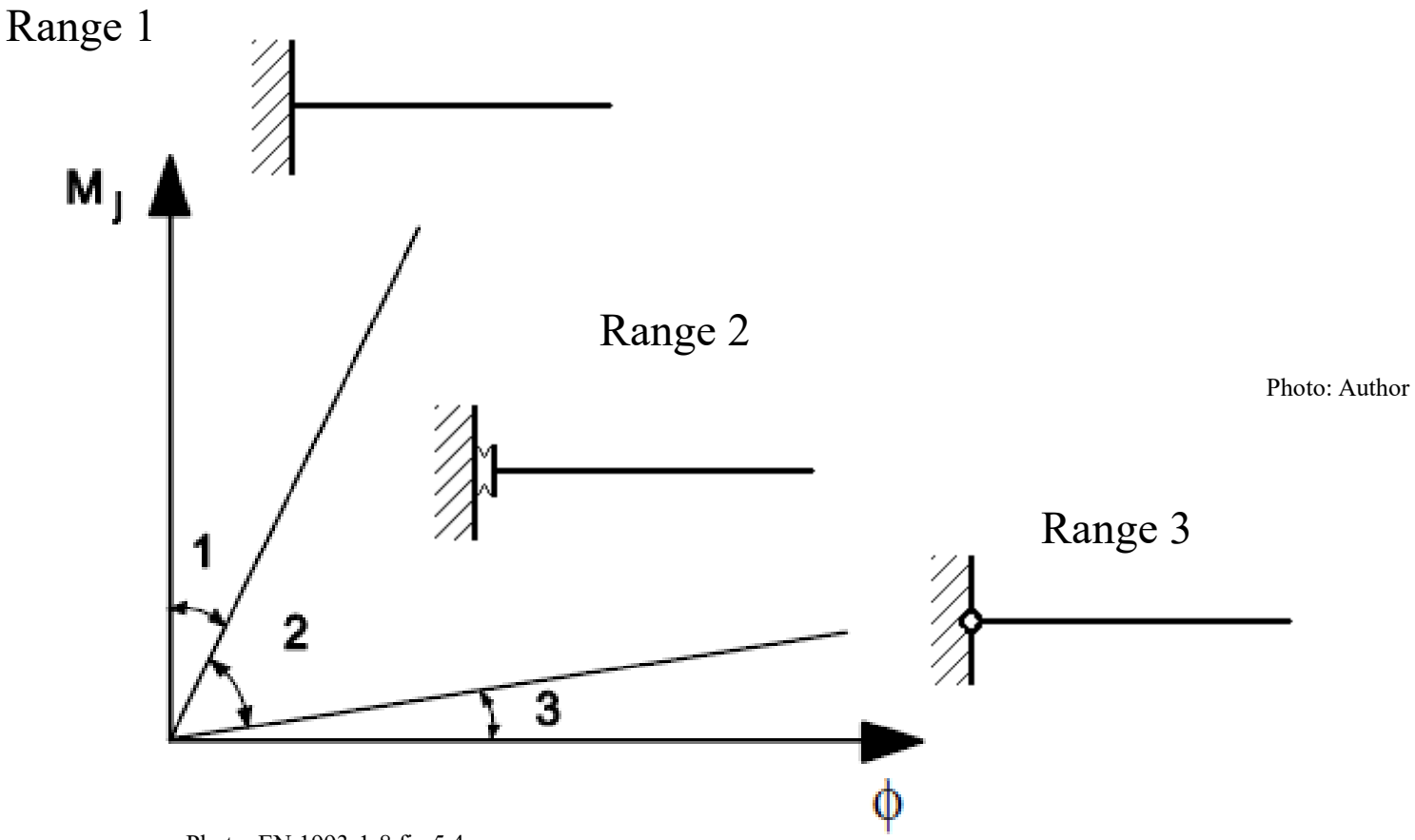


Photo: Author

Photo: EN 1993-1-8 fig 5.4

Quasi-welded joints (→ Lec # 16, 17)

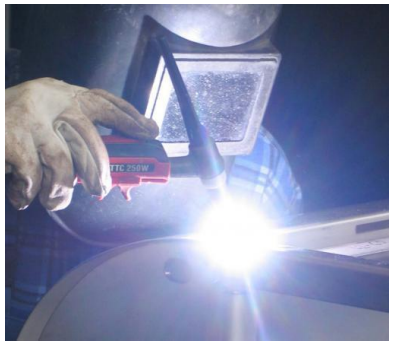
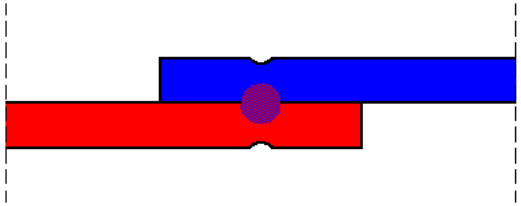


Photo: stelmet.net

Soldering - additional metal only



Pressure welding - fusion in few points only

Welding - fusion and additional metal

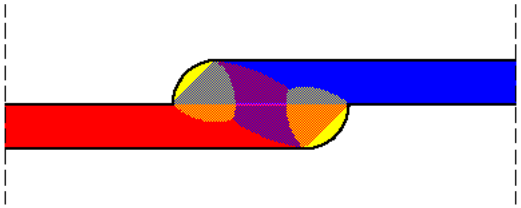
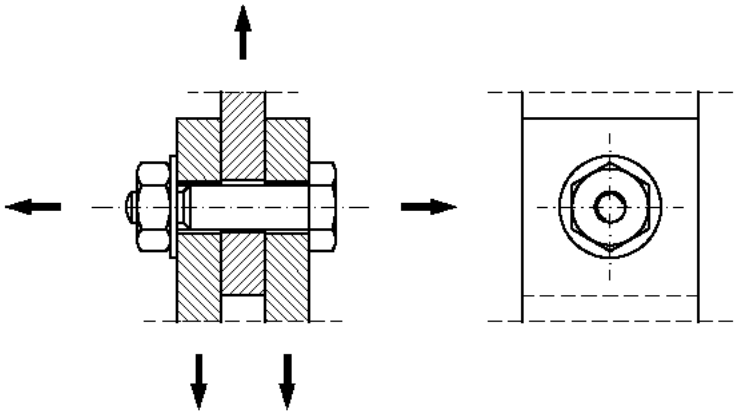


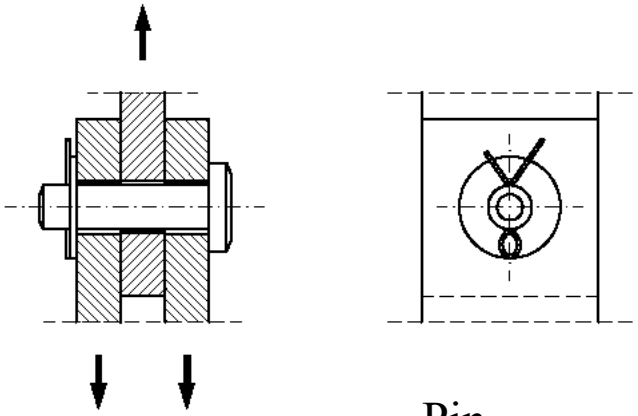
Photo: Author

Quasi-bolted joints (→ Lec # 18)

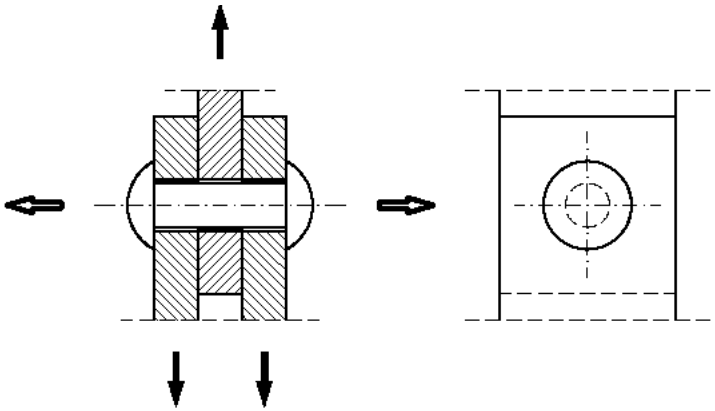
Photo: ventia.pl



Bolt



Pin



Rivet

Photo: Author

Negative and positive aspects

Aspect	Bolted joint	Welded joint	Page
Influence of weather	☺	☹	#t / 61
Susceptibility to worker's qualifications	☺	☹	#t / 62 – 63
Combination with other materials	☺	☹	#t / 64
Possibility to disassembly	☺	☹	#t / 65
Independence from the electricity	☺	☹	#t / 66
Destruction of corrosion protection	☺	☹	#t / 67
Influence on the mechanical properties of the material	☺	☹	#t / 68
Residual deformation and stress	☺	☹	#t / 69
Fire	☺	☹	#t / 70
Versatility of the relative position of plates	☹	☺	#t / 71 – 73
Uniformity of connection	☹	☺	#t / 74
Time of connection	☹	☺	#t / 75

Weather

Work quality for welded joints is much more important, than for bolted joints.

Photo: polskiekrajobrazy.pl

Photo: kobieta.onet.pl

Photo: pytamy.wp.pl

Photo: blog-medyczny.pl

Bad weather can significantly decreases ability of workers → and quality of welded joints. Bolted joints are not such susceptible.

Workers qualifications

Everybody can put bolts in holes and screw...

Photo: metalmeet.com

...but only a small part of people can make welds of high quality.

Photo: weldreality.com

Photo: weldreality.com

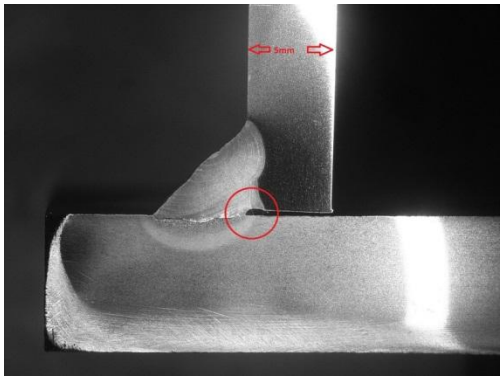


Photo: weldingtipsandtricks.com

Photo: bbs.homeshopmachinist.net

Other material

We can't weld steel to concrete. We can join them by bolts.

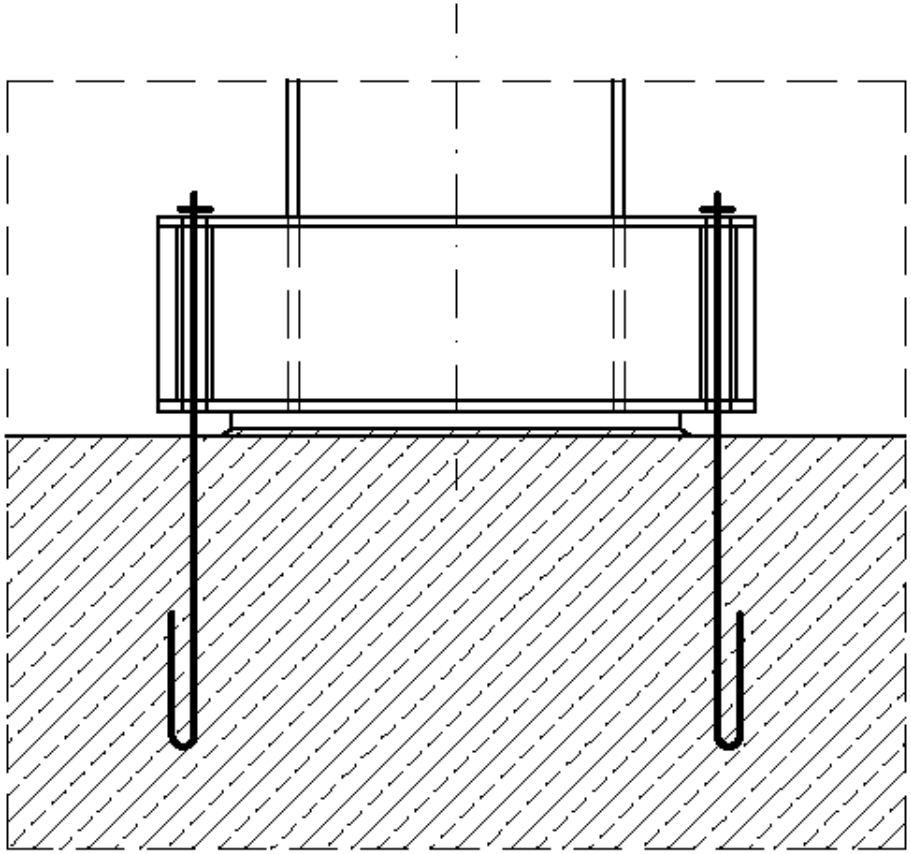


Photo: Author

Photo: civil-engg-world.blogspot.com

Disassembly

We can disassemble bolted joint without destruction - and use members once again in other place. There is possible only total destruction in case of welded joints.

Photo: panoramasilesia.pl

Photo: stockfresh.com

Electricity

We can't weld without energy. But we can screw bolts.

Photo: quora.com

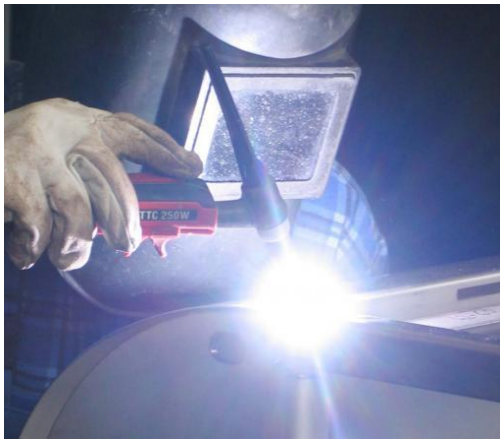


Photo: stelmet.net

Photo: narzedzia.pl

Corrosion protection

Protection is destructed by high temperature.

Photo: archinect.com

Photo: wikipedia

Influence on the mechanical properties

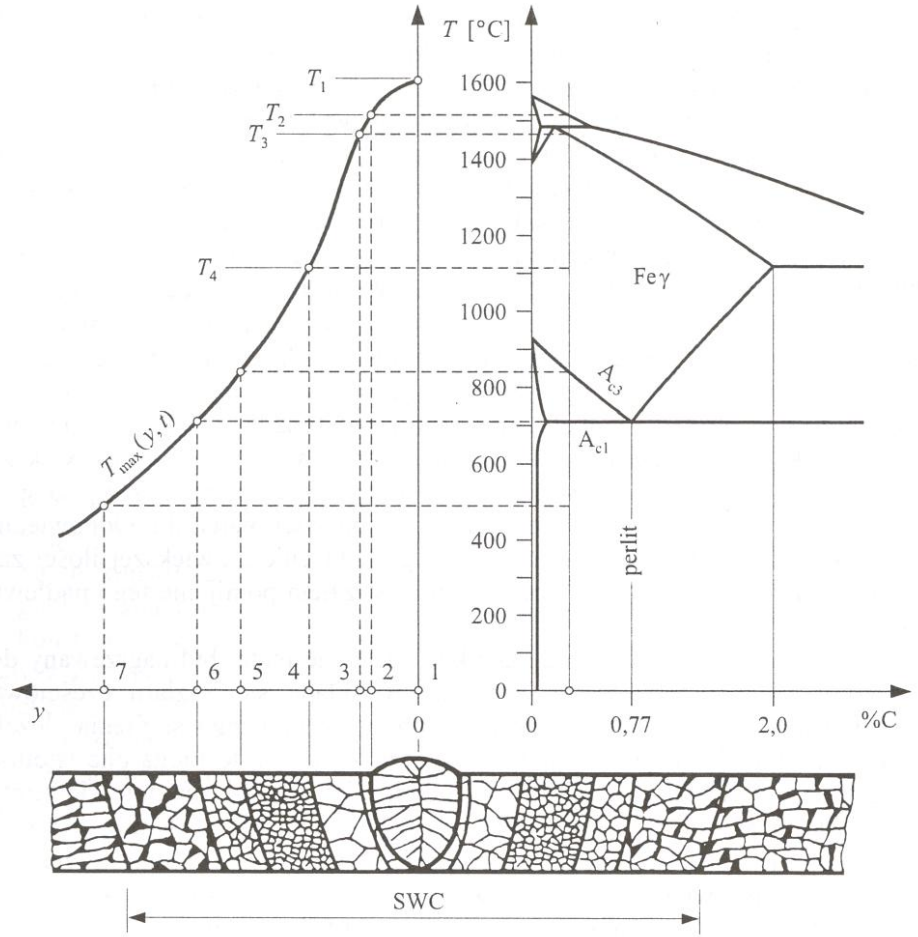


Photo: M. Łubiński, W. Żółtowski, Konstrukcje Metalowe t. II, Arkady, Warszawa 2004

Residual stresses and strains (→ Lec # 16)

Non-zero value of stress and strain appear after welding.

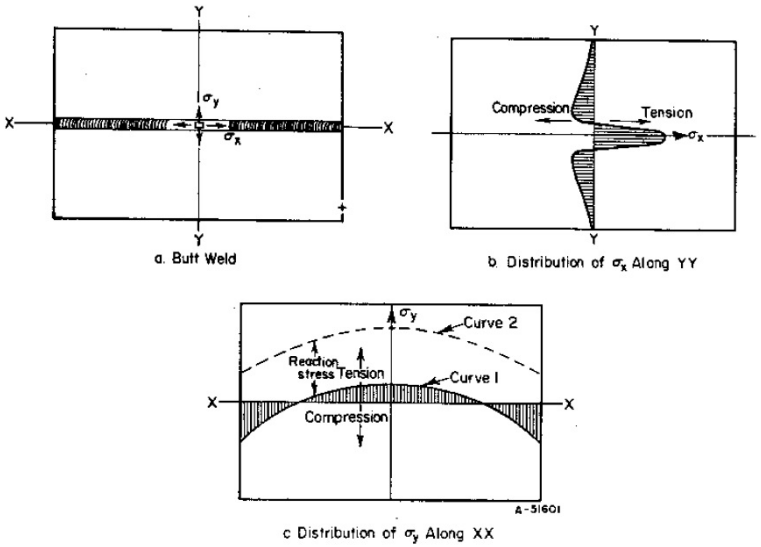


Photo: intechopen.com

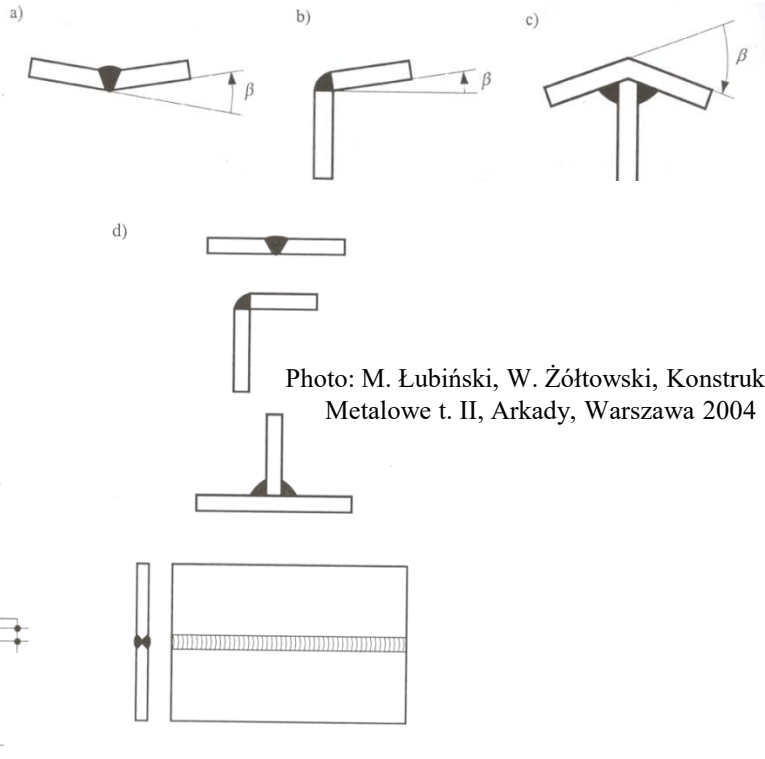


Photo: M. Łubiński, W. Żółtowski, Konstrukcje Metalowe t. II, Arkady, Warszawa 2004

Fire

Roofer or Welder Starts Fire at Notre Dame de Paris, Building Seems Intact, but Heavily Damages

Fires started during renovations of historic buildings can smolc breaking out.

Share Tweet 2 Comments

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Paris appears to have been completely unprepared for the fire of the historic building Notre Dame de Paris

Photo: smobserved.com

Oil tank ignites during welding

FEBRUARY 20, 2011 | BY **KNEWS** | FILED UNDER **NEWS**

Fire ignited by welders trying to dismantle a metal tank that contained remnants of lube oil caused fire to erupt inside the tank at the old GNIC wharf, Lombard and Sussex Streets, yesterday.

The welders were not injured in the process since they scampered from the tank immediately after the fire started.

Fire fighters were summoned to the scene after billows of black smoke filled the air as the oil burnt inside the tank.

At the scene fire fighters did the unpredictable and tried dousing the fire with water. This caused more destruction since the oil which would always float on top of the water overflowed out of the container causing the fire to spread outside the tank.

The fire fighters then used foam to quench the flames after realizing that using water was futile.

According to a fire official, they had to assess the magnitude of the fire before the used the foam.

One man said the tank which was very old was being dismantled to be sold as scrap iron since it served no purpose. The owner said that he was unaware that any lube oil was inside the tank at the time.

Photo: kaieteurnewsonline.com

Relative position of plates

~100 and more years ago, I-beams were constructed as plates connected by L-sections and rivets.

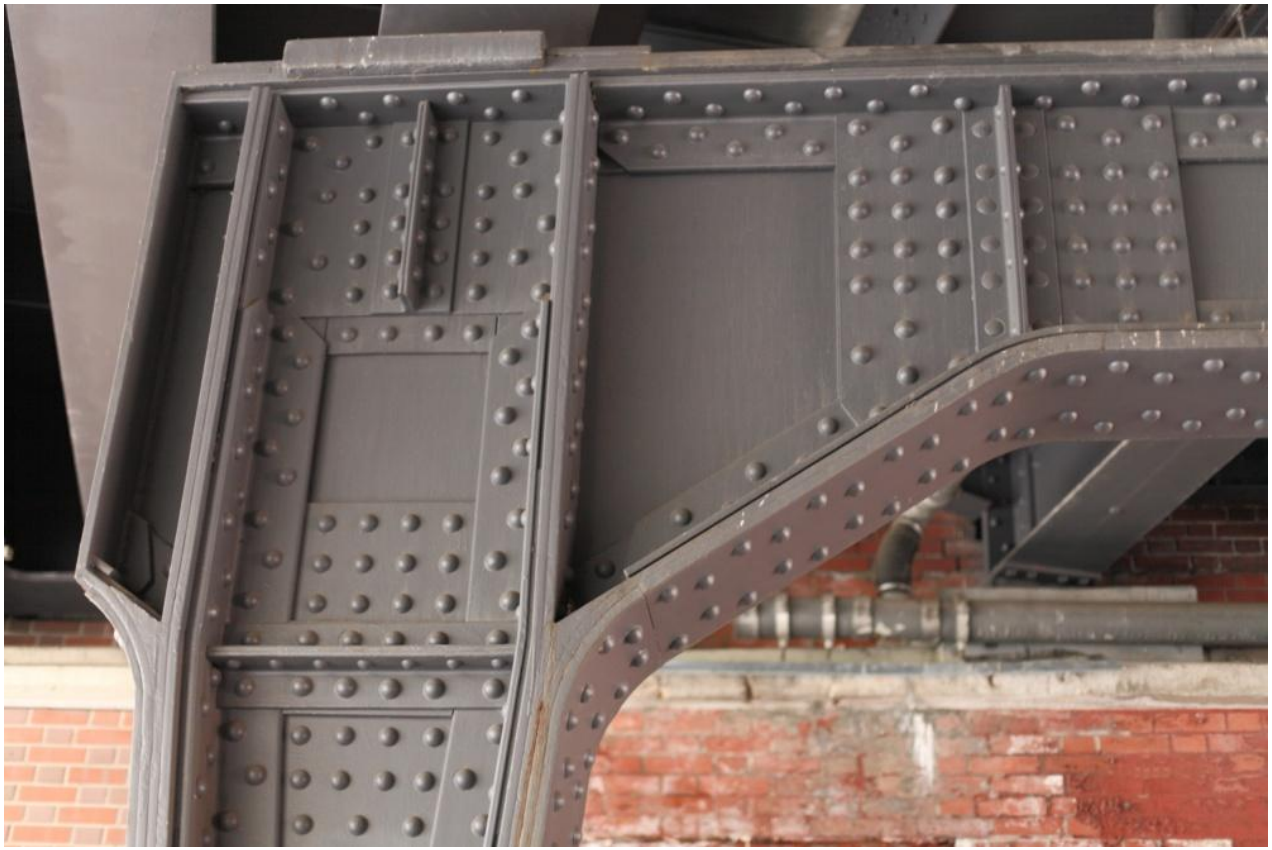


Photo: wikipedia

L-sections enable to joint elements by angle 90° only.
Flat bars enable to joint elements by angle 0° only.
CHS can't be conected.

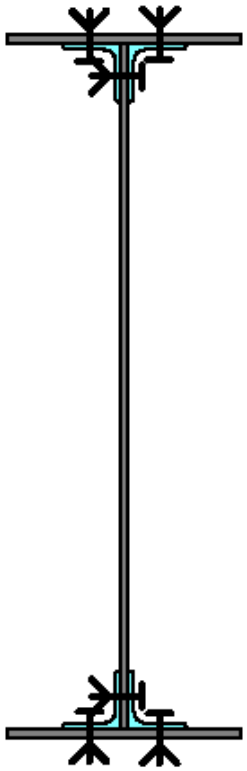


Photo: Author

Photo: fotoszoko.blox.pl

Photo: tuwroclaw.com

Because of welding, we can connect members by various angles. We can connected CHS, too.

Photo: whatsontheare.com

Photo: tboake.com

Photo: weiku.com

Photo: tatasteelconstruction.com

Uniformity

We can't notice borders between elements in well-done weld.

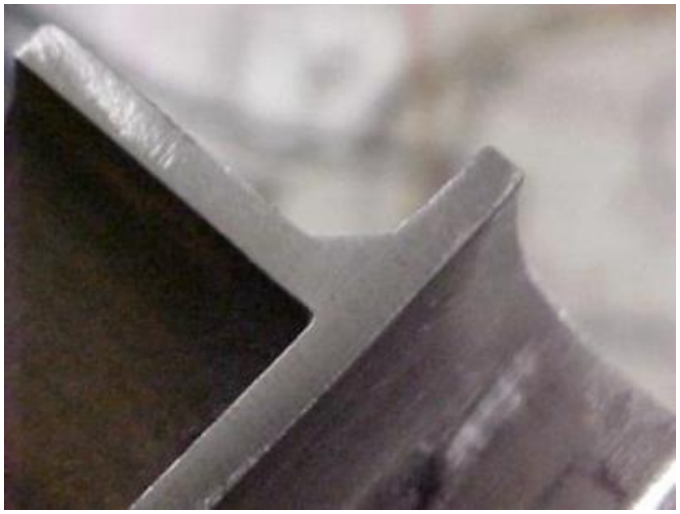


Photo: roadking.riders.pl

Photo: weldingtipsandtricks.com

Photo: bakertesting.com

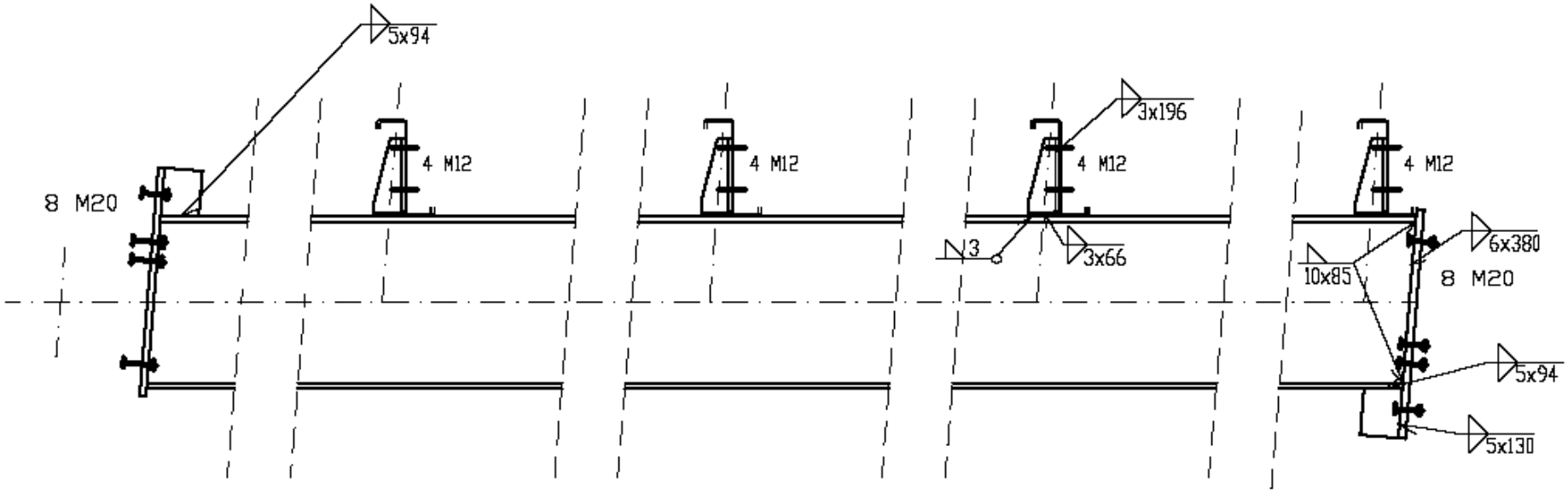
Time

Sometimes we need much more time to put and screw bolts than to make welds.

Photo: steelconstruction.info

From assemby room to construction site

Steel structures are made by members, welded in assembly room and connected on construction site by bolts.



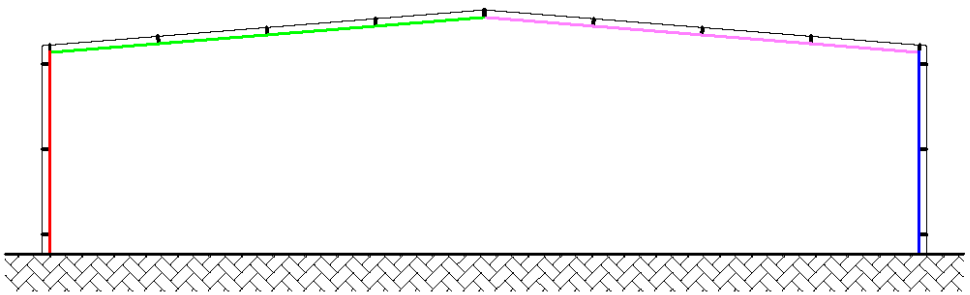


Photo: Author

Assembly room → welded joints	Construction site → bolted joints
no weather influence; specialized companies → high workers qualifications; possibility of accuracy reconstruction of corrosion protection; possibility of wide range of NDT of welds; possibility of annealing (reduction of welded stresses and strains); good fire protection;	no susceptibility on weather; everybody (even CEO) can connected members by bolts;

Structure will be transported in pieces from assembly room to construction site. This means, already at the design stage, designers must think about structure as about complex of transport members. There must be predicted and designed splice joints between transport members.

Photo: rolstal-hale.pl

Photo: nh-trans.eu

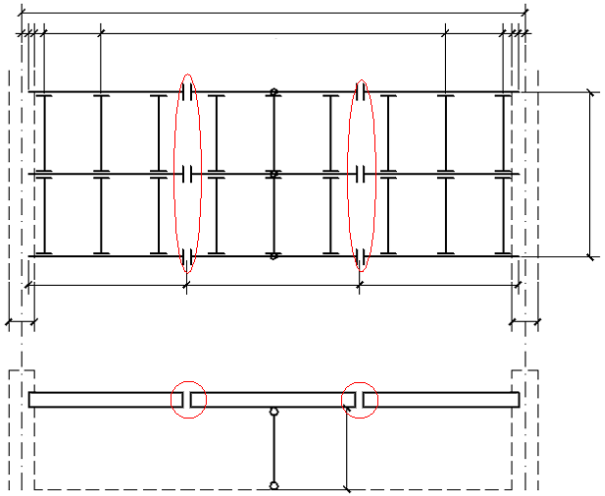


Photo: Author

Design project should be idiot-proof.

Photo: Author

There are two identical steel columns. Beam is attached only to one of them, but both have in the same place transverse stiffeners. It does not matter, if someone makes a mistake and turn columns places. Both will fit into the rest of the structure.
Members of structures should be unified.

Design documentation:

Initial drawing - first concept of structure, important for designer (for internal use only). Based on its, designer calculate loads, length of members and splice joints.

Overall drawing - official global drawing of structure. Important for workers on construction site. There are presented most important dimensions and names of members. Generally, can look the same as initial drawing.

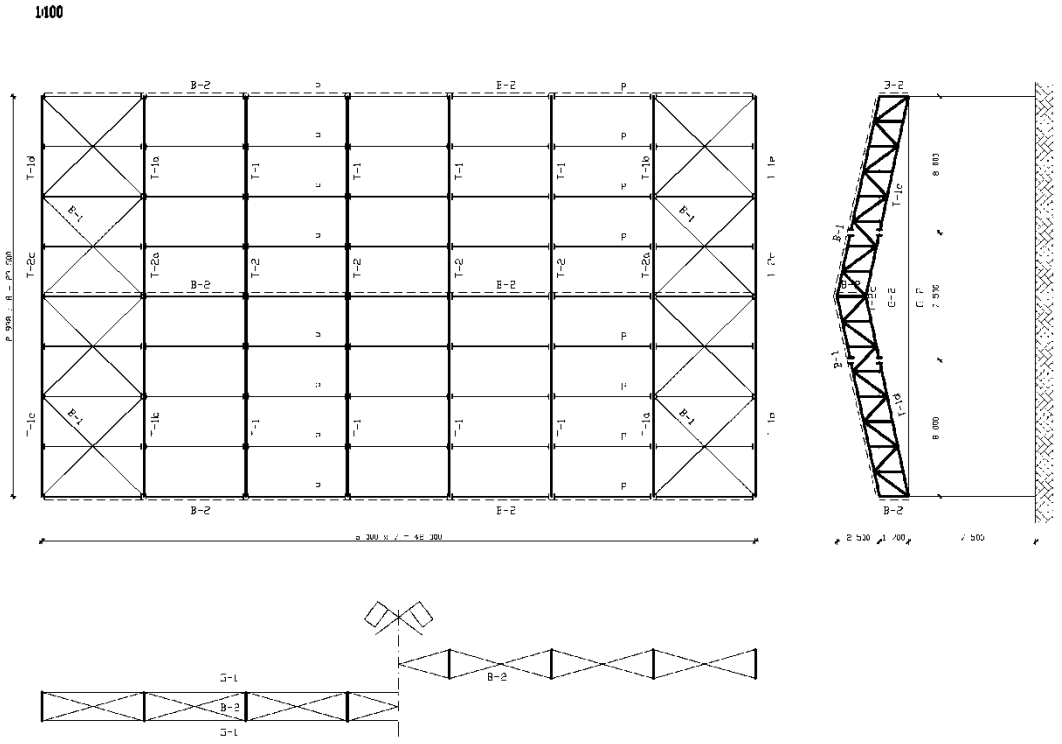
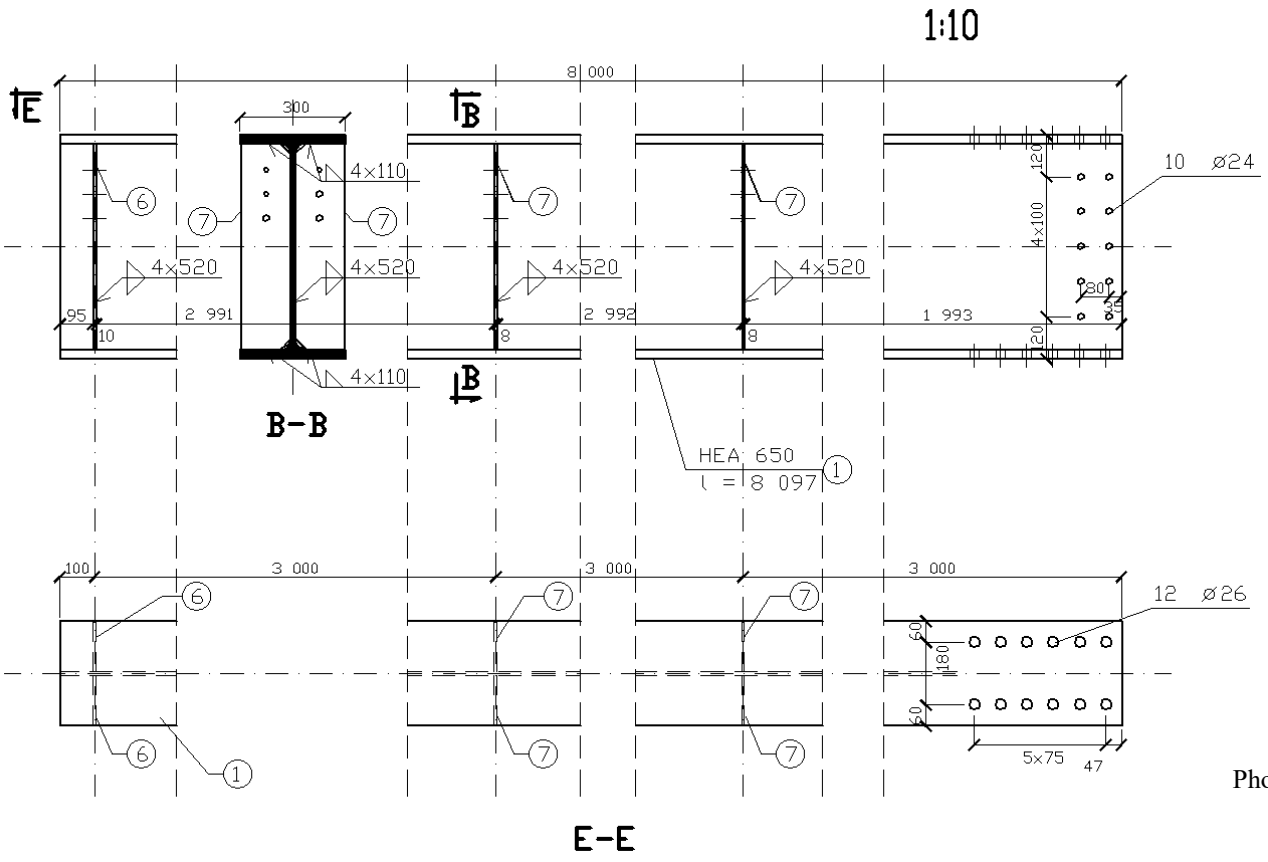


Photo: Author

Workshop drawing - drawing of transport member. Important for workers in assembly room (diameter of holes for bolts, type and length of welds, dimensions of components of transport member).

Assembly drawing - drawing of splice joints. Important for workers on construction site (type of bolts, type and length ow welds if there are welded splice joints).



For small structures, both imformation can be presented on one drawing.

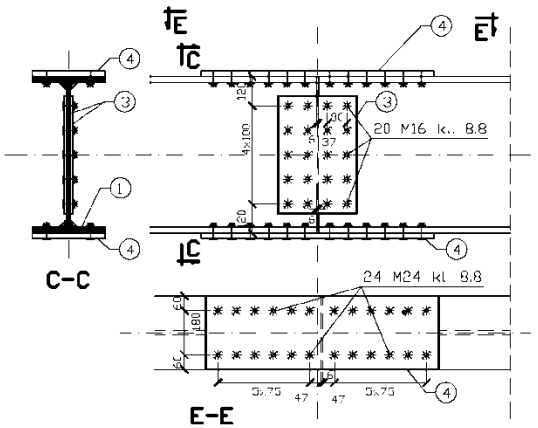


Photo: Author

MODULUS	SYMBOL OF ELEMENT	NAME OF ELEMENT	DIMENSIONS [mm]	UNIT MASS [kg / m2], [kg / m], [kg / 1000 pieces]	MASS OF ELEMENT [kg]	NUMBER OF ELEMENTS	MASS OF ELEMENTS [kg]	UNIT MASS [kg]	NUMBER OF UNITS [kg]	TOTAL MASS [kg]
Pa	1	HEA 650	8 097	190,00	1538,43	1	1538,43	1 697,69	6	10 186
	3	pl 8	320x480	64,00	9,83	2	19,66			
	4	pl 20	300x950	160,00	45,60	2	91,20			
	6	pl 8	140x588	64,00	5,27	2	10,54			
	7	pl 10	140x588	80,00	6,59	4	26,34			
	11	pl 40	120x300	320,00	11,52	1	11,52			
	M16	M16 cl 8.8	50	-	-	10	-			
	M24	M24 cl 8.8	70	-	-	12	-			
Pb	2	HEA 650	7 994	190,00	1518,86	1	1518,86	1 577,08	3	4 731
	5	pl 14	140x588	112,00	9,22	2	18,44			
	7	pl 10	140x588	80,00	6,59	4	26,34			
	8	pl 20	20x300	160,00	0,96	2	1,92			
	11	pl 40	120x300	320,00	11,52	1	11,52			
	M16	M16 cl 8.8	50	-	-	20	-			
	M24	M24 cl 8.8	70	-	-	24	-			
S	10	HEA 240	4 110	60,30	247,83	1	247,83	286,81	3	860
	12	pl 20	300x300	160,00	14,40	1	14,40			
	13	pl 30	320x320	240,00	24,58	1	24,58			
	M16	M16 cl 4.8	50	-	-	4	-			
	M20	M20 cl 4.8	420	-	-	2	-			
B	15	IPE 300	4 406	42,20	185,93	1	185,93	185,93	14	2 603
	M16	M16 cl 4.8	50	-	-	6	-			
								Sum		18 381
								2% for welds		368
Bolts	M16 cl 4.8	50 mm	107 kg / 1000 pcs					96 pieces		10
	M16 cl 8.8	50 mm	107 kg / 1000 pcs					120 pieces		13
	M20 cl 4.8	420 mm	1,06 kg / 1 pcs					6 pieces		6
	M24 cl 8.8	70 mm	347 kg / 1000 pcs					144 pieces		50
								TOTAL		**18 828**

Photo: Author

List of materials:

- Total mass of structure → cost of material;
- Mass of transport members (modulus) → cost of transport;
- Mass of welds, bolts and moduluses → labor cost.

Card of structure

Card of Structure (page 1/4)

Structure	steel truss girders			
Designer	Tomasz Michałowski			
Reliability of structure				
Consequence Class (EN 1990, EN 1993-4-1, EN 1993-4-2)		CC1	CC2	CC3
Reliability Class (EN 1990, EN 1993-3-2)		RC1	RC2	RC3
Design Supervision Level (EN 1990)		DSL1	DSL2	DSl3
Inspection Level (EN 1990)		IL1	IL2	IL3
Action Assessment Class (EN 1991-4)	Not applicable	AAC1	AAC2	AAC3

Photo: Author

Complex of the most important information of information on system safety assurance at the design and assembly stage (values of the safety factors, accuracy of supervision, quality levels of the welds and imperfections: CC, RC, DSL, IL, SC, PC, EXC, IC), bolted joints (category, klass and grade), corrosion protection and fire protection.

Trial erection in assemby room before transport to construction site: check geometry.

Photo: steelkonstruction.info

Errors or mistakes are repaired after this step.

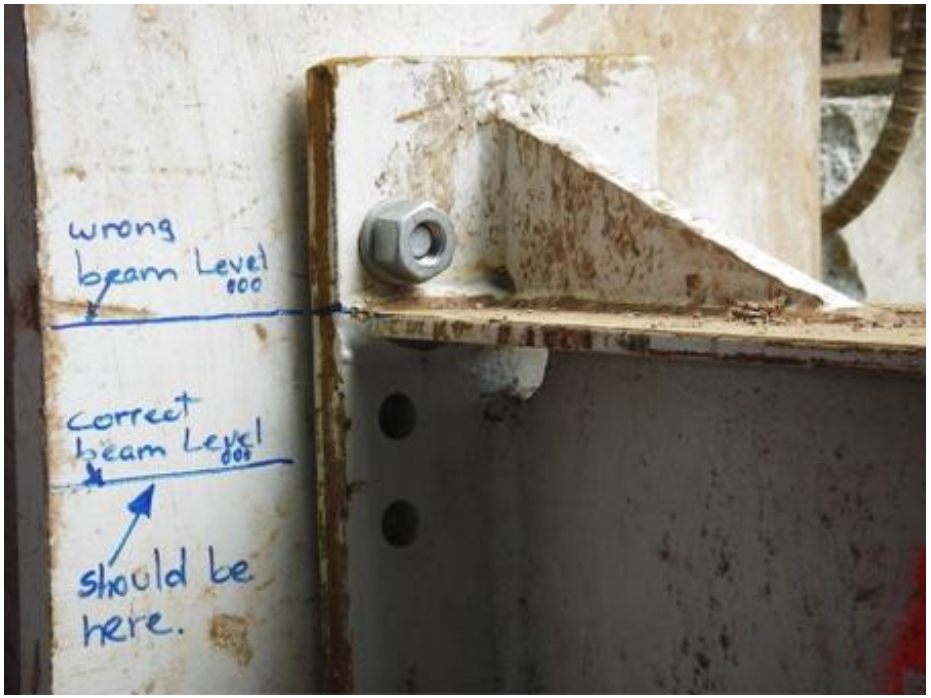


Photo: panama.uela.it

Transport:

- by road
- by rail
- by ship
- by helicopter
- on foot

Photo: rolstal-hale.pl

Photo: flickriver.com

Photo: nh-trans.eu

Photo: lotnictwo.net

Photo: inbud.pl

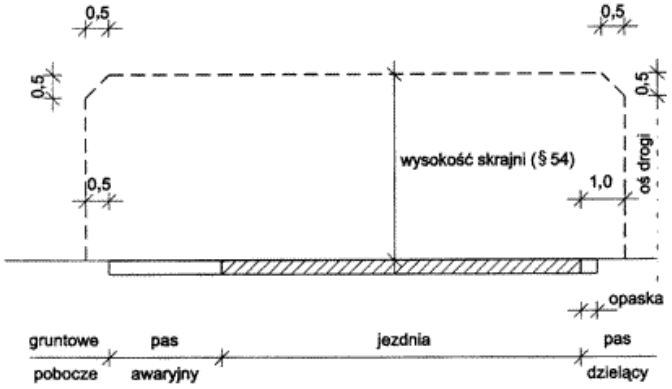
Photo: petronor.eus

We can transport even enormous huge structures, but it is very, very expensive (closing road for normal traffic, organisation bypass, monitoring of transport). Because of this, better way is transport not very big members of structure.

There are three types of limits according to loading gauge:

- max width of member;
- max length of member;
- max mass of member;

Max with of member depends on class of road or railroad:



[1] Wymiary podano w metrach.

Photo: drogi.com

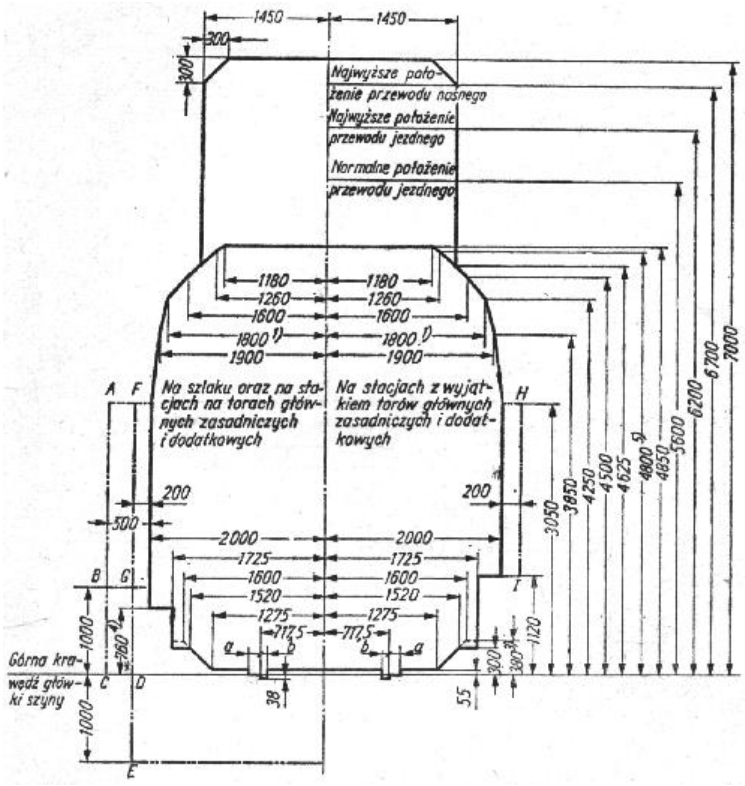


Photo: kolej.krb.com.pl

Max length for rail and road is defined by few law rules.

Max mass depends, first of all, on capacity of truck or rail platform.

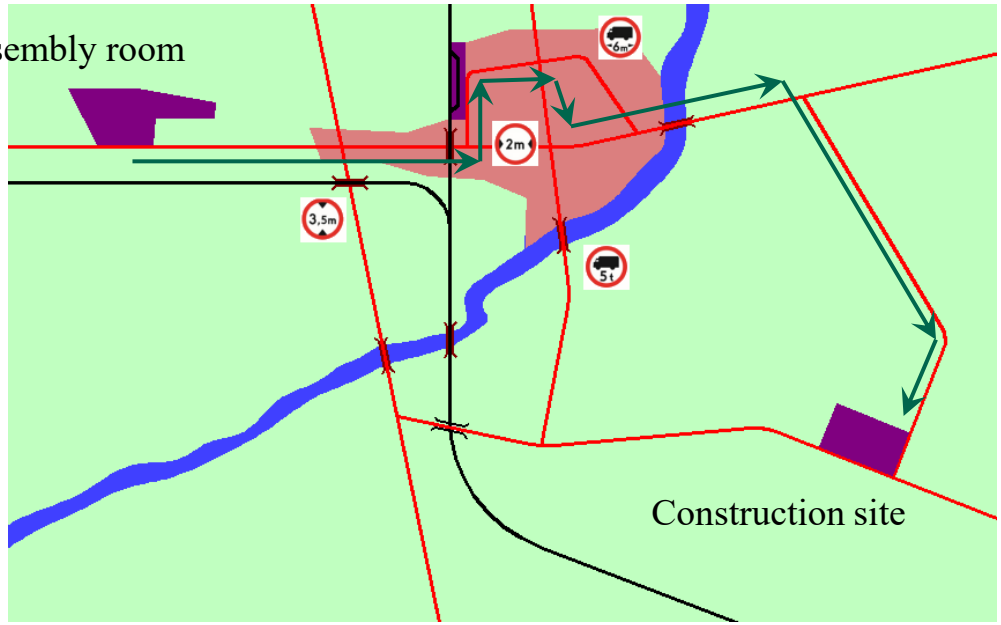
Photo: sklepdrogowy.pl

Transport by rail is more popular than transpotr by ship, air or on foot. But, because only a part of assemby rooms and construction sites are next to railroad, the most popular is tranport by cars.

Additionally, there are important many local limits.

Photo: profinfo.pl

Photo: Author



According Road Traffic Law, we no need additional permissions, when each total dimensions (structure + vehicle) are not exceeded:

- width ≤ 3,20 m;
- length ≤ 15,0 m (**total length** of one vehicle) or ≤ 23,0 m (team of two vehicles) ;
- height ≤ 4,0 m;
- axe load ≤ 11,5 t;

Generally, there's no problem, when transport membes is no longer than 12,0 m in road transport and 18,0 in rail transport.

Photo: leosped.eu

Initial assumptions about geometry:

→ Des #1 / 13

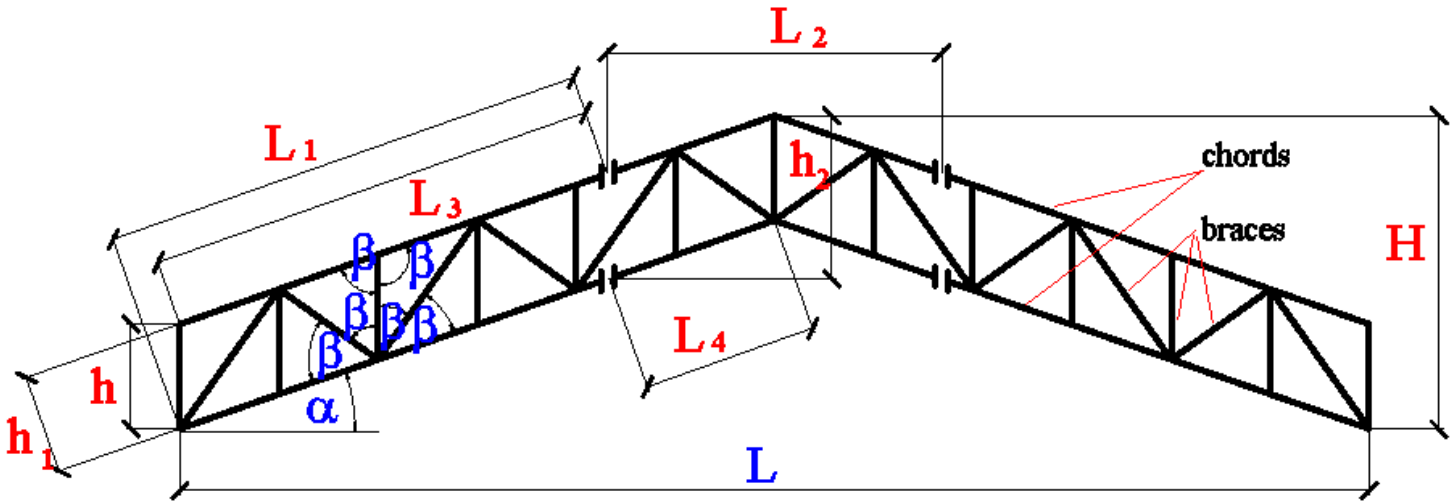


Photo: Author

$h = L\ (1/10 \sim 1/15)$

$H = L\ (1/5 \sim 1/10)$

$\alpha \geq 5^o$

$30^o \geq \beta \geq 60^o$ or $\beta \approx 90^o$

$\max (h_1; h_2) \leq 3{,}20$ m

$\max (L_1; L_2; L_3; L_4) \leq 12{,}00$ m (road transport)

Construction site: there must be analyse, how many cranes and what kind we need to erected structure. Two most important information about crane are length of arm and lifting capcity.

Photo: willbros.com

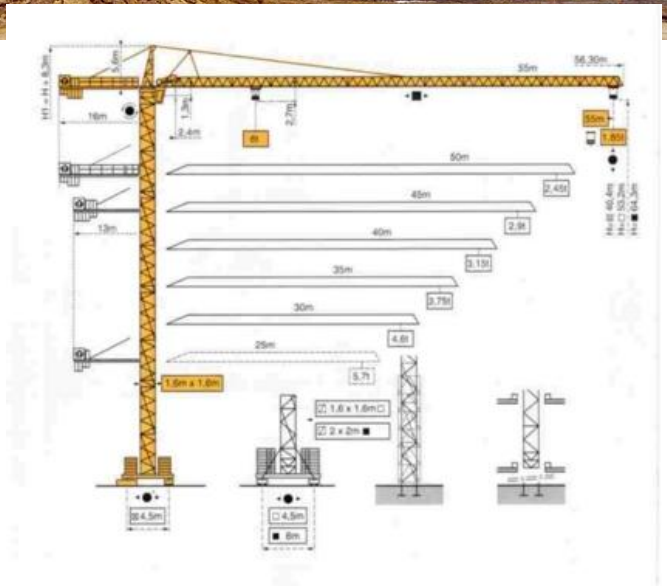


Photo: najem-wynajem.pl

Photo: focus.pl

Assembly anchoring of steel column: stabilization and plumbing on bolts or steel wedges and plates.

Photo: studio-tm.com

Photo: elcosh.org

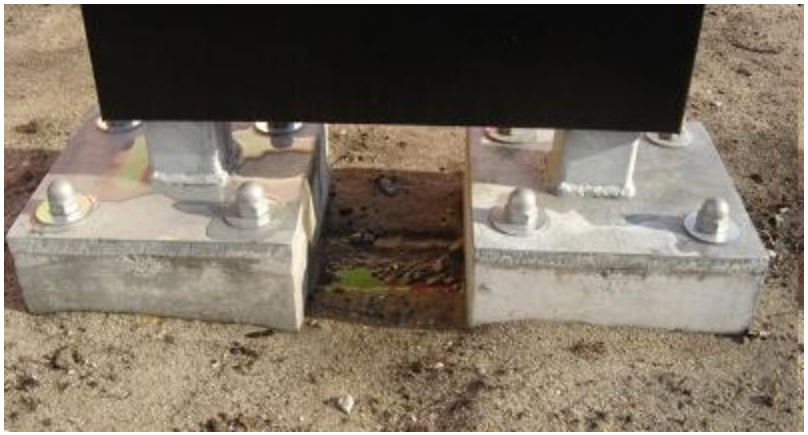


Photo: inzynierbudownictwa.pl

Then the gap between structure and concrete base is primed by mortar.

Assembly of structure – first step: mounting the first and the second segment with the temporary supports.

Photo: spaceevanston.blogspot.com

Photo: srt251clji.blogspot.com

Second step: two adjacent frames (first and second segments) connected by bracings form of a rigid body, to which are being added to next frames.

Photo: makosz.com.pl

Last step: hall is enclosed by roofing and housing.

Photo: aecom.com

There is possible of change static scheme during execution of structure.

Photo: eaglecrane.ca

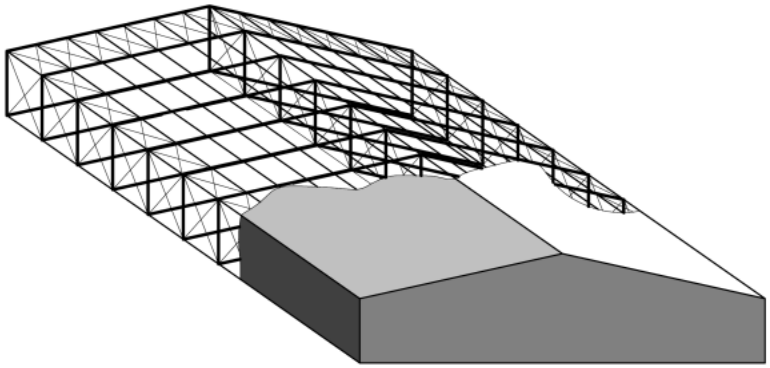
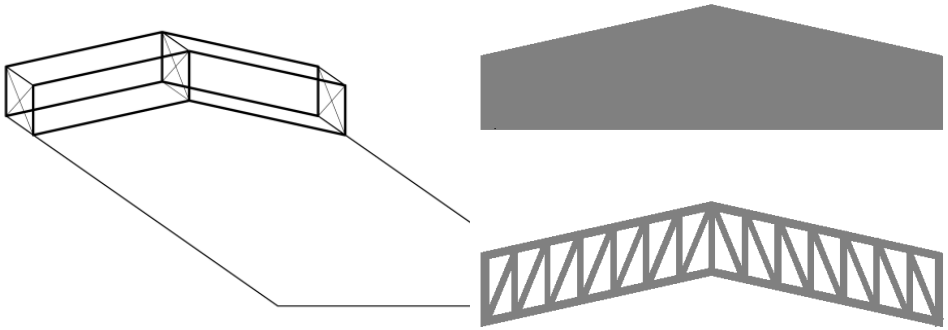


Photo: Author



For example: vertical longitudinal bracings work for wind load in execution stage. Final area of wind action (covered structure) and temporary - not covered truss - there are two completely different areas.

Photo: helpstud2.narod.ru

The element is often not protected against instability during lifting by crane. Clumsy transport can lead to flexural, torsional and lateral buckling.

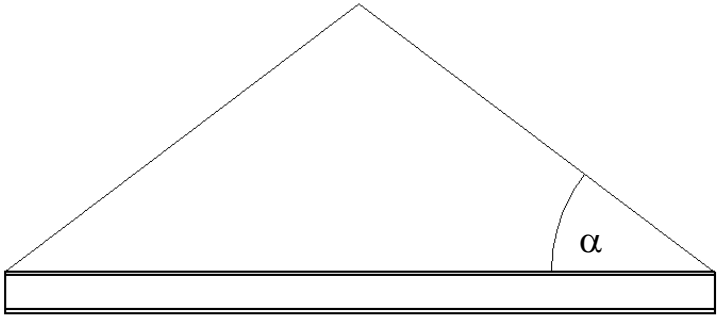
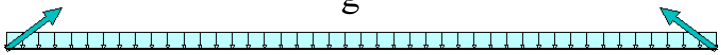


Photo: wisegeek.com

$R = g\,L / (2 \sin \alpha)$ $\qquad$ $R = g\,L / (2 \sin \alpha)$



$M_{max} = g\,L^2 / 8$

$N_c = (g\,L \cos \alpha) / (2 \sin \alpha)$

Photo: Author

Examination issues

Types of purlins

Spatial cooperation front wall columns – roof bracings – purlins

Negative and positive aspects of bolted and welded joints

Transport members, ways of transport and their limitations for transport

Problems of assembly of steel structures

Pilings - palowanie, grodze
Roofing - poktycie dachu
Housing - obudowa ścian
Wall laminboard / sandwich panel - panel obudowy ściennej
Self-tapping screw - wkręty samogwintujące
Purlin - płatew
Rigging screw - śruba rzymska
Girt - rygiel obudowy
Castellated beam - belka ażurowa
Closely spaced build-up members - pręt wielogałęziowy
Frame - rama
Girder - dźwigar
Pinned joint - węzeł przegubowy
Rigid joint - węzeł sztywny
Semi-rigid joint - węzeł podatny
Welding - spawanie
Pressure welding - zgrzewanie
Soldering - lutowanie
Bolt - śruba
Rivet - nit
Pin - sworzeń
Anchor bolt - kotew
Plumbing - wypionowanie
Mortar - zaprawa

Thank you for attention

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