COMPARATIVE ANALYSIS OF MA IN BEAMSMADE OF STEEL WITH DIFFERENT SPANS

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Abstract.

Purpose: This study aims to perform a comparative analysis of steel beam, providing a comparative parametric analysis of six different types of structural solutions for the main steel beam: I-section, H-section, □-section (rectangular), ○-section (tube), variable-height beams (trapezoidal beams) and constant-height beams (parallel-strip beams).
Method: The analysis covers ten spans, ranging from 8 m to 44 m, with a distance between main supports of l = 4 m. Five roof slope angle variants (0°, 5°, 10°, 15°, and 20°), two boundary conditions (free support and fixed support), and two cases of distributed vertical loads (g = 6 kN/m² and g = 12 kN/m²) are considered. All models were built and analyzed in the Tower 8 software (Radimpex), using S235 steel.
For each combination of slope angle (5 values) and span between main supports (10 values), beam models are constructed in Tower 8 (Radimpex). In each model, six different types of structural solutions are applied sequentially. Each beam is analyzed for both boundary conditions and both vertical load cases.
Results: For each combination, normal stresses and relative deformations were calculated and compared, taking the I-profile as a reference, so the results could be directly compared despite variations in span and slope. Normal stresses (σ) and relative deformations (δ) were calculated for each combination, with the values being compared using the I-profile as a reference (σ_n = 1.000 for the I-profile in every combination of span × slope).
Numerical analysis results are presented organized by slope angle (0°, 5°, 10°, 15°, and 20°). For each slope, two tables are given: one for free support and one for fixed support-embedding, both for the light load case. The results for the heavy load case are discussed in the paper and are almost identical in relative values. The value of 1.000 corresponds to the I-profile (the reference); values < 1 indicate better performance, while values > 1 indicate poorer performance.
Conclusions: The conclusions identify which type of structural solution is most efficient for each span and slope range, providing a quantitative basis for the selection of main beams during the design phase.
1. The I-beam is the most efficient of the four solid beams in almost all combinations.
2. The H-beam is 2-50% less efficient than the I-beam in terms of deflections for spans between 8 and 28 m, but achieves almost equal performance (±6%) for spans of 32-44 m at all slopes.
3. Hollow beams (□ and ○) are 7-94% less efficient than the I-beam, with a clear trend of performance deterioration as the span increases.
4. The beam with constant height produces 25-67% lower deflections and 33-93% lower deformations than the I-beam, provided that L ≥ 12 m.
5. Trapezoidal beam (variable height beam) depends strongly on the slope: it is inefficient at 10° (+40–118%), becomes almost comparable at 15° and outperforms the I-profile for L ≥ 36 m at a slope of 20°.
None of the profiles are efficient for very short spans (L = 8 m), where full profiles are more efficient.

Keywords: Steel beam, cross section, truss, comparative analysis, Tower 8, S235, static space, roof slope.

Introduction

1.1 Motivation: Structural steel represents one of the principal materials for spanning large distances in industrial buildings, warehouses, sports halls, and agricultural facilities. The selection of the cross-sectional type of the primary load-bearing member plays a decisive role in determining material consumption, structural self-weight, and, consequently, the overall cost of the structure.

In typical roof systems, the main load-bearing element is realized as either an open-section steel beam, a closed-section member, or—particularly for large spans—a truss system. The choice among these structural alternatives, as well as among the various cross-sectional configurations within each category, has a direct impact on both structural efficiency and economic performance.
The static response of a beam subjected to vertical loading is governed by several geometric and structural parameters, including the span length, the inclination of the member, the boundary support conditions (simply supported or fixed), and the cross-sectional geometry. The latter defines key mechanical properties such as the second moment of area, section modulus, and linear weight.
Different profile families exhibit distinct structural behaviors. Hot-rolled open sections (I and H profiles) provide high flexural stiffness about the □□□□□□ axis with relatively low self-weight. Hollow structural sections (rectangular and circular tubes) offer more uniform stiffness in orthogonal directions, enhanced torsional resistance, and favorable architectural appearance. Truss systems, composed of discrete members connected at joints, enable efficient coverage of large spans by exploiting structural depth to improve moment resistance with reduced material usage.
Within truss systems, two principal configurations are commonly distinguished: trusses with constant depth (parallel-chord trusses) and trusses with variable depth. While existing literature provides extensive treatment of individual profile types, there is a lack of systematic and parametric comparative studies that clearly identify the most efficient structural solution for given combinations of span and roof inclination

1.2 Aim and Objectives: The aim of this study is to perform a comparative evaluation of six structural solutions for steel primary members—four solid cross-sections (I, H, rectangular hollow, and circular hollow) and two truss configurations (constant-depth and variable-depth)—under varying span lengths and roof inclinations, in order to identify the most efficient solution for each parameter combination.
The specific objectives of the study are as follows:

1. To develop a parametric set of beam models covering:
    a. five roof inclination angles (0°, 5°, 10°, 15°, and 20°), and
    b. ten span lengths ranging from 8 m to 44 m, with increments of 4 m.
2. To apply two uniformly distributed vertical load cases:
    a. a lower load case (g = 6 kN/m), and
    b. a higher load case (g = 12 kN/m).
3. To analyze each configuration under two boundary conditions:
    a. simply supported, and
    b. fixed supports, using the structural analysis software **Tower 8 (Radimpex)**.
4. To determine, for each parameter combination:
    a. normal stresses (σ), and
    b. relative deflections (δ).
5. To compare the six structural solutions based on the obtained stress and deformation results.
6. To normalize the results by adopting the I-section as a reference case, thereby enabling direct comparison across different structural systems.

7. To formulate practical design recommendations that assist engineers in selecting the most appropriate structural solution as a function of span and roof inclination.

1.3 Scope and Limitations of the Study: This study focuses on the analysis of individual steel beams and is limited to the following parameters and assumptions:

[1] Only isolated steel beams are considered, with either horizontal or inclined orientation, without inclusion of columns and without examining the global behavior of a structural system such as a portal frame.
[2] Five inclination angles are analyzed: 0°, 5°, 10°, 15°, and 20°.
[3] Ten span lengths are considered: 8, 12, 16, 20, 24, 28, 32, 36, 40, and 44 m.
[4] The material used is structural steel of grade S235.
[5] The applied loads are exclusively vertical (gravitational), uniformly distributed, with two intensity levels: 6 kN/m and 12 kN/m.
[6] Two boundary conditions are taken into account: simply supported at both ends and fully fixed at both ends.
[7] Six structural configurations are analyzed: I-section, H-section, square hollow section (□), circular hollow section (○), truss with variable height, and truss with constant height.
[8] Structural analysis is performed within a linear-elastic framework using the software Tower 8.
[9] Member verification is based solely on a simplified check of normal stresses, without incorporating advanced stability analyses (e.g., lateral-torsional buckling, local buckling, etc.).

The study does not consider horizontal loads (such as wind and seismic actions), dynamic effects, snow loads with accumulation, material fatigue, or fire protection aspects. Furthermore, the global behavior of the structural system (portal frame) is not analyzed and is proposed as a direction for future research.

Theoretical Background and Literature

2.1 Steel as a Structural Material: Structural steel is an industrially produced iron–carbon alloy, with a carbon content typically below 0.25% for standard structural grades. Due to its controlled manufacturing process, steel is characterized by material homogeneity and consistent quality.

The main properties that make steel suitable as a load-bearing material include:

1. high tensile and compressive strength,
2. predictable elastic behavior up to the yield point,
3. good isotropy of the material,
4. a high strength-to-weight ratio compared to traditional construction materials.

In this study, S235 steel grade is used, which is one of the most commonly applied grades in Europe for structures subjected to standard loads. The main mechanical properties of this material are presented in Table 2.1.

Table 2.1 — Mechanical properties of S235 steel

Karakteristika	Simboli	Vlera
Kufiri i rrjedhshmërisë	f_y	235 N/mm²
Rezistenca në tërheqje	f_u	360 N/mm²
Moduli i elasticitetit	E	210 000 N/mm²
Moduli i prerjes	G	81 000 N/mm²
Koeficienti i Puasonit	ν	0.3
Pesha specifike	γ	78.5 kN/m³

The static behavior of S235 steel up to the yield point is practically linear-elastic. This means that the stress–strain relationship follows Hooke's law within this range, which simplifies numerical modeling and allows the use of linear elastic analysis for calculating stresses and deformations.

2.2 Steel beams as primary load-bearing elements: A beam is a linear structural element whose geometry is characterized by a length (span) that is much greater than the dimensions of its cross-section. The main function of a beam is to transmit vertical loads coming from the roof, floor, or other structural elements to its supports.

The behavior of a beam under a uniformly distributed vertical load is described by the classical Euler–Bernoulli bending equation. Normal stresses and deformations are calculated respectively as:

$$\sigma = M/W + N/A$$

and

$$\delta = k \cdot qL^4/(EI),$$

where M is the maximum bending moment, N the maximum axial force, A the cross-sectional area, W the section modulus, q the distributed load, L the span length, E the modulus of elasticity, I the second moment of area (moment of inertia) of the cross-section, and k a coefficient depending on the boundary conditions of the supports.

From these expressions it is evident that normal stresses decrease with an increase in the section modulus W, while deformations decrease with an increase in the moment of inertia I and increase proportionally to the fourth power of the span L. Therefore, the two geometric characteristics that decisively determine the efficiency of a beam are the section modulus W and the moment of inertia I.

2.2.1 Horizontal and Inclined Beams: When a beam is horizontal, the distributed vertical load acts perpendicular to its axis, generating a pure bending moment. When the beam is inclined at an angle α relative to the horizontal, the distributed vertical load can be decomposed into two components: a component perpendicular to the beam axis ($q \cdot \cos \alpha$), which produces a bending moment, and a component parallel to the beam axis ($q \cdot \sin \alpha$), which induces an axial compressive force. For small inclination angles considered in this study (up to 20°), the effect of the parallel component remains relatively small, although it is not negligible.

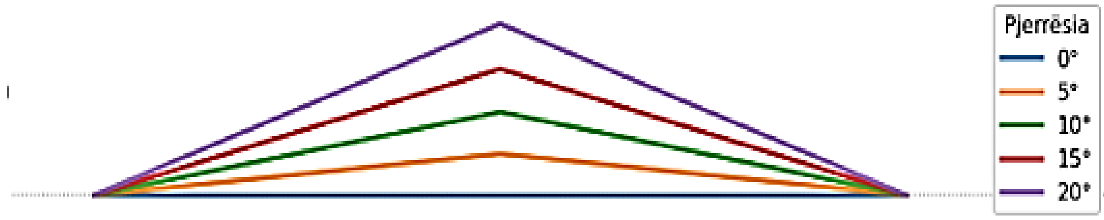

Figure 2.1 — The five roof slope angles analyzed in this study

2.2.2 Boundary Conditions of Supports: In this topic, two support boundary conditions are analyzed: simple (pin/roller) support and fixed (encastre) support. In the case of simple support, the beam is free to rotate at the support, the bending moment at the ends is zero, and the maximum bending moment occurs at mid-span (M_max = $qL^2/8$, δ_max = $5qL^4/384EI$). In the case of fixed support, rotation at the support is restrained, negative moments are generated at the ends, and the maximum positive moment at mid-span is smaller (M_max = $qL^2/12$ at the ends, δ_max = $qL^4/384EI$ — five times smaller than in the case of simple support). simple support fixed support

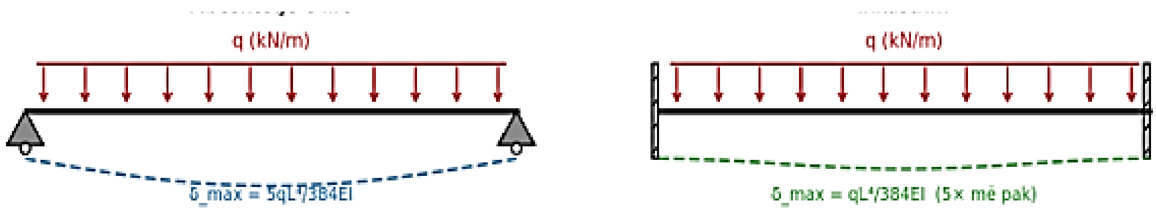

Figure 2.2 — Beam under uniform load with free support (left) and with embedment (right), with the corresponding deformation shapes.

In practice, boundary conditions are realized through the structural details of the beam connections to columns or other supports. Figure 2.3 shows two types of real structural connections: a simple connection and a rigid connection

Figure 2.3 — Two types of structural connections: a simple connection (left) with an angle plate that allows free rotation and transmits only shear forces; and a rigid connection (center, orange) with bolted top and bottom plates that also transmits bending moments. Source: Simpson Strong-Tie.

2.3 Types of cross-sections for steel beams: The industrial production of structural steel offers a wide range of standardized profiles (Figure 2.4). In this topic, four main families of full profiles (I-profile, H-profile, rectangular profile, circular profile/tube) and two types of trusses are compared, which are presented in detail below.

Figure 2.4 — Common types of standardized steel profiles. In this topic, the I-profile (top left) and circular, square and rectangular profiles (bottom) are studied. U and L profiles are not the subject of this

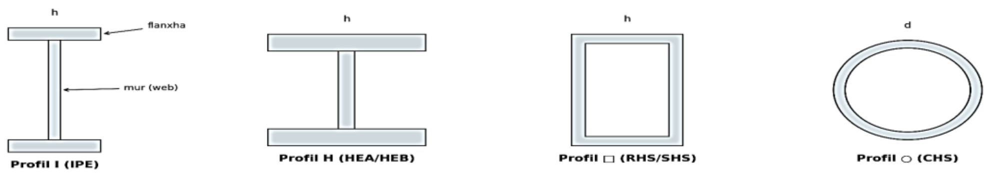

Figure 2.5 — Schematic of the four complete cross-sections analyzed: I-profile, H-profile, □-profile (rectangular) and ○-profile (circular/tube).

2.3.1 I-profile (IPE): The I-profile is an open, hot-rolled profile, shaped like the letter "I". It is characterized by thin, relatively narrow flanges and a thin wall (tail) connecting them. The most common European series of I-profiles are the IPE (I Profile European), which have flanges of constant thickness and geometry optimized to provide a high moment of inertia in the main direction with a relatively low weight.

Figure 2.6 — I-sections used as main beams and columns in an industrial steel structure.

2.3.2 H-section (HEA, HEB): The H-section is also a hot-rolled open section, but with wider and thicker flanges than the I-section, and with thicker walls. The most popular European series are HEA (lighter) and HEB (heavier), with flanges with a width almost equal to the cutting height. The H-section offers a more balanced moment of inertia in both main directions compared to the I-section, better lateral-torsional loss behavior, but a weight per linear meter greater than that of the I-section for the same height.
2.3.3 section (rectangular / square — RHS, SHS): Rectangular (RHS — Rectangular Hollow Section) and square (SHS — Square Hollow Section) sections are closed sections, manufactured with or without welding. They offer balanced behavior in the two main

directions, very good resistance to torsion due to the closed cut, and a clean aesthetic appearance preferable in exposed constructions. Their disadvantage is that joint connections are more difficult to achieve compared to open profiles.

2.3.4 Profile (circular/tube — CHS): A circular profile (CHS — Circular Hollow Section) is a tube with a circular cross-section and a constant wall thickness. It offers completely symmetrical behavior in all directions, the best possible resistance to torsion, and a very clean aesthetic appearance. Joints at the joints are technically more difficult and more expensive, and the weight per linear meter is usually greater than that of an I-profile for the same modulus of resistance in the main direction.

2.4 Trusses as an alternative for large spans: For large spans (usually over 20–25 m), full beams become uneconomical because they require profiles with very large heights to satisfy the deformation requirements. In these cases, trusses constitute a much more efficient alternative.

Two types of trusses are compared: with constant height and with variable height. The two main shapes of variable-height trusses (triangular and trapezoidal) as well as the shape of constant-height trusses are shown in Figure 2.7.

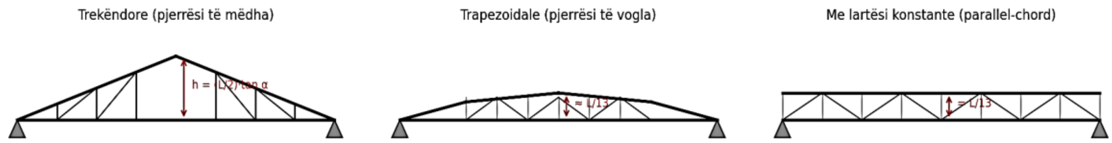

Figure 2.7 — The three truss geometries analyzed: triangular truss (for large slopes), trapezoidal truss (for small slopes), and constant-height truss (parallel-chord).

2.4.1 Parallel-chord truss: A parallel-chord truss has the upper chord and the lower chord parallel to each other throughout the span. Its height is the same at the mid-span and at the support. The main advantages are its simple and easy-to-manufacture geometry, and its suitability for horizontal coverings. The main disadvantage is that the material is not optimally distributed: the height is the same at the support where the moment is zero as at the mid-span where the moment is maximum.

Figure 2.8 — Parallel-chord truss in the roof of an industrial warehouse: the upper and lower chords are parallel, with diagonal members between them

2.4.2 Variable-height truss: A variable-height truss has the upper chord not parallel to the lower chord. The most common form is one with a sloping upper chord that follows the slope of the roof, while the lower chord remains horizontal — this makes the truss height greater in the middle of the span and smaller at the support, following the shape of the bending moment diagram. The main advantage is better material distribution efficiency. The disadvantage is that the geometry is more complicated and the connections at the joints are more difficult to realize.

Results

3.1 General presentation: This chapter presents the results of the numerical analysis, organized by slope angle (0°, 5°, 10°, 15° and 20°). For each slope, two tables are given: one for free support and one for embedment, both for the light load case. The results for the heavy load case are discussed in §4.7 and are almost identical in relative values. The value 1.000 belongs to profile I (reference); values < 1 indicate better behavior, values > 1 indicate worse behavior.

3.2 Results for 0° slope (horizontal beams)

Table 3.1a — 0° slope, free support, light load

L (m)	**I σ**	**H σ**	**□ σ**	**○ σ**	**K.kon. σ**	**I δ**	**H δ**	**□ δ**	**○ δ**	**K.kon. δ**
8	1.000	1.466	1.192	1.178	0.616	1.000	2.321	1.173	1.031	0.141
12	1.000	1.377	1.338	1.260	0.532	1.000	2.176	1.511	1.171	0.121
16	1.000	1.471	1.515	1.529	0.500	1.000	2.458	1.737	1.696	0.115
20	1.000	1.310	1.107	1.536	0.488	1.000	2.118	1.125	1.683	0.101
24	1.000	1.342	1.430	1.620	0.481	1.000	2.047	1.733	1.895	0.099
28	1.000	1.410	1.711	1.940	0.506	1.000	2.394	2.611	2.854	0.113
32	1.000	1.078	1.711	1.789	0.411	1.000	1.347	2.590	2.341	0.081
36	1.000	1.021	1.896	1.802	0.365	1.000	1.130	2.988	2.265	0.069
40	1.000	1.190	—	1.700	0.370	1.000	1.440	—	2.020	0.069
44	1.000	1.069	—	1.775	0.333	1.000	1.189	—	2.212	0.066

Table 3.1b — 0° slope, recessed, light load

L (m)	**I σ**	**H σ**	**□ σ**	**○ σ**	**K.kon. σ**	**I δ**	**H δ**	**□ δ**	**○ δ**	**K.kon. δ**
8	0.685	1.000	0.808	0.795	0.493	0.198	0.453	0.229	0.202	0.109
12	0.675	0.948	0.896	0.844	0.442	0.196	0.424	0.292	0.228	0.083
16	0.676	1.000	1.015	1.029	0.368	0.196	0.478	0.336	0.329	0.071
20	0.679	0.893	0.738	1.036	0.310	0.195	0.411	0.218	0.326	0.058
24	0.684	0.911	0.949	1.076	0.329	0.195	0.397	0.334	0.366	0.059
28	0.675	0.952	1.145	1.301	0.337	0.195	0.463	0.502	0.549	0.063
32	0.667	0.733	1.144	1.189	0.278	0.194	0.261	0.497	0.450	0.046
36	0.677	0.688	1.260	1.208	0.260	0.194	0.219	0.573	0.436	0.041

40	*0.680*	*0.800*	—	*1.140*	*0.240*	*0.194*	*0.278*	—	*0.388*	*0.039*
44	*0.676*	*0.716*	—	*1.176*	*0.275*	*0.203*	*0.241*	—	*0.445*	*0.038*

Observations for 0° slope: The I profile clearly dominates among the solid profiles. The H profile produces 38–47% higher deflections than the I profile for small spans (8–28 m), but the difference decreases to 2–19% for spans 32–44 m. The hollow profiles (□ and ○) have similar behavior among themselves — for spans 8–20 m, deflections are 11–54% higher than the I profile, while for spans 24–44 m this difference reaches 43–94%. Their deformations become up to 199% larger for large spans. The constant-height truss is the most efficient alternative: its deflections are 38–67% lower than the I profile, and the deformations are only 6.6–14.1% of those of the I profile — a reduction of 85.9–93.4%

3.3 Results for 5° slope

Table 3.2a — 5° slope, free support, light load

L (m)	***I σ***	***H σ***	***□ σ***	***○ σ***	***K.var. σ***	***K.kon . σ***	***I δ***	***H δ***	***□ δ***	***○ δ***	***K.var. δ***	***K.kon . δ***
8	*1.000*	*1.136*	*1.114*	*1.068*	*1.091*	*0.886*	*1.000*	*1.327*	*1.079*	*0.972*	*0.332*	*0.193*
12	*1.000*	*1.091*	*1.068*	*1.091*	*0.864*	*0.682*	*1.000*	*1.237*	*1.091*	*1.027*	*0.328*	*0.195*
16	*1.000*	*1.128*	*1.231*	*1.179*	*0.795*	*0.615*	*1.000*	*1.314*	*1.256*	*1.180*	*0.308*	*0.189*
20	*1.000*	*1.019*	*1.000*	*1.192*	*0.827*	*0.635*	*1.000*	*1.156*	*0.999*	*1.177*	*0.322*	*0.195*
24	*1.000*	*1.061*	*1.143*	*1.184*	*0.796*	*0.633*	*1.000*	*1.187*	*1.174*	*1.182*	*0.315*	*0.195*
28	*1.000*	*1.077*	*1.212*	*1.269*	*0.846*	*0.654*	*1.000*	*1.226*	*1.292*	*1.295*	*0.339*	*0.209*
32	*1.000*	*1.000*	*1.216*	*1.255*	*0.745*	*0.588*	*1.000*	*1.057*	*1.232*	*1.211*	*0.295*	*0.182*
36	*1.000*	*0.981*	*1.264*	*1.283*	*0.679*	*0.547*	*1.000*	*1.012*	*1.275*	*1.230*	*0.271*	*0.170*
40	*1.000*	*1.057*	—	*1.226*	*0.717*	*0.566*	*1.000*	*1.079*	—	*1.138*	*0.294*	*0.184*
44	*1.000*	*1.000*	—	*1.259*	*0.648*	*0.500*	*1.000*	*1.018*	—	*1.185*	*0.273*	*0.174*

Table 3.2b — 5° slope, embedded, light load

L (m)	***I σ***	***H σ***	***□ σ***	***○ σ***	***K.var. σ***	***K.kon . σ***	***I δ***	***H δ***	***□ δ***	***○ δ***	***K.var. δ***	***K.kon . δ***
8	*0.932*	*1.227*	*1.068*	*1.045*	*0.932*	*0.750*	*0.361*	*0.621*	*0.403*	*0.359*	*0.296*	*0.174*
12	*0.955*	*1.182*	*1.159*	*1.136*	*0.909*	*0.636*	*0.379*	*0.605*	*0.480*	*0.414*	*0.266*	*0.164*
16	*0.949*	*1.231*	*1.308*	*1.308*	*0.769*	*0.538*	*0.377*	*0.654*	*0.550*	*0.527*	*0.227*	*0.149*
20	*1.000*	*1.135*	*1.058*	*1.346*	*0.654*	*0.462*	*0.407*	*0.604*	*0.428*	*0.560*	*0.219*	*0.146*
24	*1.000*	*1.163*	*1.265*	*1.367*	*0.714*	*0.510*	*0.408*	*0.609*	*0.567*	*0.589*	*0.220*	*0.150*
28	*1.000*	*1.192*	*1.385*	*1.500*	*0.692*	*0.500*	*0.396*	*0.642*	*0.683*	*0.704*	*0.222*	*0.153*
32	*1.039*	*1.078*	*1.412*	*1.490*	*0.647*	*0.471*	*0.434*	*0.509*	*0.699*	*0.672*	*0.197*	*0.135*

36	*1.057*	*1.057*	*1.491*	*1.528*	*0.642*	*0.453*	*0.453*	*0.480*	*0.756*	*0.692*	*0.186*	*0.130*
40	*1.075*	*1.189*	*—*	*1.472*	*0.604*	*0.434*	*0.469*	*0.564*	*—*	*0.647*	*0.193*	*0.138*
44	*1.074*	*1.111*	*—*	*1.519*	*0.574*	*0.426*	*0.465*	*0.503*	*—*	*0.679*	*0.184*	*0.134*

Observations for 5° slope: With the introduction of 5° slope, the differences between the full profiles are significantly reduced. The H profile produces only 9–14% higher deflections than the I profile for spans of 8–28 m and reaches practical parity (−2% to +6%) for spans of 32–44 m. The variable height truss becomes feasible and gives 13–35% lower deflections than the I profile for spans ≥ 12 m. The constant height truss remains the absolute best: 31–50% lower deflections and deformations only 17–21% of those of the I profile.

3.4 Results for 10° slope

Table 3.3a — 10° slope, free support, light load

L (m)	***I σ***	***H σ***	***□ σ***	***○ σ***	***K.var. σ***	***K.kon . σ***	***I δ***	***H δ***	***□ δ***	***○ δ***	***K.var. δ***	***K.kon . δ***
8	*1.000*	*1.458*	*1.125*	*1.083*	*2.125*	*1.333*	*1.000*	*1.484*	*1.059*	*0.955*	*3.422*	*0.848*
12	*1.000*	*1.400*	*1.280*	*1.200*	*2.040*	*1.040*	*1.000*	*1.466*	*1.146*	*1.029*	*3.383*	*0.621*
16	*1.000*	*1.500*	*1.455*	*1.455*	*2.182*	*0.909*	*1.000*	*1.607*	*1.322*	*1.267*	*3.616*	*0.574*
20	*1.000*	*1.333*	*1.074*	*1.444*	*2.000*	*0.852*	*1.000*	*1.506*	*1.023*	*1.332*	*3.335*	*0.575*
24	*1.000*	*1.308*	*1.346*	*1.462*	*1.731*	*0.846*	*1.000*	*1.492*	*1.345*	*1.418*	*2.857*	*0.579*
28	*1.000*	*1.370*	*1.593*	*1.778*	*1.926*	*0.852*	*1.000*	*1.611*	*1.717*	*1.816*	*3.210*	*0.612*
32	*1.000*	*1.069*	*1.586*	*1.621*	*1.586*	*0.690*	*1.000*	*1.174*	*1.827*	*1.698*	*2.611*	*0.509*
36	*1.000*	*1.000*	*1.742*	*1.645*	*1.613*	*0.645*	*1.000*	*1.063*	*2.111*	*1.723*	*2.717*	*0.464*
40	*1.000*	*1.188*	*—*	*1.562*	*1.469*	*0.594*	*1.000*	*1.257*	*—*	*1.583*	*2.394*	*0.473*
44	*1.000*	*1.062*	*—*	*1.656*	*1.406*	*0.562*	*1.000*	*1.096*	*—*	*1.700*	*2.346*	*0.451*

Table 3.3b — 10° slope, embedded, light load (without var. trusses)

L (m)	***I σ***	***H σ***	***□ σ***	***○ σ***	***K.kon . σ***	***I δ***	***H δ***	***□ δ***	***○ δ***	***K.kon . δ***
8	*1.167*	*1.375*	*1.292*	*1.250*	*1.250*	*0.619*	*0.841*	*0.647*	*0.588*	*0.837*
12	*1.080*	*1.240*	*1.240*	*1.240*	*1.040*	*0.608*	*0.820*	*0.664*	*0.612*	*0.682*
16	*1.091*	*1.318*	*1.409*	*1.364*	*0.909*	*0.612*	*0.890*	*0.766*	*0.729*	*0.545*
20	*1.037*	*1.148*	*1.074*	*1.333*	*0.741*	*0.595*	*0.821*	*0.597*	*0.749*	*0.522*
24	*1.000*	*1.154*	*1.192*	*1.308*	*0.808*	*0.594*	*0.820*	*0.749*	*0.782*	*0.530*
28	*1.037*	*1.185*	*1.370*	*1.481*	*0.815*	*0.600*	*0.875*	*0.923*	*0.969*	*0.558*
32	*0.966*	*0.966*	*1.310*	*1.345*	*0.690*	*0.583*	*0.658*	*0.959*	*0.901*	*0.465*

36	*0.935*	*0.935*	*1.387*	*1.355*	*0.677*	*0.574*	*0.600*	*1.088*	*0.912*	*0.428*
40	*0.938*	*1.000*	—	*1.281*	*0.625*	*0.567*	*0.687*	—	*0.836*	*0.440*
44	*0.938*	*0.969*	—	*1.344*	*0.594*	*0.569*	*0.608*	—	*0.893*	*0.425*

Observations for 10° slope: A key result emerges at this slope: the variable-height truss behaves very poorly. Its deflections are 41–118% higher than the I-profile and the deformations are 134–262% larger. The explanation is that at 10°, the height of a triangular truss would only be about L/11.3, which is not sufficient for an effective force arm. The constant-height truss continues to be effective with deflections 15–44% lower and deformations 38–55% lower than the I-profile for spans ≥ 12 m.

3.5 Results for 15° slope

Table 3.4a — 15° slope, free support, light load

L (m)	***I σ***	***H σ***	**□ *σ***	**○ *σ***	**K.var. *σ***	**K.kon. *σ***	***I δ***	***H δ***	**□ *δ***	**○ *δ***	**K.var. *δ***	**K.kon. *δ***
8	*1.000*	*1.417*	*1.167*	*1.083*	*2.167*	*1.250*	*1.000*	*1.756*	*1.091*	*0.980*	*3.228*	*1.091*
12	*1.000*	*1.360*	*1.240*	*1.200*	*1.480*	*0.960*	*1.000*	*1.708*	*1.263*	*1.073*	*2.314*	*0.717*
16	*1.000*	*1.455*	*1.409*	*1.409*	*1.591*	*0.818*	*1.000*	*2.021*	*1.548*	*1.501*	*2.777*	*0.804*
20	*1.000*	*1.296*	*1.074*	*1.444*	*1.407*	*0.741*	*1.000*	*1.742*	*1.059*	*1.460*	*2.284*	*0.629*
24	*1.000*	*1.320*	*1.360*	*1.520*	*1.280*	*0.760*	*1.000*	*1.707*	*1.485*	*1.596*	*1.986*	*0.637*
28	*1.000*	*1.385*	*1.615*	*1.808*	*1.462*	*0.808*	*1.000*	*1.903*	*2.039*	*2.195*	*2.422*	*0.667*
32	*1.000*	*1.107*	*1.607*	*1.679*	*1.393*	*0.643*	*1.000*	*1.242*	*2.131*	*1.926*	*2.033*	*0.557*
36	*1.000*	*1.033*	*1.767*	*1.667*	*1.200*	*0.600*	*1.000*	*1.092*	*2.475*	*1.950*	*1.720*	*0.473*
40	*1.000*	*1.161*	—	*1.581*	*1.065*	*0.548*	*1.000*	*1.342*	—	*1.779*	*1.554*	*0.475*
44	*1.000*	*1.031*	—	*1.625*	*1.000*	*0.625*	*1.000*	*1.134*	—	*1.917*	*1.547*	*0.466*

Table 3.4b — 15° slope, embedded, light load (without var. trusses)

L (m)	***I σ***	***H σ***	**□ *σ***	**○ *σ***	**K.kon. *σ***	***I δ***	***H δ***	**□ *δ***	**○ *δ***	**K.kon. *δ***
8	*0.958*	*1.167*	*1.042*	*1.000*	*1.167*	*0.579*	*0.919*	*0.619*	*0.553*	*1.091*
12	*0.920*	*1.080*	*1.040*	*1.040*	*1.000*	*0.565*	*0.905*	*0.679*	*0.594*	*0.775*

16	*0.909*	*1.136*	*1.182*	*1.182*	*0.864*	*0.607*	*1.059*	*0.836*	*0.809*	*0.689*
20	*0.852*	*1.000*	*0.889*	*1.148*	*0.704*	*0.554*	*0.899*	*0.575*	*0.772*	*0.584*
24	*0.880*	*1.040*	*1.080*	*1.200*	*0.800*	*0.554*	*0.883*	*0.776*	*0.829*	*0.600*
28	*0.885*	*1.077*	*1.269*	*1.385*	*0.808*	*0.561*	*0.978*	*1.035*	*1.105*	*0.621*
32	*0.857*	*0.893*	*1.214*	*1.250*	*0.679*	*0.543*	*0.657*	*1.060*	*0.977*	*0.517*
36	*0.833*	*0.833*	*1.300*	*1.267*	*0.667*	*0.534*	*0.577*	*1.218*	*0.976*	*0.443*
40	*0.839*	*0.935*	—	*1.194*	*0.613*	*0.534*	*0.688*	—	*0.884*	*0.438*
44	*0.812*	*0.844*	—	*1.219*	*0.594*	*0.532*	*0.592*	—	*0.954*	*0.432*

Observations for 15° slope: The variable height truss shows a clear improvement compared to the 10° slope. For spans of 24–44 m, its deflections decrease to 0–48% higher than the I-profile, and for L = 44 m it reaches practical equilibrium (σ = 1.000). The constant height truss remains more efficient with deflections 25–45% lower and deformations 33–53% lower than the I-profile.

3.6 Results for 20° slope

Table 3.5a — 20° slope, free support, light load

L (m)	***I σ***	***H σ***	***□ σ***	***○ σ***	***K.var. σ***	***K.kon. σ***	***I δ***	***H δ***	***□ δ***	***○ δ***	***K.var. δ***	***K.kon. δ***
8	*1.000*	*1.417*	*1.125*	*1.083*	*1.917*	*1.208*	*1.000*	*1.947*	*1.118*	*0.994*	*2.598*	*1.438*
12	*1.000*	*1.360*	*1.240*	*1.200*	*1.240*	*0.920*	*1.000*	*1.863*	*1.335*	*1.101*	*1.723*	*0.874*
16	*1.000*	*1.409*	*1.409*	*1.409*	*1.318*	*0.818*	*1.000*	*2.084*	*1.536*	*1.498*	*1.885*	*0.788*
20	*1.000*	*1.259*	*1.074*	*1.370*	*1.185*	*0.704*	*1.000*	*1.880*	*1.080*	*1.541*	*1.633*	*0.656*
24	*1.000*	*1.320*	*1.360*	*1.520*	*1.360*	*0.760*	*1.000*	*1.836*	*1.574*	*1.706*	*1.785*	*0.672*
28	*1.000*	*1.385*	*1.615*	*1.808*	*1.462*	*0.769*	*1.000*	*2.074*	*2.227*	*2.410*	*1.975*	*0.699*
32	*1.000*	*1.071*	*1.607*	*1.679*	*1.143*	*0.643*	*1.000*	*1.283*	*2.290*	*2.088*	*1.478*	*0.546*

36	*1.000*	*1.000*	*1.767*	*1.700*	*0.967*	*0.667*	*1.000*	*1.109*	*2.658*	*2.065*	*1.270*	*0.496*
40	*1.000*	*1.161*	—	*1.581*	*1.065*	*0.677*	*1.000*	*1.377*	—	*1.859*	*1.320*	*0.474*
44	*1.000*	*1.065*	—	*1.677*	*0.968*	*0.742*	*1.000*	*1.156*	—	*2.021*	*1.284*	*0.479*

Table 3.5b — 20° slope, embedded, light load (without var. trusses)

L (m)	***I σ***	***H σ***	***□ σ***	***○ σ***	***K.kon . σ***	***I δ***	***H δ***	***□ δ***	***○ δ***	***K.kon . δ***
8	*0.875*	*1.125*	*0.958*	*0.917*	*1.208*	*0.556*	*1.006*	*0.609*	*0.544*	*1.254*
12	*0.840*	*1.040*	*1.000*	*0.960*	*1.000*	*0.540*	*0.953*	*0.687*	*0.583*	*0.820*
16	*0.818*	*1.091*	*1.136*	*1.136*	*0.864*	*0.548*	*1.059*	*0.794*	*0.776*	*0.726*
20	*0.815*	*0.963*	*0.852*	*1.111*	*0.704*	*0.533*	*0.941*	*0.562*	*0.782*	*0.610*
24	*0.800*	*1.000*	*1.040*	*1.160*	*0.800*	*0.533*	*0.924*	*0.792*	*0.858*	*0.629*
28	*0.846*	*1.038*	*1.231*	*1.346*	*0.808*	*0.546*	*1.041*	*1.106*	*1.191*	*0.640*
32	*0.786*	*0.821*	*1.179*	*1.214*	*0.679*	*0.520*	*0.655*	*1.127*	*1.028*	*0.497*
36	*0.767*	*0.800*	*1.267*	*1.233*	*0.667*	*0.513*	*0.564*	*1.288*	*1.014*	*0.451*
40	*0.774*	*0.871*	—	*1.161*	*0.613*	*0.509*	*0.686*	—	*0.904*	*0.437*
44	*0.774*	*0.806*	—	*1.226*	*0.645*	*0.510*	*0.582*	—	*0.984*	*0.440*

Observations for 20° slope: At 20°, the variable-height truss reaches its best efficiency. For L = 36 m and L = 44 m, its loads become 3% lower than the I-profile. The constant-height truss produces 24–36% lower loads for medium/large spans, but is 21% worse than the I-profile at L = 8 m, confirming that for very small spans trusses are generally not suitable.

3.7 Summary of main results

1. The I-profile is the most efficient profile among the four full profiles in almost all combinations.
2. The H-profile is 2–50% worse than the I-profile in loads for spans 8–28 m, but reaches practically the same (±6%) for spans 32–44 m at all slopes.
3. Hollow profiles (□ and ○) are 7–94% weaker than the I profile, with a clear tendency to deteriorate with span.
4. The constant-height truss produces 25–67% lower loads and 33–93% lower deformations than the I profile — provided that L ≥ 12 m.
5. The variable-height truss strongly depends on the angle: it is inefficient at 10° (+40–118%), approaches at 15°, and surpasses the I profile for L ≥ 36 m at the 20° slope.

6. None of the trusses is efficient for very small spans (L = 8 m), where solid profiles are more efficient.

Graphical interpretation of results

To facilitate the identification of trends, the results of normalized stresses and strains are presented graphically in Figures 4.1–4.10, with one plot for stresses and one for strains for each of the five slopes.

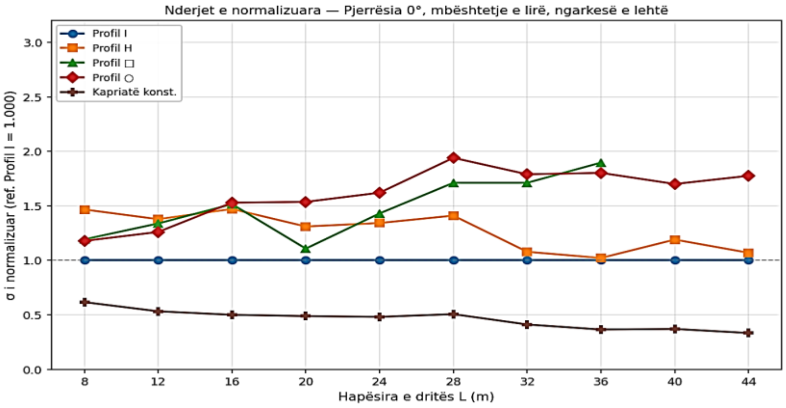

Figure 4.1 — Normalized values for 0° slope.

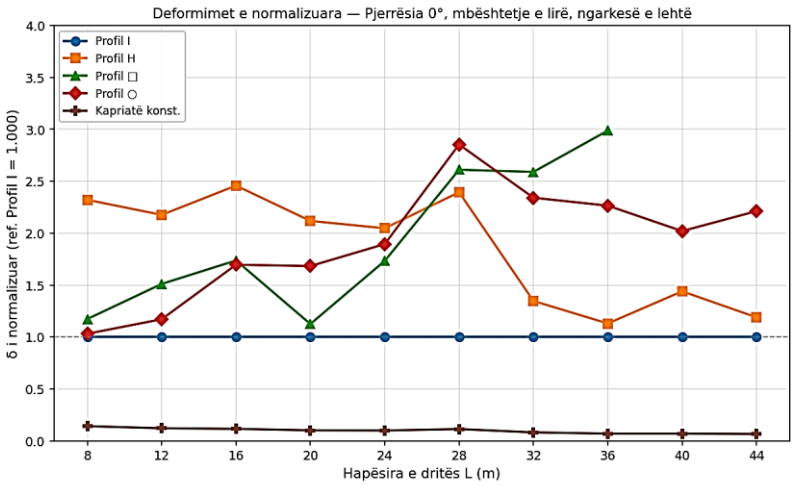

Figure 4.2 — Normalized deformations for 0° slope.

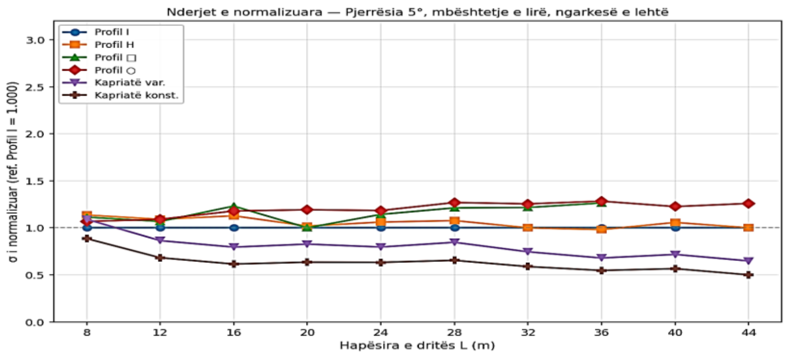

Figure 4.3 — Normalized values for 5° slope.

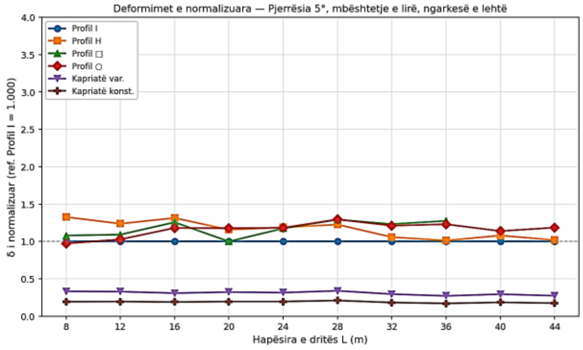

Figure 4.4 — Normalized deformations for 5° slope.

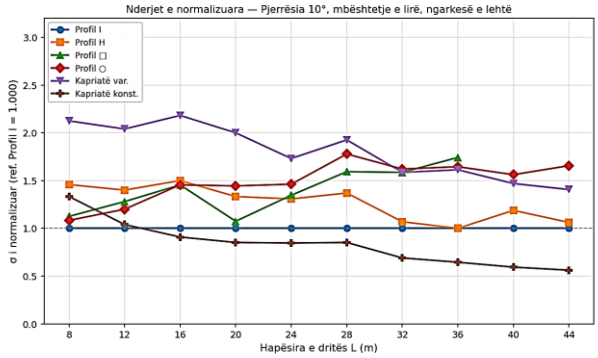

Figure 4.5 — Normalized values for 10° slope.

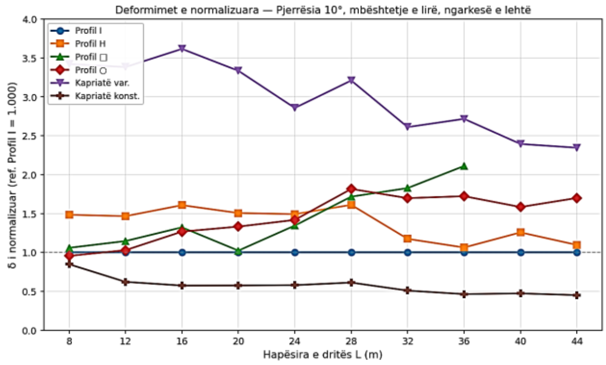

Figure 4.6 — Normalized deformations for 10° slope.

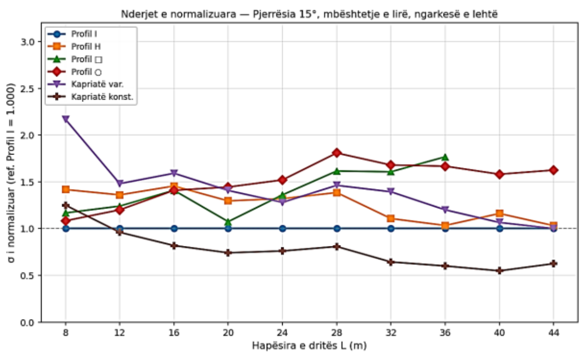

Figure 4.7 — Normalized values for 15° slope.

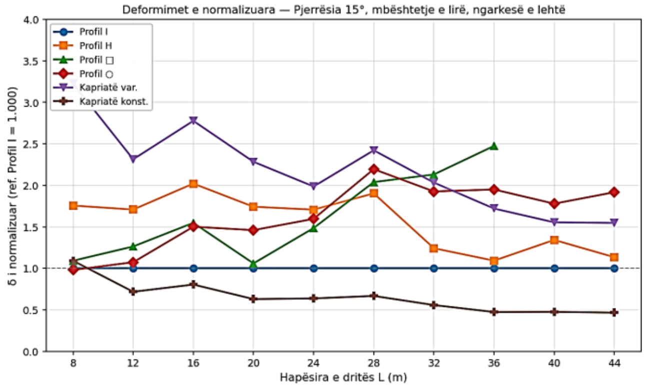

Figure 4.8 — Normalized deformations for 15° slope.

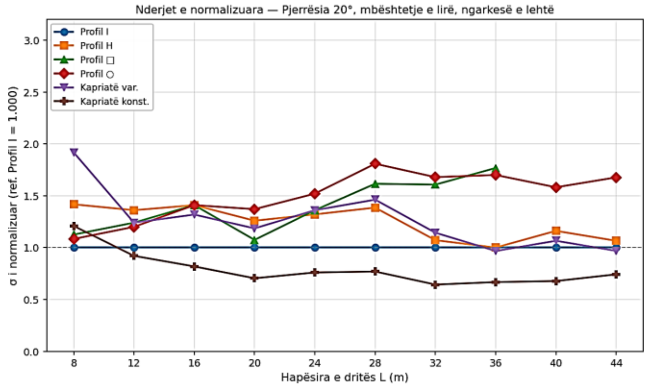

Figure 4.9 — Normalized values for 20° slope.

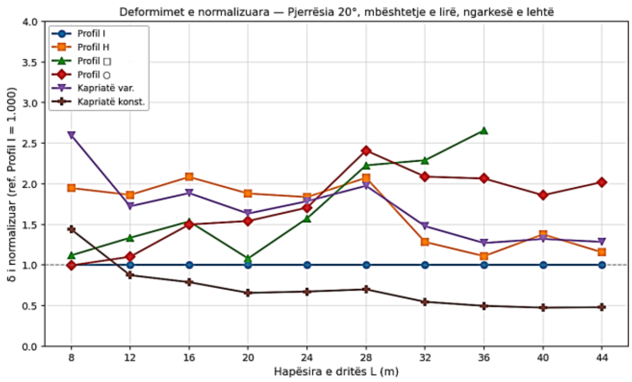

Figure 4.10 — Normalized deformations for 20° slope.

Conclusion

This topic provided a quantitative, parametric, and normalized comparison of six major alternatives for steel main supports, covering a wide range of static spans, slope angles, and boundary conditions. The results confirmed some well-known trends in design practice—such as the superiority of I-sections for horizontal beams with small spans and the efficiency of trusses for large spans—but also presented less intuitive observations: the high sensitivity of variable-height trusses to slope angle, and the large deformation margin in trusses that suggests the possibility of further optimization with higher steel grades.

Due to the limitations discussed—particularly the lack of stability checks, full-frame analysis, and wraps in the areas of maximum moment—this topic does not formulate direct recommendations for practical design. Instead, it provides a quantitative comparative basis and identifies concrete directions for further research that would be necessary to move from the observations of this study to fully verified recommendations for design.

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