EURO-CODE COMPLIANT ADAPTIVE LAYOUT OPTIMISATION OF TWO-DIMENSIONAL STEEL TRUSSES

G.M.D. Denuwanthi [1], H.M.S.T. Herath [1, *]

[1] Department of Civil Engineering, University of Moratuwa, Moratuwa

Truss optimisation plays a vital role in the design and analysis of various engineering structures, ranging from bridges to aerospace applications. Over the years, researchers have proposed numerous numerical methods to achieve optimal truss configurations, considering factors such as weight minimisation, stiffness maximisation, and cost efficiency. However, despite the significant progress in the field, the absence of universally accepted standards for determining the optimum truss solution remains a challenge. This paper presents a novel methodology for optimising steel trusses using Euro-code standards as a reference framework specifically focusing on pin-jointed truss systems. The proposed methodology aims to combine numerical optimisation algorithms with the relevant design provisions outlined in Euro-code, ensuring compliance with structural integrity and safety criteria.

The process involves a Python script for convex optimisation and the numerical optimisation algorithm employs an adaptive member-adding solution scheme which provides a computationally efficient means of generating near-optimum trusses for the problems. The objective function of the optimisation algorithm is to minimise the total structural volume of the truss and the process satisfies the force equilibrium at each node of the truss as well as limiting stress criteria as defined in the Euro-code.

The research provides a thorough overview of the relevant Eurocode provisions that pertain to steel trusses. Initially, the optimisation studies employ a method to handle layout and geometry optimisation simultaneously to determine the optimal layout of the truss structures, taking into account practical and manufacturing constraints. Then, the methodology progresses to size optimisation which involves optimising the member cross-sections to enhance their stiffness and overall structural performance. Finally, the use of commercially available steel sections for the construction of optimised trusses is assessed to avoid financial challenges due to the high costs associated with additive manufacturing technologies within the context of Sri Lanka. To ensure the scientific robustness and practical applicability of the proposed methodology, rigorous examinations are conducted using practical examples.

Keywords: Truss Optimisation, Steel Trusses, Layout Optimisation, Geometry Optimisation, Size Optimisation

[*] Correspondence: sumuduh@uom.lk

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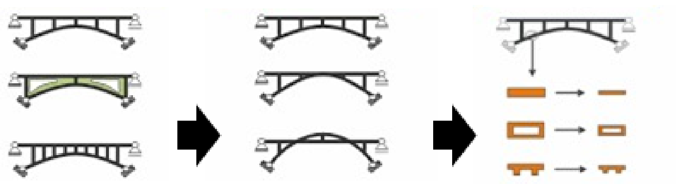
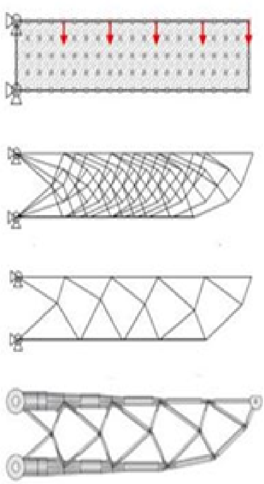
TRUSS OPTIMIZATION



Topology (Layout) Optimization → Shape (Geometry) Optimization → Size (Cross-section) Optimization

PROPOSED FRAMEWORK



Step 01- Design domain, loads and boundary conditions are defined according to requirement

Step 02 –The initial ground structure is created by considering a subset of possible connections

Step 03- Simultaneous layout and geometry optimization

Step 04 – Size optimization

THEORY

Objective Function

The objective function is to minimize the total structural volume of material.

$$\min_{\mathbf{a},q} V = \mathbf{l}^T.\mathbf{a}$$

$$\mathbf{a} = [a_1, a_2, ..., a_m]^T$$

$$\mathbf{l} = [l_1, l_2, ..., l_m]^T$$

Constraints

Force equilibrium

The forces of each node must be in equilibrium

Limiting stress criteria

Each member must have a cross sectional area that is large enough to carry the force being transmitted

EN 1993 Part 1-1:

For tension members

$$\frac{q_i^k}{N_{t,Rd}} \leq 1.0$$

$$N_{Rd} = \text{Min}\{N_{pl,Rd}, N_{u,Rd}\}$$

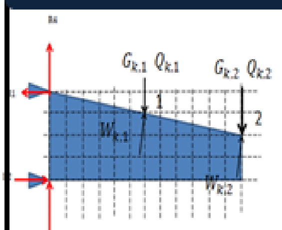
For compression members

$$\frac{q_i^k}{N_{c,Rd}} \leq 1.0$$

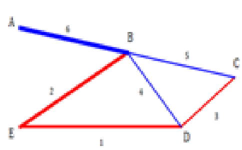
$$N_{Rd} = \text{Max}\{-N_{b,Rd}, -N_{c,Rd}\}$$

IMPLEMENTATION

Loading	G_k	Q_k	W_k
Purlin 1	1296.13	2280.00 N	1923.41 N
Purlin 2	755.80 N	1260.00 N	1062.94 N



Optimization problem



Optimum truss layout

Member	Length (m)	N_{Ed} (kN)	Selected section	N_{Rd} (kN)	Utilization ratio (N_{Rd}/N_{Ed})	Volume (cm^3)
1	2.25	-7.92	CHS 33.7 / 2	-9.35	0.85	423.3
2	1.58	-16.28	CHS 33.7 / 2	-17.82	0.91	304.9
3	0.90	-5.71	CHS 16 / 3.2	-6.46	0.88	115.8
4	1.06	4.48	CHS 10.2 / 0.6	4.98	0.90	19.2
5	1.52	4.55	CHS 10.2 / 0.6	4.98	0.91	27.5
6	1.52	17.49	CHS 12 / 2.3	19.27	0.91	106.5
			Total Structural Volume			997.3