OPTIMIZATION OF MODERN TWO-SPAN TRUSSES USED IN BUILDING STRUCTURES

Khadjieva Salima Sadikovna
Senior Lecturer, General Technical Disciplines
Andijan State Technical Institute, Andijan, Uzbekistan
Email: sxadjiyeva011@gmail.com
+99890 203 20 66

Abstract
This article examines the optimization of modern two-span trusses widely used in building structures. The factors affecting geometric parameters, load-bearing capacity, strength, and economic efficiency of trusses are analyzed. The possibilities of applying modern calculation methods and computer software to determine optimal structural solutions are highlighted. The research results contribute to reducing material consumption, improving structural reliability, and optimizing construction costs.

Keywords: Two-span truss, optimization, building structure, steel structure, strength, deformation, load-bearing capacity, economic efficiency, computer modeling, structural solution.

Introduction

The development of the national economy on the basis of scientific and technical progress, the readjustment and modernization of production, the efficient use of production equipment, the quality of machines, equipment and tools produced by machine-building enterprises, their technical level, productivity, accuracy and safety in use require improvement. One of the most important conditions for creating new designs of machines, tools and vehicles is the increase in the efficiency of using metals from materials of a specific profile in machine-building, which reduces their cost per unit of power.

Today, in the construction industry, special attention is paid to the use of lightweight, durable and cost-effective structures in the construction of large-span buildings and structures. Among such structures, trusses occupy an important place. In particular, two-bay trusses are widely used in the roofing of industrial buildings, warehouses, sports complexes, shopping centers and other large structures.

The issue of optimizing trusses is relevant in order to increase the efficiency of building structures. As a result of optimization, the weight of the structure is reduced, material consumption is reduced, and economic efficiency is increased.

All engineering structures made of deformable solids in production and their parts must meet the requirements of strength, rigidity, and rigidity in order to withstand the effects of loads imposed on them and to avoid dangerous situations from the beginning to the end of their service life. For example, two-bay symmetrical trusses are mainly used as load-bearing structures for the roofs of one-story houses.

Truss structures have a wide range of applications. They are used in the construction of hangars, industrial buildings, sports and entertainment facilities, technological buildings, and more. The rationale for using trusses in large-scale construction is determined by many factors, such as truss configuration, structural rigidity requirements, and loads. A truss is a continuous lattice structure consisting of individual straight rods connected at their nodes. This system is geometrically stable even if all actual nodal connections are replaced by ideal hinges. In reality, truss nodes are not hinges. Truss chords are continuous rods, and the nodal connections are significantly rigid. Trusses, like beams, can be made of metal, reinforced concrete, and wood. Typical truss spans are 18, 24, and 36 meters. Trusses are the basis of many rod systems and have a wide variety of purposes. They are used in building roof structures (rafters, purlins), interfloor ceilings, as contour diaphragms for shells, folds, and other applications. Trusses are used in industrial, civil, and agricultural construction. A truss bends under an external vertical load, typically applied at the nodes. This creates axial tensile and compressive forces in the truss elements, allowing for a more complete utilization of the material's load-bearing capacity than beams.

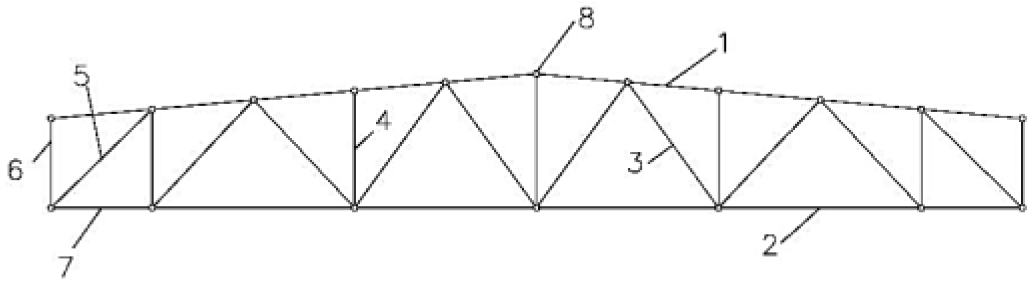

Figure 1 – Truss diagram:
1 – Upper chord; 2 – lower chord; 3 – diagonal; 4 – post; 5 – supporting diagonal;
6 – Supporting post; 7 – supporting brace; 8 – ridge joint

Trusses can be double-supported (split), multi-supported (continuous), or cantilevered. Continuous trusses, unloaded in the span due to the action of support moments, are lighter than split trusses. However, they are more complex to manufacture and install and are more sensitive to support settlements.

Continuous and cantilever trusses are not standardized and are rarely used, primarily for unique roofing applications over large spans. The outline of the upper chord of the trusses is determined primarily by the building's architecture and is coordinated with the roofing material and slope. The line of the lower chord is determined by the presence of a suspended ceiling, overhead transport, and interior design requirements.

Trusses with parallel chords and trapezoidal trusses are the simplest in shape and manufacture, therefore they are widely used in civil and industrial buildings for various purposes, having a low overall height compared to other truss types.

Triangular trusses are used to cover buildings with steep (25–45°) cold roofs made of small-sized materials (roofing steel, tiles, flat and corrugated asbestos-cement sheets, etc.). The design drawbacks of these trusses include the variety of elements and joints. Segmental trusses are the

most cost-effective in terms of material consumption, and their efficiency increases with increasing span. However, they are labor-intensive to manufacture due to the curvature of the top chord and the varying lengths of the lattice elements.
Therefore, in practice, segmental trusses are replaced by polygonal trusses, with straightened top chord elements within the main joints.

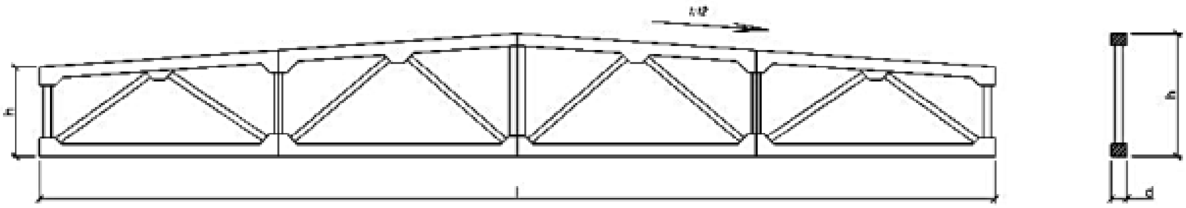

Figure 2 – Composite double-slope reinforced concrete truss consisting of two half-trusses with a pre-stressed bottom chord

Metal and reinforced concrete trusses offer a number of key advantages over other structures, such as wood or composite ones. Metal trusses are characterized by high strength, durability, and load-bearing capacity, making them ideal for large spans and industrial structures. They are lighter than their reinforced concrete counterparts, simplifying installation and reducing foundation loads. Reinforced concrete trusses, in turn, combine the compressive strength of concrete with the tensile strength of reinforcement, providing high load-bearing capacity and fire resistance. Both types of trusses offer excellent resistance to external influences, including temperature fluctuations and aggressive environments, and also allow for the creation of complex architectural forms. In conclusion, it can be said that metal and reinforced concrete trusses are the optimal choice for the construction of industrial, civil, and agricultural facilities due to their strength, durability, and adaptability to various operating conditions.
A truss (French ferme ← Latin firmus "strong") is a rod system in structural mechanics that remains geometrically unchanged after replacing its rigid joints with hinged ones. In the absence of rod misalignment and off-node loading, only tensile-compressive forces arise in truss elements. Trusses are formed from straight rods connected at nodes to form a geometrically unchanged system to which loads are applied only at the rod connections (nodes)[1][2] and only in the form of point forces—for example, these nodes serve as supports for the truss itself, supports for the roadbed of a bridge, anchor points for loads and equipment, etc.

Figure3. Railway bridge truss

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Trusses, with reservations, may include truss beams, which are a combination of a two- or three-span continuous beam and a spring tie; They are typical for steel and timber structures, with a top chord made of continuous rolled sections (sawn beams or laminated lumber). They can also be used for small bridge spans using reinforced concrete trusses.
Trusses are widely used in modern construction, primarily to span large spans to reduce material consumption and lighten the structure, for example, in large-span structures such as bridges, industrial building truss systems, and sports facilities, as well as in the construction of small lightweight building and decorative structures such as pavilions, stage structures, tents, and podiums.
The fuselage of an airplane, the hull of a ship, the supporting body of a car (except for open bodies that work as a simple beam), a bus or a diesel locomotive, a wagon frame with a truss - from the point of view of strength of materials, are trusses (even if they do not have a frame as such - the truss structure in this case is formed by stampings and amplifiers that reinforce the skin), accordingly, in their strength calculations, the corresponding methods are used [10]

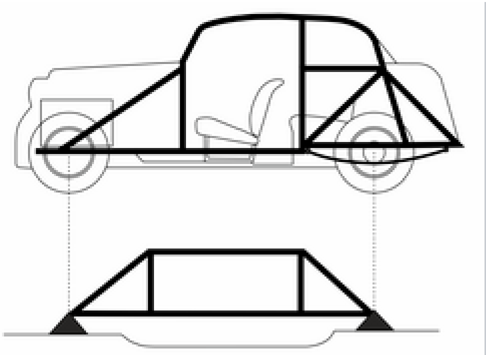

Figure 4. Diagram of a monocoque car body.

The truss elements are reinforced and stamped onto the body shell.
Trusses, like beams, can have different support structures (support types). The truss design can be statically determinate or indeterminate, which determines the design of the truss support nodes: hinged or rigid.
By support type, trusses are divided into:
beam (split/continuous, cantilever)
- double-support
- multi-support
- arched
- cable-stayed
- frame
- combined
Trusses can be supported on purlin trusses, columns, or walls.
By direction of support reactions:
spread arched trusses and others.
Groups of steel structures for selecting steel grades:
Group I: gussets and truss support plates;

Group II: chords, diagonals, trusses, and posts.

For the first group, steel grade no lower than C255 is accepted, and for the others, C245.

According to the cross-section type, steel trusses are designed from rolled sections:

- angle
- single angle
- two symmetrical angles
- two asymmetrical angles (for uprights and diagonals; chords are made of symmetrical angles)
- pipe (round, square, rectangular)
- channel
- T-beam and I-beam

Structurally, any truss consists of the following elements: chord, upright, diagonal, and truss (support diagonal).

panel — the distance between chord nodes;

span — the distance between supports;

truss height — the distance between the outer faces of the chords;

truss rise — the ratio of the truss height to its span; depends on the roofing material and the construction conditions of the structure.

The truss chord supports longitudinal loads, the lattice supports transverse loads. The truss serves as a supporting element that reduces the calculated length of the supporting diagonal or struts and diagonals of the truss

Both of the above problems have a homogeneous solution, and which one to use depends on the information given to solve the problem. If the material is known, a truss that can withstand the greatest load is designed from it, or if the load acting on the truss is known, a truss that uses the least material is designed.

A two-beam truss is a lattice structure consisting of several rods, which allows for the effective distribution of external loads. Truss elements work mainly under tensile and compressive forces.

The main advantages of trusses:

- The ability to cover large spans;
- Lightness of construction;
- Low material consumption;
- High load-bearing capacity;
- Ease of installation work.

In addition, one-story houses can be built using two-pitched trusses to cover the roof, in which case the external load is known and the problem of designing a truss with the least material consumption can be used. When solving this problem, it is necessary to take into account both the strength and the priority of the truss, that is, the optimization problem must be carried out based on the conditions of strength and priority.

In solving the above problems, the formulas of external forces and the size of the truss, which include the dimensions of the truss, are taken as the objective functions of optimal design. The objective functions must also be expressed in terms of the optimizing parameter. In this problem, it is convenient to take the angle between the rafters at the upper end of the truss as

the optimizing parameter. Then, we use the force function applied to the truss through the truss size, which takes into account the optimizing parameter. By solving the obtained results, the angle value that determines the optimal design of the truss is found. If the truss is designed using the stability condition, the external load on the truss is taken as the force function, and if it is designed using the priority condition, the force function is taken as the force function.
Optimization of two-girder trusses is an important means of increasing the economic efficiency of building structures. The use of modern computational technologies improves the quality of the project, reduces construction times, and ensures rational use of materials.

Conclusion

Optimization of modern two-beam trusses used in building structures serves to increase the reliability, strength and economic efficiency of buildings and structures. The selection of optimal geometric parameters and constructive solutions reduces material consumption, reduces operating costs and extends the service life of structures. The use of modern computer technologies further increases the accuracy and efficiency of the optimization process.

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