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Evaluation of lightweight steel construction systems as an alternative to conventional construction systems

Beyza Nur Cabacı*[1], Ali İhsan Ünay[1]

[1] *Gazi University, Faculty of Architecture, Master's Program, Çankaya, 06570 Ankara, Turkey*

Abstract. Light steel building systems are constructed using galvanized sheet steel profiles that are suitable for cold forming and feature lower carbon content compared to structural steel. Their prefabricated nature enables faster construction processes than conventional methods, making them an increasingly attractive option for modern building needs. Conventional systems often struggle to meet the growing demands for sustainability, rapid construction, and economic efficiency. In this context, light steel systems offer notable advantages such as flexibility in design, speed of assembly, and suitability for various building types. This study provides a comprehensive overview of the characteristics, design principles, and global applications of light steel structures. It also discusses the comparative advantages and limitations of light steel systems relative to conventional building methods. Through a review of existing literature, technical guidelines, and standards, the study highlights how light steel systems contribute to addressing contemporary challenges in construction. By examining different regional practices, the study aims to offer an insight into the current status and future outlook of light steel structures in the global construction market.

Keywords: Light Steel Construction; Conventional Construction; Sustainability; Structural performance; Architectural flexibility; Economic Efficiency

1. Introduction

The construction industry faces numerous challenges globally, including the increasing demand for sustainable practices, faster construction processes, and the necessity for structures that can withstand seismic events. These problems are especially pertinent in earthquake prone areas, where building safety and resilience are of utmost importance. Previously, construction practices have depended on the use of materials like concrete, brick, wood, and stone. In spite of centuries of such success for these materials, they have limitations including greater environmental impact, increased construction duration, and similar levels of seismic performance.

Light steel construction systems have been recognized as a promising substitute for conventional construction techniques. The systems provide numerous benefits including decreased construction time, better seismic resistance, and greater sustainability thanks to steel recyclability. Despite these benefits, the global adoption of light gauge steel building systems has been uneven, and comprehensive studies comparing their performance with conventional methods in various contexts have been limited.

This study aims to address this gap by conducting a global comparative analysis of the sustainability and seismic performance of light gauge steel building systems and conventional construction methods. The study will focus on key regions, including Europe, North America, and Asia, where these systems have been implemented to varying degrees. Through this analysis, the research seeks to provide insights into the advantages and challenges associated with lightweight steel construction, thereby contributing to the broader discourse on sustainable and resilient building practices. Through knowledge of the comparative benefits of lightweight steel systems, stakeholders in construction are able to make more informed choices, and this could reflect in higher adoption of the systems in regions where conventional methods still dominate. The research is not only timely but also critical in global efforts towards enhancing the sustainability and resilience of the built environment.

2. Material and Methods

This study presents a comparative evaluation of lightweight steel and conventional construction systems, focusing on sustainability, seismic performance, and economic efficiency. It is based on existing literature and building codes. The systems analyzed include reinforced concrete, timber framing, heavy steel structures and light steel systems made of cold formed, thin walled steel sections. They are reviewed in terms of structural behavior,

* Corresponding author, E-mail: bnur.cabaci@gazi.edu.tr

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construction processes, and environmental impact. The methodology relies on a literature review using academic databases. Additionally, construction practices from Europe, North America, and Asia were examined to understand practical applications

3. Conventional Construction Systems

3.1 Reinforced Concrete Systems

Concrete and reinforced concrete are widely used throughout the world, especially in the United States and Canada, as the primary structural building material. Concrete, also known as "man-made stone," is made by mixing cement, sand, aggregate and water, and can be molded into almost any shape when it has a plastic consistency. This flexibility enables flat slabs or panels to serve the dual purpose of a load-carrying structure and a finished floor or ceiling surface. Concrete developed in the 19th century, when Portland cement was discovered, has low tensile strength; steel reinforcement embedded in the concrete to improve strength in this direction gives ductility and moment stability to the structure by resisting tensile forces after cracking. Modern reinforced concrete design was shaped by the work of European engineers in the late 19th century and is now widely used in critical engineering projects such as buildings, bridges, and dams (Yakut, n.d.).

Reinforced concrete structures are made up of interconnected members that work together to bear the loads placed on them. For instance, the second floor in Fig. 1 uses concrete joist-slab construction. A series of parallel joists support the weight of the upper slab. The forces from these joists are transferred to the beams, which are then supported by columns. The ductility provided by steel reinforcement during earthquakes increases structural safety. Another advantage of reinforced concrete systems is that they provide 1-3 hours of fire resistance without the need for additional fire insulation. Additionally, the wide availability and ease of transporting materials like sand, gravel, crushed stone, water, cement, and reinforcing steel make reinforced concrete systems both economical and practical, especially in remote or logistically challenging areas. With the rapid growth of urban populations in both developing and developed countries, reinforced concrete has become the preferred material for residential construction. However, the lack of design and application expertise in many regions makes proper reinforcement placement and detailing even more critical (Wight, 2016).

3.2 Wooden Systems

Conventional timber building systems are categorized into masonry (log masonry) and frame systems (Çakır, 2000 as cited in Yıldırım, 2010). In modern practice, they are classified as log, frame (post and beam), and panel systems, with additional structures using layered wooden elements for spanning large openings (Götz et al., 1989, as cited in Yıldırım, 2010).

Log masonry systems, requiring large amounts of timber and exhibiting poor earthquake resistance compared to frame systems, have seen limited use. In contrast, timber frame systems, characterized by smaller load-bearing sections, ease of transportation, and flexible architectural solutions, became more widespread. Conventional timber frames often used regional infills like stone, brick, adobe, or wood. However, heavy stone infills increased seismic vulnerability, while timber infills enhanced strength and rigidity during earthquakes, especially when reinforced with slats to support plaster (Acar et al., 2004, as cited in Eren, 2015).

In traditional timber construction, wall studs were left exposed, and lateral stability was achieved through corner braces. In more advanced timber systems, cladding elements took over this role, boosting rigidity (Eren, 2015). The development of these advanced systems in the 19th century was driven by steam-powered routers and machine-made nails, which allowed for more efficient joints, faster construction, and standardized components (Eren, 2015)

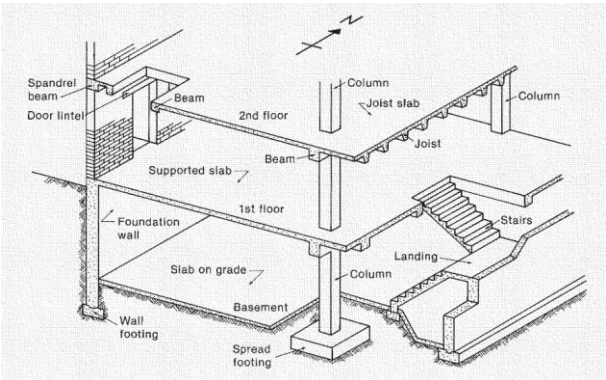


Fig. 1. Reinforced Concrete System (Wight, 2016)

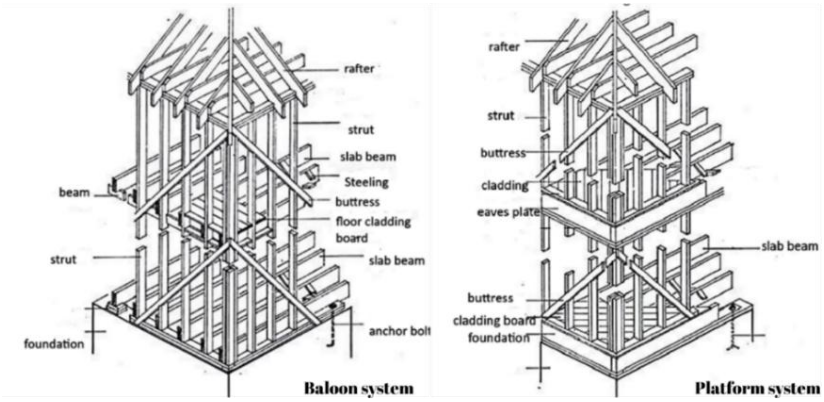


Fig. 2. Platform System and Baloon System (Eren, 2015)

In frame systems, wall and floor elements are assembled on site. These systems are classified as either single base or double base, depending on how they connect to the foundation (Çakır, 2000, as cited in Yıldırım, 2010). In platform frame systems, one story wall panels are prefabricated for each floor using a standard method. Timber studs are evenly spaced and covered, forming strong, continuous load-bearing walls. This approach boosts both strength and construction speed (Çakır, 2000; Avlar, 2002; Chiuini & Underwood, 2007; Götz et al., 1989, as cited in Yıldırım, 2010).

Balloon frame systems, an early form of the advanced timber system, feature slender, closely spaced uprights running continuously from foundation to roof. Although initially praised for their lightweight nature, balloon frames declined due to fire risks and construction challenges associated with lengthy uprights (Eren, 2015). Fig. 2 illustrates the schematics of the balloon and platform systems.

Both conventional and modern systems require metal fasteners for joint integrity. Conventional joints suffered from strength loss due to material removal at connections, whereas today, adhesives and threaded plates, albeit limited to factory conditions, improve joint performance. Nevertheless, simple mechanical fixings generally suffice in timber construction (Eren, 2015).

3.3 Structural Steel Systems

The use of metal materials as load bearing elements became widespread in the first half of the 19th century; in the previous period, metals primarily served as connection components. The Severn Bridge, completed in England in the late 18th century, is recognized as the first structure made entirely of metal. While steel was initially preferred for commercial buildings, it soon found widespread use in housing as well. This shift was largely due to its ability to span long distances, offer slender and durable sections, remain lightweight, and allow for efficient heat conduction. Additionally, since steel components were produced in factories and assembled on-site, construction times were significantly reduced. Thanks to dry assembly, construction was unaffected by weather conditions, and the need for site space was minimized. After the completion of the structure, steel frames could also be adapted to new functions, thus extending the service life of the building (Eren, 2015). The connection technology of steel structures also evolved over time. Riveting was widely used in the 1920s and was displaced by bolting in the 1930s. In the 1950s, welding in workshops became established, followed by on-site welding in the 1970s. In the 1990s, controlled on-site welding and other systems of connection began to appear. Most common types of connections today are bolted connections, which are friction-dependent, bolt shear and bearing, and welded connections, which consist of full or partial penetration grooves and fillet welds (Design and Construction of Structural Steel Work, 2021). Steel construction eliminates the need for formwork and scaffolding, allowing for smaller foundations. It can be reused even on weak ground, offers greater flexibility in architectural design, and enhances the visual appeal of buildings. Its lightweight nature makes it suitable for high-rise structures, while its earthquake resistance ensures safety in seismic regions. In addition, steel speeds up the construction process, facilitates on-site inspections, and allows for later transportation and modifications. Being 100% recyclable, it also supports sustainability, and it can be used to strengthen structures when necessary (Türk Yapısal Çelik Derneği, 2020).

4. Lightweight Steel Construction

Two types of structural systems are used in steel structures: one is the widely preferred system consisting of hot-rolled heavy steel structural members, and the other is the light steel structural system consisting of cold-formed thin-walled steel profiles, which is increasingly being used. The definition of “light” is related to the thinner cross-sections of the elements and components used in the construction. Light steel structures are completely different from steel frame structures in terms of the profiles used and structural system features (Ozcan, 2005).

Stainless steel cold formed sections are commonly used for structural components where the focus is on material efficiency rather than high strength. This construction method is cost effective, offering a high production potential with minimal investment in manufacturing technology. Cold formed sections are created from flat sheets, typically using two main techniques: press braking and roll forming. Press braking works best for simple shapes and smaller quantities, making it ideal for prototyping. Roll forming, on the other hand, is perfect for producing larger quantities and more intricate shapes. As illustrated in Fig. 3, the roll forming machine is used in the production process, and Fig. 4 presents the most common section profiles.

The light steel system is a construction method where structural elements, such as wall panels, roof panels, and floor beams, are pre-fabricated in factories and then assembled on site. The elements of the light steel system work both independently and in combination with supporting components to form a complete structural system. Due to its durability and fast installation process, the light steel system is a preferred choice for projects requiring efficiency, strength, and quick turnaround times (Ozcan, 2005).

Steel consists of 0.16–0.20% carbon and the remainder is iron; as the carbon content increases, hardness also increases. It also contains nitrogen, phosphorus, silicon, copper, and manganese; with the addition of nickel, chromium, molybdenum, and vanadium, high-quality alloys are obtained. Compared to structural steel, light steel has lower carbon content and strength because it is produced from softer alloys suitable for cold forming; its profiles and sheet thicknesses are thinner. Therefore, in the light steel system, all walls are load-bearing (Özcan, 2005). The light steel system is similar to the timber construction system consisting of load-bearing walls; horizontal floor and roof beams, along with vertical interior and exterior walls, carry all the loads of the building. Galvanized thin-walled profiles are reinforced to withstand both horizontal and vertical loads. Connection elements, cross bracing, and sheathing panels provide additional rigidity to the structure (Yıldırım, 2010). Standard-section light steel panels are designed to match the dimensions of 5 cm thick structural timber (Eren, 2015). Because of their limited spanning capacity, light steel elements are generally more suitable for residential and low-rise buildings. Their easy manufacturing, transportation, rapid assembly, and low dead loads make them particularly advantageous for smaller projects. On the other hand, conventional heavy steel systems, which are perfect for large spans and high rise structures, are not cost effective for smaller buildings and demand more complex organization and skilled labor (Ekinci, 2006).

4.1 History of Light Steel Systems

Cold formed steel structural members have been used for over a century, with their application expanding significantly in the last few decades. These members are highly versatile, allowing for optimization in size and design. This flexibility brings both theoretical and practical design challenges, but also offers innovative solutions. The growing use of cold formed steel is driven by improved understanding of its behavior, the availability of design standards and suitable materials, and the increasing demands of the construction industry (Baehre et al., 1982).

Initially used in interior partition systems and as roof supporting beams (purlins) due to their light weight, cold-formed steel profiles gradually became widespread in simple building and roof systems in industrial structures and recreational facilities. The first technical studies on cold-formed steel began in the 1930s in the United States, and the first standards prepared by AISI were developed by 1946. In the post-World War II periodesearch on light steel structures expanded, particularly in Japan, Germany, and Scandinavian countries, with the first use of this technology occurring in Germany by the late 1950s. In the 1980s, the light steel frame system reached its current form. During the same period in the United States, with the increasing demand for wood and rising costs, light steel houses began to replace conventional timber frame structures thanks to advantages such as portability and 100% recyclability of light steel. Today, approximately 20% of single and multi-story buildings in the United States are constructed with light steel frame systems. While these developments also continued outside the United States, especially in Australia and Canada, the sector did not develop at the same rate in Europe due to the existing building stock being largely completed and the relatively lower housing demand. Today, the light steel industry has reached its most advanced level in the United States (Mimarlar Odası İzmir Şube, 2006).

With the development of production techniques that made the use of cold formed steel profiles possible in the construction sector, this material also started to find a place in building construction. With the introduction of light steel into the sector, the use of cold formed panels became widespread in building components such as roof coverings and floor reinforcements. In addition, both cold formed and pressed profiles were developed for curtain wall cladding, beam systems, and formwork elements. The first applications of these materials were seen in simple, fire resistant film studio buildings constructed in the United States and the United Kingdom. During this period, the Lowell House designed by Richard Neutra attracted attention by being completed in a very short time based on the principles of the light steel system; this prefabricated light steel building, introduced at an exhibition in Chicago in 1933, stood out for its similarity to the timber platform frame system. Following these developments, the light steel system became a common construction method in the United States in the pre-World War II period (Eren, 2015).

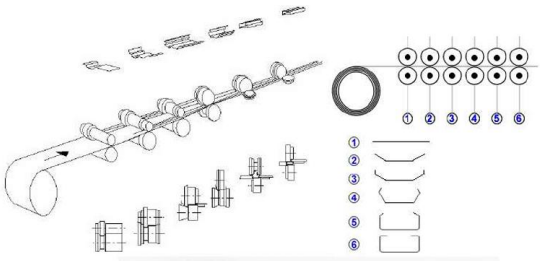


Fig. 3. Roll Form Machine (Mendes, 2019)

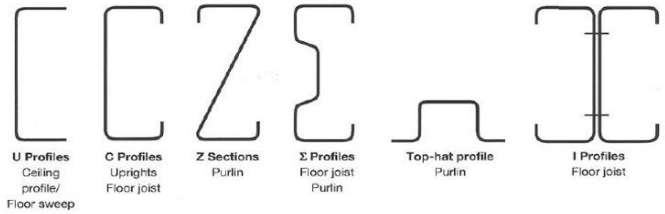


Fig. 4. Most Common Section Profiles (Mendes, 2019)

4.2 System Design

In light steel building systems, the plan geometry is of great importance in terms of the behavior of the load bearing system. The most suitable plan types are square or rectangular plans where the load bearing walls are placed at right angles. This arrangement simplifies the connections and increases the stability of the structure.

Sloped or curved plans can also be applied according to architectural requirements; however, in such arrangements, connection points and load-bearing behavior must be carefully addressed.

According to the AISI (1995) standard, the spacing of steel studs in load bearing walls should not exceed 60 cm, and floor joists should be aligned on the same axis as the wall studs. Especially in cases where joists are placed at an angle to the wall plane, the spacing should be tightened. In corner joints that are not at right angles, structural continuity should be ensured by using special profiles (Yıldırım, 2010). In walls with curved plans, the header profiles are bent according to the curved form. Flexible, standard compliant elements such as "Contour track" or "Flex-C track" have been developed to reduce buckling that may occur during this process. However, if the cladding material does not adapt to the curvature, loss of rigidity and visual distortions may occur. Therefore, for curved walls, a minimum radius of 12 meters and a maximum stud spacing of 3 meters are recommended. OSB, gypsum board, and laminated wood can be used for cladding (Yıldırım, 2010).

In light steel structures, facade design is a critical component not only in terms of aesthetics but also in terms of load bearing capacity. Since facade walls serve as load bearing elements in these systems, the placement, size, geometry, and cladding details of openings directly affect the structural performance. While the load bearing system determines the facade design, elements such as the possibility of leaving openings, their dimensions and forms, and the texture of the cladding material are considered as fundamental design criteria. Openings in walls can be arranged according to architectural requirements; in such cases, the stud spacing can be narrowed depending on the system module. However, since walls in light steel systems serve as load bearing elements, such interven-

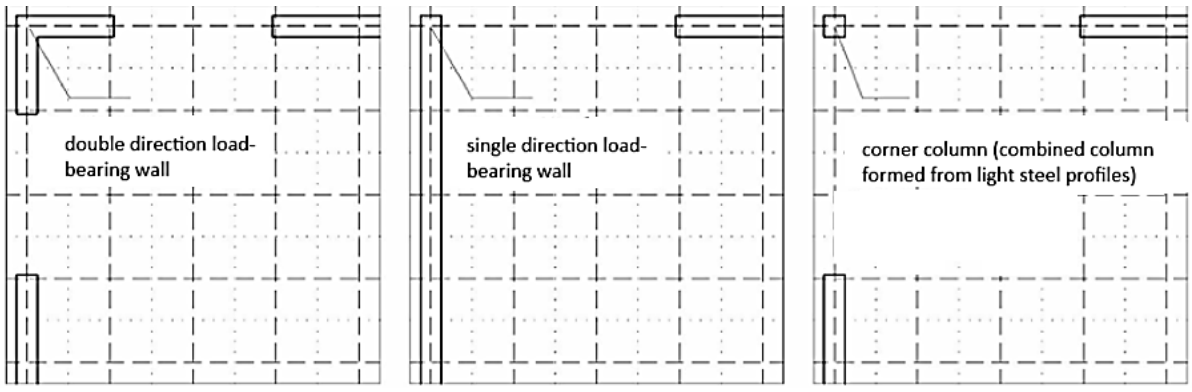


Fig. 5. Examples Of Load-Bearing Walls On Facade (Yıldırım, 2010).

tions must be planned in a way that does not affect the load bearing capacity. Since the profiles are usually placed behind the cladding, the structural system remains hidden from the outside, giving the facade a mostly solid appearance. Similar to masonry buildings, large wall openings can weaken the structure, so light steel systems also tend to feature wide surfaces with smaller openings. However, instead of using load-bearing facade walls, it is also possible to use rigid light steel frames that carry loads through moment transfer. In these systems, the frame itself provides rigidity without relying on diagonal bracing or cladding panels. In cases that require greater stiffness, the studs can be designed as box (composite) sections. When diagonal bracing is used, wall openings are not possible in those areas, so the placement of bracing elements must be planned with both structural stability and facade design in mind Yıldırım, 2010).

Corner points are among the most critical areas in terms of structural rigidity. Therefore, the principles of light steel systems do not recommend creating openings at corner points. Just like in masonry systems, these regions, where load bearing walls support each other, provide resistance especially against horizontal loads. If an opening must be created at a corner, the load-bearing capacity should be ensured by a moment resisting steel frame, and the studs at the connection points should be designed as composite sections and columns. As shown in Fig. 5, various design methods for corner windows in light steel structures are presented.

The shape and orientation of openings on the facade also affect the structural behavior. In particular, openings that extend horizontally with limited height reduce the resistance of load bearing walls against horizontal loads. This is because such openings interrupt the transfer of diagonal loads and weaken the walls' ability to carry shear forces. As a result, buckling and shear effects may occur in the studs near the openings (Yıldırım, 2010).

4.3 Materials Used in Lightweight Steel Structural Systems

The materials used in light steel structural systems both enhance structural strength and meet performance criteria such as thermal and acoustic insulation. In these systems, structural sheathing materials can be used as alternatives to horizontal and diagonal bracing; however, this choice must be considered during the early stages of design. Materials such as Oriented Strand Board (OSB) and plywood stand out for structural sheathing purposes. It is recommended that OSB Class 3 panels have a minimum thickness of 11 mm, and plywood panels at least 12 mm; during installation, self-drilling screws should be used at intervals of no more than 20 cm along the edges and 30 cm in the middle areas. According to findings from the NAHB Research Center, materials like OSB, plywood, or gypsum board provide more effective support for the buckling resistance of steel studs compared to bracing methods. Reducing the screw spacing creates more contact points on the steel profiles, thereby increasing this resistance; moreover, sheathing panels with a 2:1 aspect ratio contribute higher strength compared to those with a 4:1 ratio. However, as the screw spacing decreases, the impact of this ratio difference on structural strength diminishes.

According to North American standards, the thicknesses of OSB panels used in light steel structures vary depending on their area of application. For structural sheathing in load bearing walls, a minimum thickness of 9 mm is recommended; for floor substrates, 18 mm; for bottom sheathing of roof trusses, again a minimum of 9 mm; and for flat roofs or attic spaces, panels with a thickness of 18 mm are advised (Akay, 2013). OSB and gypsum boards, which are widely used in light steel systems, have a broad range of applications from exterior facades to roof surfaces and floor coverings. OSB is a moisture-resistant, high strength panel that has become a widely used alternative to plywood around the world (Yıldırım, 2010). It is not only suitable for exterior facades but also works well on interior walls where heavy furniture or decorative elements need to be mounted (Mendes, 2019). OSB panels are made by pressing wood strands, each about 10 cm long, into layers with each layer oriented perpendicular to the one below. In light steel structural systems, they are especially valued for sheathing and providing rigidity. Their light weight, ease of transport and cutting, and ability to be screwed into easily make them highly practical during construction.

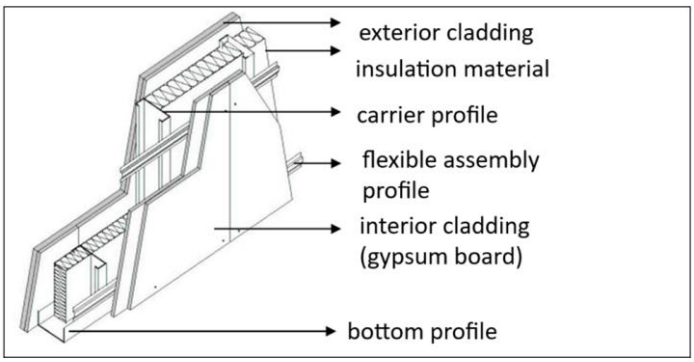


Fig. 6. Light Steel Wall Section (Ekinci, 2006)

Designed to withstand harsh weather conditions, these panels simplify exterior facade applications and are capable of carrying heavy loads such as furniture and decorative objects. In addition to providing structural strength, they also offer thermal insulation, making them a versatile material. Thanks to their high performance in horizontal applications, they help distribute stresses evenly within structures, thereby increasing stability. Shear tests have shown that OSB panels significantly enhance the ductility and stability of wall systems.

According to the EN 300 standard, OSB panels are divided into four classes based on their usage conditions and mechanical properties: OSB/1 panels are used for general purpose interior decoration and furniture in dry environments, while OSB/2 panels are suitable for structural use in dry environments. OSB/3 panels are recommended for structural use in humid environments, and OSB/4 panels are preferred for applications requiring high structural performance in humid conditions. Today, OSB/3 class panels are widely used in light steel systems due to their superior performance against weather conditions during the construction process (Mendes, 2019).

Another wood based material, cross laminated timber (CLT), was developed in Germany by Friedrich Otto Hetzer in the 20th century. This material is produced by gluing together layers of wooden lamellae arranged in crosswise directions, preserving the natural properties of the wood while eliminating internal defects. Due to its layered structure, stress is distributed more evenly across the surface instead of concentrating at specific points, giving the material a more homogeneous load-bearing capacity.

Another material is composite panels, which are produced by combining wood particles with Portland cement and shaping them through pressing. These panels combine the flexibility of wood with the durability of cement, and are used in both interior and exterior cladding applications, offering high resistance to impacts, fire, sound, moisture, and fungal attacks. However, they also have disadvantages such as high cost, heavy weight, and the need for wider metal profiles during installation. Moreover, due to their rigid structure, they can be prone to cracking (Mendes, 2019).

Non-structural cladding materials are also widely used in light steel systems. This group includes non-standard OSB panels, as well as gypsum boards, which are particularly preferred for interior cladding and decorative finishing layers. Gypsum boards are produced by placing a gypsum-based mixture between two layers of paper, and depending on the additives used, they can be applied in different environmental conditions. Commonly used for interior walls and ceiling applications, these panels can be mounted directly onto the steel frame or on top of OSB panels; their joints are sealed with tape to prepare the surface for paint or ceramic finishes. Isolpro panels, produced from a mixture of lightweight concrete and polystyrene, provide thermal and acoustic insulation and can be adapted for a variety of surface applications on interior and exterior walls, floors, and façades.

In Turkey, gypsum boards are commonly applied on the interior surfaces of external walls, on both faces of internal partition walls, and on ceilings. Insulation materials such as glass wool or rock wool are placed behind these boards to provide both thermal and acoustic insulation. Manufactured in compliance with the TS EN 520 standard by companies such as Knauf, Lafarge-Dalsan, and ABS, these products include the ALB type, white in color, used for interior spaces, and the moisture-resistant ALY type, green in color, used in wet areas and exterior applications. For curved surfaces, 6 mm thick boards are shaped with water before installation. Both OSB panels and gypsum boards can be used for structural sheathing purposes; however, OSB panels offer a higher degree of stability (Akay, 2013). The typical configuration of a light steel wall section is illustrated in Fig. 6.

Another fundamental material used in light steel structures is mineral stone wool. Since steel does not naturally provide thermal insulation, this deficiency is compensated by filling materials. In the panels, profiles are placed at 60 cm intervals with a maximum thickness of 1.5 mm, limiting the formation of thermal bridges to only the areas where steel is directly present. The surface area ratio of these thermal bridges is a maximum of 0.375%, while all remaining areas are insulated with stone wool. In addition to this insulation, polystyrene-based cladding is commonly applied on facades to ensure waterproofing and eliminate thermal bridges. Due to the low thermal mass in light steel systems, HVAC systems become effective in a short time, allowing the indoor climate to be rapidly adjusted without waiting for walls to heat up or cool down. This results in lower energy consumption compared to conventional buildings.

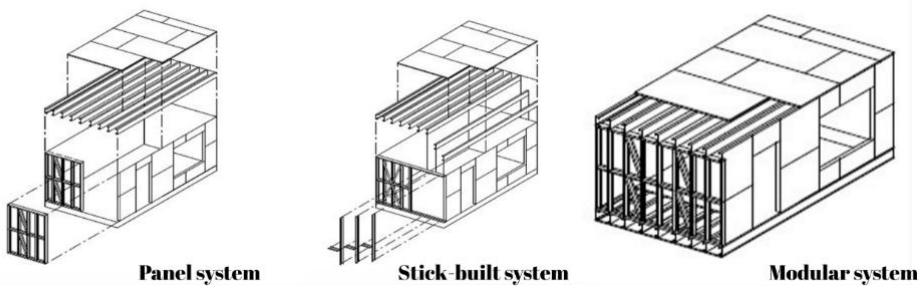


Fig. 7. Panel System, Stick Built System, Modular System (Mendes, 2019)



Fig. 8. Modular Construction (Lawson et al., 2008)

Moreover, stone wool significantly contributes to sound insulation. The use of high-density materials together with low density layers enhances acoustic performance; thanks to the multilayered panel structure, while OSB and gypsum board applications provide structural support, stone wool plays a key role in resonance reduction and sound damping. This combination provides sound insulation up to three times better than conventional construction methods (Mendes, 2019).

4.4 Lightweight Steel System Construction Techniques

The light steel system has attracted the attention of many organizations worldwide and has become an increasingly widespread construction method thanks to its ease of production, clean site conditions enabling fast assembly, waste-free structure, and cost advantages that can compete with reinforced concrete. In light steel residential construction, three primary assembly methods are employed: the bar (stick-built) system, the panel system, and the modular system, as illustrated in Fig. 7.

Among these systems, the panel construction method stands out as the most widely adopted technique. Profiles are manufactured in factory settings according to project-specific dimensions and transported to the construction site as wall, roof, and floor panels. These panels are then assembled on a pre-prepared foundation. The lightweight nature of the panels significantly eases the transportation and installation processes (Eğitmen, 2013). Compared to the bar (stick) system, the panel system offers a fourfold faster assembly process (Özcan, 2005). Furthermore, it enables uninterrupted work regardless of weather conditions, thereby ensuring the timely completion of projects, and eliminates deformation risks such as shrinkage, swelling, and warping commonly encountered in conventional materials like wood. The integration of door and window openings during the panel production stage further reduces on-site assembly time. Factory-based production enhances quality control and dimensional accuracy while minimizing the need for site labor and promoting greater automation opportunities. In addition, compared to on-site production, it offers a fivefold safer working environment, providing significant advantages in terms of occupational health and safety. Panels manufactured in controlled factory environments deliver high geometric precision and reliability (Grubb et al., n.d.).

Another method employed in the production of light steel structures is the stick-built system. In this construction technique, profiles prepared to the full story height are transported to the construction site, and the assembly operations are carried out directly on-site. Compared to modular and panel systems, this method generally results in a longer construction period. Moreover, if the galvanization on the profiles is damaged during transport or processing, the affected areas must be recoated with anti-corrosion paint (Eğitmen, 2013). In this method, panels are assembled piece by piece on-site, and then surface cladding and other components like insulation are added. The profiles come with pre-punched holes, which makes installation easier. The stick-built system also offers flexibility, as changes can be made during construction. Unlike modular systems, it does not require manufacturers to invest in a dedicated factory, which significantly reduces initial costs (Yandzio et al., 2015). Another construction method is the modular building system. According to Terim (2006), this system was promoted globally by the United Kingdom and several major companies. To enhance fire resistance, special

thermal insulation solutions have been developed specifically for modular elements. Moreover, by using additional connection components, it is possible to construct buildings up to six stories high within this system (Mimarlar Odası İzmir Şubesi, 2006). The modular units are transported by crane and stacked on top of each other, with the entire system stabilized through steel cables or tensioning elements. This method stands out due to its rapid assembly within 2–3 days and the transportable and reusable design of its modules (Eğitmen, 2013). In this construction method, units are completed in the factory and then transported to the site for horizontal and vertical assembly (Yandzio et al., 2015). Especially in large-scale productions, it is considered the most cost-effective system because fixed costs such as prototyping and assembly, which are independent of scale, can be spread across many units. Additionally, conducting production off-site provides a significant advantage in terms of occupational health and safety, as it is five times safer compared to on-site construction. The world's largest structure built with the modular system, consisting of approximately 1,400 modules, is located in Manchester, and its visual representation is provided in Fig. 8 (Lawson et al., 2008).

The elements used in the assembly of light steel structural systems are important in terms of strength, economy, and production speed. Assembly elements and methods can be classified as fasteners such as screws and bolts, spot welds and rivets, and anchorage elements. Screws and bolts are removable fastening tools, whereas spot welding, riveting, and welding processes are non-removable fastening methods. Anchorage operations are generally performed by fixing light steel structural profiles to reinforced concrete foundations.

Welded joints are not typically used in light steel systems since they ruin galvanized coatings and quality cannot be guaranteed under site conditions. Heavy equipment requirements and extended application time also make welding less convenient. In addition, replacement and dismantling are not practical with welded joints. Spot welding is also not ideal since it ruins the galvanized surface and reusability is not practical. Alternatively, bolted connections are also commonly used. They offer efficient assembly of light steel elements with reinforced concrete or other steel elements. In light steel systems, bolted connections are commonly used to join light steel elements to reinforced concrete or other steel components (Yıldırım, 2010). When connecting steel profiles to OSB panels, the screw heads should have a minimum diameter of 7mm and must be countersunk into the OSB to prevent any protrusions that could affect the surface finish. Since OSB panels serve a structural function, screws should be placed at least 9mm from the panel edges. Additionally, the spacing between screws should be carefully calculated to ensure the stability of shear walls under horizontal loads (Mendes, 2019).

5. Lightweight Steel System Practices in Selected Regions

In Europe, cold-formed profiles have primarily been used as purlins or beams since the 1950s, and were later incorporated into various structural applications such as columns, wall studs, primary load-bearing elements, and roof trusses. The fact that cold-formed steel became more economical compared to timber and hot-rolled steel accelerated this trend (Baehre, 1982). During the 1970s, the use of high-yield-strength steels and deep sections became widespread to enhance load-bearing capacity, while longitudinal and transverse profile shaping techniques were developed. In the same period, the "stress skin" design, where the surface bears horizontal loads, also provided economic advantages. In Western Europe, especially in the United Kingdom and Scandinavian countries, Cold-Formed Steel (CFS) is frequently employed in multi-storey residential buildings. In these structures, CFS panels reinforced with OSB are applied in combination with dry materials or lightweight concrete. Within the EU, manufacturers are heavily investing in R&D activities focused on CFS solutions for multi-storey structures. It is noted that the Spanish company Teccon Evolution has obtained a European Technical Approval for this system. A study conducted in the United Kingdom found that the Metsec SFS system was 39% more cost-effective than conventional block walls, offering additional advantages such as reduced labor costs, environmental benefits, and quicker project completion (Nagy & Dubina, 2011).

In the North American residential market, light steel structures account for 20% of the share. They are commonly used in the construction of single or two storey villa type homes, especially in earthquake-prone areas like California, where cold-formed C-section steel profiles are typically employed. Rising timber prices and the growth of the supporting industry have made steel-framed housing an economically viable alternative (Wang et al., 2014).

Cold-formed steel elements are produced using C and Z section profiles and are typically applied in the form of either attached or detached structures. Due to inadequate sound insulation, their use in multi-storey buildings remains limited. Two main methods are employed to resist lateral loads and seismic effects: the first involves light steel shear walls formed with gypsum boards and galvanized steel sheets, and the second utilizes diagonal steel bracing elements. Vertical loads are carried by the light steel structure, while horizontal loads are resisted by conventional steel bracing. Additionally, placing glass wool within the wall studs and floor joists effectively interrupts thermal bridges, thereby providing thermal insulation (Wang et al., 2014).

CFS systems are also used in multi-storey buildings through structural shear wall panels, load-bearing wall panels, and floor/roof panels. In Canada, Bayley Metal Products constructed the six-story Kingsway Arms

Retirement Home, 9,890 m², with this system. Steelform developed a unique solution named the "Mega Joist" to provide additional structural support for the wall beams and intermediate floors. Moreover, in 2007, the American Iron and Steel Institute (AISI) published the first seismic design standard specifically for CFS structures (Nagy & Dubina, 2011).

Japan has shown significant interest in light steel structures due to its high seismic risk. Structures known as "Sheet Steel Housing" are constructed using box-shaped steel panels and floor systems. Steel sheets with a thickness of 1.0 mm are utilized, and both surfaces are covered with gypsum boards to provide durability, stability, thermal, and acoustic insulation. The use of timber has been limited due to its combustibility and the long reconstruction time required after disasters, while the preference for steel has also increased as part of efforts to preserve forests. In 2000, 70% of residential buildings in Japan were made of steel, 19% of wood, and 11% of reinforced concrete. The production of cold-formed steel has risen since the 1950s, and by 1980, 70% of these products were being used in the construction sector (Nagy & Dubina, 2011). Following the 1995 Hanshin earthquake, approximately 50,000 temporary housing units were constructed, of which around 3,000 featured steel frames. In the same year, the Japanese Ministry of Construction published performance standards for steel-framed houses. In 1996, steel manufacturers initiated studies focusing on structural performance and insulation. By 2005, approximately 20,000 steel-framed houses had been constructed (Nagy & Dubina, 2011). The KC (Kozai Club) light steel construction system, introduced in 2000, was officially recognized with the publication of new regulations in 2001 and gained widespread acceptance in the market (Kawakami, 2008). In this system, fire, thermal, and sound insulation are provided by applying thermal insulation and ventilation layers on the exterior surfaces and gypsum board on the interior surfaces. In KC-type structures, wood based cladding materials are generally preferred; in three-story buildings, the ground floor is constructed with reinforced concrete, while the upper floors are built using a steel framing system. This type of structure provides 60 minutes of fire resistance. To achieve higher fire and seismic performance, Nippon Steel developed the "Nittetsu Super Frame" (NSF) system. Seismic safety is addressed in two stages: during moderate earthquakes, the focus is on maintaining structural rigidity, while during more severe seismic events, the ability to dissipate energy becomes crucial. When wood cladding is not sufficient, new ceramic-based panels with high rigidity and energy dissipation capacity have been introduced. In the NSF system, floors are built using the platform framing method, and interstory deformation is prevented by high-rigidity connectors. The system received official structural performance approvals in 2005 and 2007. Moreover, in line with ISO 834 standards, fire insulation for cladding elements is achieved through the "membrane method," which protects against fire temperatures up to 945°C.

While light steel construction systems have reached usage rates of up to 20% in the housing sector in Western countries, this rate remains below 1% in Türkiye. This situation reveals that industry stakeholders in Türkiye have not shown sufficient interest in light steel systems (Türk Yapısal Çelik Derneği, 2020). In Turkey, light steel systems are generally applied as panel systems, and these systems are referred to as prefabricated structures. Around 80–90% of prefabricated construction companies utilize this system (İMO Eskişehir Şubesi, 2020, as cited in Fenli & Ünal, 2023). In addition, the on-site cladding system, in which panels are assembled directly at the construction site, is also widely preferred (Seçkin, 2022, as cited in Fenli & Ünal, 2023). In terms of design, the TS 11372 standard was followed until 2014. After this date, within the scope of harmonization with the European Union, the TS EN 1993-1-3 Eurocode 3 standard was adopted. Furthermore, the Turkish Building Earthquake Code, which came into force in 2019, includes a dedicated section for light steel structures and sets out the rules for sizing structural system elements. The regulation specifies that horizontal load-bearing systems must be designed either as “sheathing panel systems” or as “braced panel systems” (Fenli & Ünal, 2023). Fig. 9 illustrates the construction requirements for light steel structural systems as specified in the Turkish Building Earthquake Code. In practice, the production of steel structures consists of three main stages: the production of steel panels, the assembly of the load-bearing system, and cladding with OSB panels. All production and assembly processes are carried out in accordance with the project specifications, and the structure is anchored to the reinforced concrete foundation using steel anchors (Taşkıran, 2005, as cited in Fenli & Ünal, 2023).

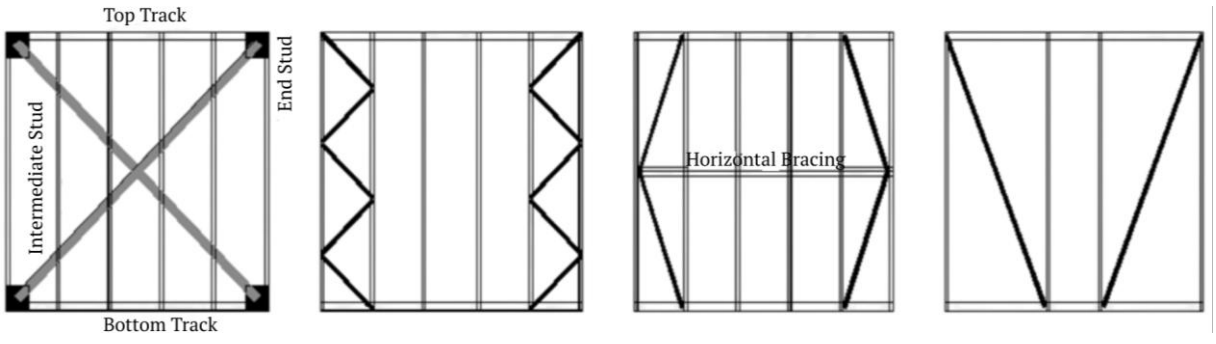


Fig. 9. Turkish Building Earthquake Code Light Steel Framing System (Çevre ve Şehircilik Bakanlığı, 2018)

6. Universal Design Codes

The development of standards for stainless steel structural design began with the American Iron and Steel Institute (AISI), which published the first specific standard in 1968 based on research conducted at Cornell University. This standard underwent revisions in 1974 and was later superseded by an American Society of Civil Engineers (ASCE) standard in 1991. In Europe, the Guide to the Design of Stainless Steel Structures, published by Euro Inox in 1994, was incorporated into Eurocode 3 in 1996. Japan and South Africa introduced their own standards in 1995 and 1997, respectively, while Australia and New Zealand followed with a standard in 2001. These initiatives established the global framework for stainless steel structural design (Gardner, 2005).

In Turkey, the regulation titled TS 11372, "Steel Structures - Lightweight - Formed with Cold-Formed Profiles - Rules of Calculation" came into force on April 28, 1994. This standard outlines calculation rules based on elastic theory for sizing thin-walled elements produced by cold-forming structural steel plates, intended for use as load-bearing elements not subjected to significant impact loads. After 1999, the use of light gauge steel for permanent structures in Turkey became increasingly common. However, TS 11372 is not specifically tailored for light gauge steel; it applies more broadly to cold-formed steel elements within structures. The mention of "steels thicker than 4 mm" further emphasizes that the regulation was not designed with mild steel applications in mind (Öncü, 2010).

The AISI initiated early efforts for the use of cold-formed steel elements in construction as early as the 1930s. Recently, the CSA S136 standard developed by the Canadian Standards Association (CSA), widely used in Canada, was merged with AISI standards and is now implemented as the AISI - North American Standard (NAS). This unified standard is also referenced in countries lacking their own codes for light gauge steel structures (Öncü, 2010).

Eurocode 3, developed for the design of steel structures across Europe, dedicates its third part specifically to structures composed of cold-formed steel. Beyond Europe, Eurocode 3 is commonly used as a reference in African nations and parts of the Middle East. Furthermore, in Australia and New Zealand, where light steel construction is prevalent, a standard issued by the National Association of Steel-Framed Housing (NASH) is applied, and a joint-use agreement with Japan supports its implementation. Scandinavian countries are also actively conducting research and developing standards in the field of light gauge steel construction (Öncü, 2010).

6. Results and Discussion

CFS (Cold-Formed Steel) framed houses offer significant advantages in terms of environmental comfort and health. These houses maintain temperature balance with heating and cooling properties that enhance energy efficiency. Additionally, the steel used in CFS framing systems does not require additional protective chemicals and does not emit gases or volatile organic compounds, thereby improving indoor air quality. Steel is also resistant to mold and decay, which is an important factor for health. These structures offer healthier living conditions, energy efficiency, and sustainability.

The earthquake and fire resistance of CFS provides a major advantage, especially for regions with seismic and fire risks. Steel has the capacity to absorb energy and, with its flexibility, helps the structure sustain less damage during earthquakes. Light structures are less affected by earthquakes compared to conventional heavy structures, which increases the suitability of CFS for earthquake-prone regions. In steel frame systems, Framecad CFS profiles are securely connected with screws to form a robust structure. The long-term durability of these structures is based on the material quality and structural integrity.

The modular prefabrication method provides a significant advantage in accelerating construction processes and reducing labor costs. CFS enables the transportation of prefabricated components to the site, minimizing the need for labor and shortening construction time, thus making the construction process more efficient. Additionally, prefabrication improves construction quality and reduces site congestion and waste.
While the global adoption of CFS is significant in some regions, it remains limited in others. One of the main reasons for this is the lack of comparative analyses and comprehensive research on the performance of CFS framed building systems. However, the advantages offered by these systems hold substantial potential, especially in earthquake-prone areas. Steel structures provide a strong alternative to conventional methods, with their flexibility in architectural designs, recyclability, and sustainability.

7. Conclusion

This study has comprehensively examined the advantages of light steel frame systems compared to conventional construction methods in terms of sustainability, seismic performance, and economic efficiency. The prefabricated nature of these systems allows for faster construction processes and offers significant advantages, particularly in regions with high seismic risks. Moreover, the adoption of these systems is of great importance in meeting the rapid urban development requirements driven by increasing urbanization demands.
The global use of light steel systems is widespread in some regions while limited in others. One of the strongest aspects of these systems is their earthquake resistance, which is crucial in seismically active areas. Additionally, their flexibility in architectural design, recyclability, and low carbon emissions contribute to sustainability, making them an attractive alternative to conventional construction methods.

However, a major barrier to the widespread adoption of light steel frame systems is the lack of sufficient comparative analyses and the need for more comprehensive research on the global dissemination and performance of these systems. This study highlights the importance of addressing this knowledge gap and emphasizes the need for further research to promote the broader adoption of these systems. Looking ahead, it is expected that light steel frame systems will gain wider acceptance. Real-world applications and comprehensive studies will further demonstrate the benefits of these systems, and they will become a critical component in the urbanization process by offering sustainable, efficient, and resilient construction solutions.

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