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## The Age of Steel: The Transformation of the Nineteenth-Century Construction Industry

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## Abstract

*The building industry experienced a major shift in the 19th century, which was referred to as "The Age of Steel," due to various reasons. To begin with, technological advancements such as the Bessemer process and open-hearth technique reduced the cost and increased accessibility of steel for use in buildings. Moreover, the development of railroads facilitated efficient transportation of steel hence its wide application in construction projects. This change also had a significant influence on engineering and architectural design since steel's exceptional strength-to-weight ratio allowed for taller structures with more open spaces, leading to the creation of towering skyscrapers that became symbols of modernity and progress. Additionally, the use of steel in construction had major economic implications by boosting economic growth through job creation in the expanding construction sector and accelerating urbanization. Thus, technological advancements, transformative impact on design and economic benefits were responsible for the rise of steel as a building material making it a cornerstone of modern construction practices. To sum up, "The Age of Steel" was a turning point in the development of the building sector in the nineteenth century. Steel's extensive use transformed engineering and architectural design while promoting economic growth due to its greater affordability and efficiency. Our current built environment clearly demonstrates its legacy as we continue to use this amazing material to build buildings that define the skylines of our cities.*

**Keywords:** Steel ,19th century, Skyscrapers, Economic growth, Industrial Revolution

## 1. Introduction

With the invention of steel, the construction industry underwent a dramatic change in the nineteenth century in terms of both building design and construction methods. Known as the Age of Steel, this era signaled a dramatic shift from conventional building practices and materials, opening the door for previously unheard-of breakthroughs in engineering and architecture. The use of steel not only provided unmatched strength and durability but also increased design flexibility, allowing architects to construct previously unthinkable complex structures and towering skyscrapers [1], [2].

This study examines the major breakthroughs and inventions that defined this revolutionary period, demonstrating how the widespread use of steel altered the construction industry forever and left a lasting impression on the annals of architectural

history. The study concentrates that how this era influenced both the development of physical infrastructure and societal advancement, from the introduction of industry and mass production techniques to the appearance of iconic landmarks like the Eiffel Tower. We can better comprehend the Age of Steel's significant influence on contemporary building techniques and recognize its enduring legacy in forming our physical environment by looking at it from a historical perspective [3].

Steel was a key component in the construction industry's transformation in the 19th century, ushering in a period of invention, structural integrity, and architectural wonders. The following main ideas emphasize the significance of steel at that time:

- **Industrial Revolution Catalyst:** The Industrial Revolution and the advancement of steel were intimately related. The development of mass manufacturing and cost-cutting capabilities in steel manufacture contributed to the expansion of the construction sector [4].
- **Benefits for Structure:** Steel's remarkable tensile strength, resilience, and adaptability made it possible to build bigger, taller structures. Buildings with more elaborate and taller designs may be created by architects and engineers, something that was not possible with conventional building materials [4].
- **Iconic Landmarks:** Throughout the 19th century, notable structures that demonstrated the possibilities of steel were built which shows that steel has played a prominent role in shaping modern architecture and engineering. When the Eiffel Tower was finished in 1889, it served as a shining example of how steel could be used in building and still stand as a testament to the advancement of a country. Further, Golden Gate Bridge in United States and Sydney Harbour Bridge in Australia are the phenomenal landmarks of steel structure as well [6].
- **Building Bridges:** Steel was essential to the construction of bridges. Famous constructions such as the Brooklyn Bridge and the Forth Bridge in Scotland are truly an indication to the power of steel and proved that steel was the best material for connecting areas and crossing long distances [7].
- **Efficiency and Speed:** Steel was easy to fabricate and assemble, which sped up construction and cut expenses and project schedules. The speed and efficiency achieved lightweight material, prefabrication, and standardization, along with structural integrity, make steel an attractive choice in the construction industry [8].
- **Architectural Flexibility:** The use of steel allowed architects to experiment with avant-garde layouts that featured lots of windows, open areas, and elaborate facades. Structural steel has the ability to realize any design conceived by architects and structural engineers, spanning from basic and utilitarian structures to intricate and visually remarkable masterpieces. [9].
- **Urban Development:** Steel's influence on skyscrapers and urban infrastructure changed cityscapes and made it possible for contemporary cities to have tall skyscrapers. Moreover, the foundation of urban development relies on the requirement for strong and resilient constructions. Steel emerges as the fundamental element for smart cities infrastructure due to its long-lasting nature. Whether it's scrapers, bridges, or tunnels, steel offers the necessary structural strength to sustain the cutting-edge technologies that make cities smarter. [10].
- **Economic Impact:** The production of steel and its derivatives led to a notable expansion in the economy, resulting in the creation of jobs and a push for technological breakthroughs in building and metallurgy. According to a report by the world steel association (2019), the

global steel industry accounts for over 2 million direct jobs and approximately 20 million indirect jobs [11].

In the 19th-century construction sector, steel changed everything by opening up new avenues for architecture, making it possible to build famous buildings, and advancing society as a whole.

## 2. How the Introduction of Steel Revolutionized the Industry in the 19th Century?

The arrival of steel significantly transformed the 19th-century industry in multiple ways:

**Structural Strength:** Compared to more conventional building materials like stone and wood, steel was far stronger and more resilient. This made it possible to build bridges and buildings that were stronger and taller.

**Architectural Flexibility:** The strength and flexibility of steel allowed architects more artistic expression. They had the ability to create complex and inventive constructions that were unattainable with ordinary materials.

**Skyscrapers:** The development of steel allowed for the building of skyscrapers. The Flatiron Building in New York (1902) and the Home Insurance Building in Chicago (1885) are two well-known examples that symbolize the beginning of modern urban landscapes.

**Efficiency:** By using more efficient steel production and assembly techniques, building time and expenses were decreased. Building projects might be completed more quickly and ambitiously because to this efficiency.

**Transportation Infrastructure:** Steel played a pivotal role in the expansion of transportation networks. It enabled the construction of long-span bridges like the Brooklyn Bridge (1883), connecting previously inaccessible areas.

**Industrial Growth:** The steel industry itself flourished, creating jobs and stimulating economic growth. Steel production technologies advanced, making it more accessible for various applications [12].

**Iconic Landmarks:** The Eiffel Tower (1889) and the Statue of Liberty (1886) showcased the grandeur of steel construction and became symbols of progress and freedom.

By permitting the construction of larger, more inventive structures, encouraging urban development, and having a substantial impact on economic and industrial progress, the introduction of steel transformed the 19th-century industry.

## 3. Key Advancements and Innovations in Steel Production and Use

Several noteworthy developments in the manufacturing and application of steel during the 19th century revolutionized the building and industrial landscapes. These are a few significant developments:

**Bessemer Method:** The Bessemer process, developed in 1856 by Sir Henry Bessemer, involved forcing air through molten iron to extract impurities and producing high-quality steel in large quantities. Because of this invention, producing steel is now much less expensive and more widely available [13].

**Furnace without a fire:** The 1860s saw the development of the open-hearth furnace, which offered a flexible way to make steel. More control over the composition of steel was made possible, and higher-quality products resulted.

The creation of structural steel, which is distinguished by its extreme strength and endurance, made it possible to create substantial structures, bridges, and infrastructure. The potential of structural steel was demonstrated by notable constructions such as the Brooklyn Bridge.

**Railroads:** Steel was essential to the development of railroads. Transportation was transformed by steel tracks and locomotives, which increased its speed, effectiveness, and reach.

**Skyscrapers:** The capacity to build skyscrapers was made possible by the availability of steel, especially in the later part of the 19th century. Famous structures like Chicago's Home Insurance Building (1885) were some of the first skyscrapers to use steel frames.

**Mass Production:** Steel's employment in a variety of industries, such as shipbuilding, machinery, and weapons, was made possible by its mass production. Technology breakthroughs and industrial progress were fueled by this.

**Architectural Innovation:** Steel's strength and flexibility opened up new design possibilities for architects, leading to innovative architectural designs. Steel enabled the use of elaborate facades, expansive windows, and open areas as architectural elements [14].

**Economic Impact:** By generating jobs and promoting adjacent businesses, the steel industry emerged as a major force behind economic expansion. This had a significant effect on the economy in the 19th century.

The world as we know it now was drastically altered by significant breakthroughs and advances in steel production and use during the 19th century, which revolutionized the industrial, transportation, and building sectors [15].

#### **4. Famous People's and Engineers' Contributions to the Steel Industry**

The achievements of prominent people and engineers who were instrumental in the development of the steel industry are largely responsible for its prosperity. Here are some significant individuals and the work they did.

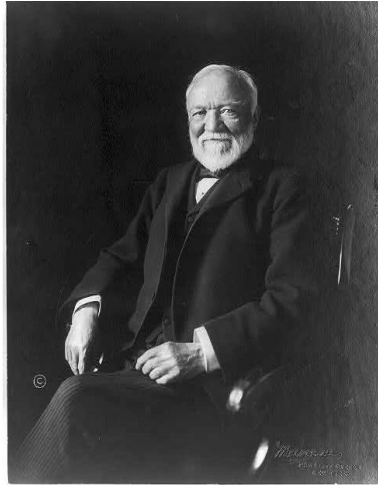
##### **Bessemer, Henry (1813–1898):**

Henry Bessemer is widely recognized for creating the Bessemer process in 1856. This innovative technique purged impurities from molten iron, enabling the mass manufacture of steel. Steel production became more affordable as a result, increasing its accessibility.



**Figure 1:** Bessemer, Henry, English Inventor [16]

**Carnegie Andrew (1835–1919):** Andrew Carnegie, a well-known industrialist, founded the Carnegie Steel Company, a significant participant in the steel sector. Steel became more affordable for a wider range of uses thanks to his vertical integration and economical production techniques. 2.1 Serviceability-Limit State



**Figure 2:** Carnegie Andrew, American Industrialist [17]

**William Kelly (1811–1888):**

Co-inventor of the Bessemer method: William Kelly independently created a comparable steelmaking method around the same time as Henry Bessemer is frequently credited with creating the Bessemer process. Their joint efforts helped this technology become widely used.



**Figure 3:** William Kelly, American Ironmaster

**Sir Robert Hadfield (1858–1940):**

The invention of manganese steel, renowned for its remarkable strength and wear resistance, was one of Sir Robert Hadfield's major contributions to the steel industry. This alloy was used in the railroad and mining industries.



**Figure 4:** Sir Robert Hadfield, English Metallurgist [19]

**Benjamin Huntsman (1704-1776):**

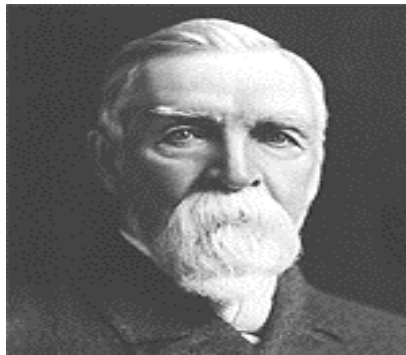
The high-quality steel known as "crucible steel" was created by Benjamin Huntsman (1704–1776), who is credited with its development. Crucible steel is made by melting steel. Steel was now of higher grade for a wider range of uses thanks to this breakthrough.



**Figure 5:** Benjamin Huntsman, English Inventor [20]

**John Fritz (1822–1913):**

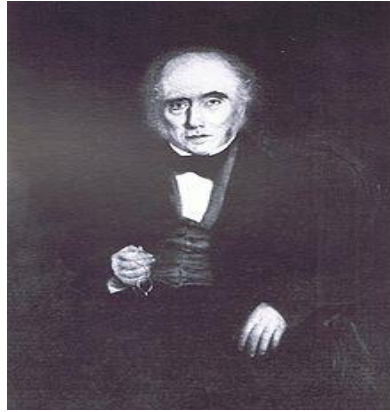
Innovations with Steel: John Fritz was a trailblazing engineer who significantly influenced the advancement of steel as a structural material. He was a major force behind the advancement of steel construction, especially in the US [14].



**Figure 6:** John Fritz, American pioneer of steel technology [14]

**Sir David Mushet (1772-1847):**

Improvements in Steel Alloys: Sir David Mushet (1772–1847) made significant contributions to the creation of steel alloys, increasing their sturdiness and strength. His contributions set the stage for additional developments in the steel industry.



**Figure 7:** Sir David Mushet, Scottish Engineer [22]

Through their inventions, leadership, and breakthroughs, these remarkable people and engineers made significant contributions to the advancement of the steel industry. The modern world has been profoundly impacted by their achievements, as steel continues to be an essential material for building, transportation, and manufacturing.

## **5. Development of Structural Steel and its Impact on Architecture and Infrastructure**

### **Development of Structural Steel:**

The Creation of Structural Steel: Initial Application although iron and steel have been used in construction for generations, a major shift occurred in the 19th century. Innovations like the Bessemer process, which increased the efficiency and affordability of steel production, marked the beginning of the widespread usage of structural steel [14].

**Bessemer process:** Henry Bessemer developed the Bessemer process in 1856, which made it possible to produce steel in large quantities. This process produced high-quality steel by forcing air through molten iron to eliminate impurities [13].

**Buildings and Bridges:** The advent of structural steel made it possible to build large-span bridges and skyscrapers. The Brooklyn Bridge in New York City and the Eiffel Tower in Paris are two famous examples.

### **Impact on Architecture and Infrastructure:**

**Skyscrapers:** Architects were able to design taller buildings with thinner walls because of structural steel's superior strength-to-weight ratio. As a result, skyscrapers proliferated and altered urban landscapes all over the world.

**Large-span constructions:** Bridges and stadiums are two examples of large-span constructions that were made possible by structural steel. These buildings offer vital connections for transportation as well as locations for sporting events and entertainment.

**Flexibility in Design:** Steel's strength and malleability allow engineers and architects to be creative in their designs. It permits curving surfaces, open floor designs, and creative architectural features.

**Cost-Effectiveness:** Using structural steel can frequently cut construction expenses and schedules. It's an affordable option for a lot of construction jobs.

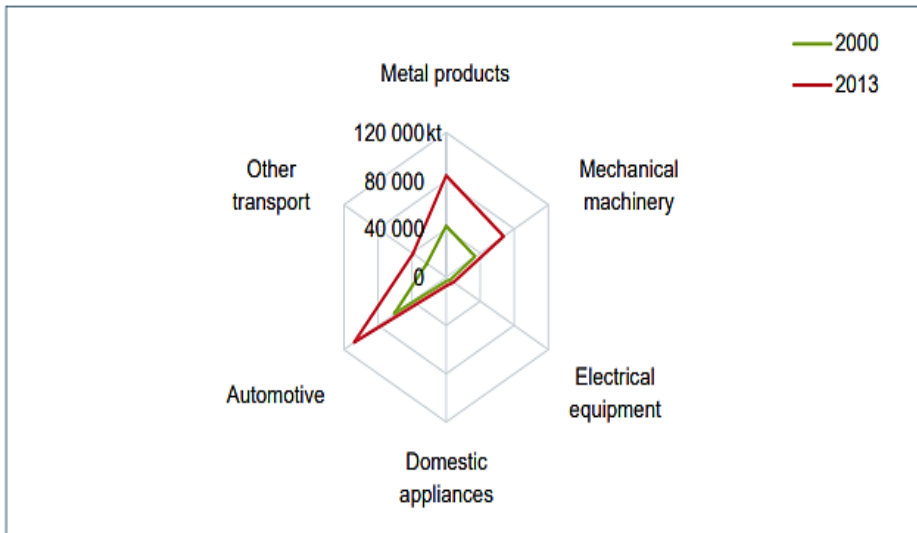


**Durability:** Steel buildings are renowned for their resilience to environmental changes and extended lifespan, which makes them perfect for infrastructure.

**Sustainability:** As a result of advancements in ecologically friendly steel production methods, sustainable building techniques are being adopted.

## 6. Analyzing the Economic Implications of the Steel Industry's Growth

The expansion of the steel industry during the 19th century had a huge impact on other industries and helped to shape the world economy. The composition of indirect steel exports in the world remained relatively stable between 2000 and 2013 across 74 countries analyzed. The automotive sector accounted for the largest share of indirect steel trade, representing 34% in 2013. Metal products comprised 27% of total indirect exports, while mechanical machinery accounted for 22%. Other transport sectors contributed 12% to the overall indirect exports. Electrical equipment made up 3% of the total, and domestic applications constituted 2% [23].



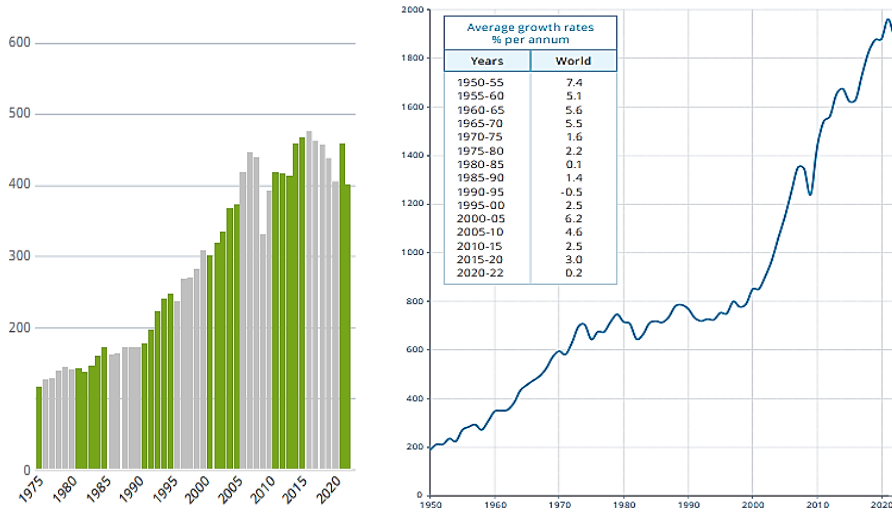
**Figure 8:** Indirect exports of steel, by sectors, thousand tones, finished steel equivalent, 2003 and 2013

The following examines the economic ramifications:

**Urbanization and Industrialization:** The steel sector was a major driver of industrialization. The availability of steel for infrastructure, railroads, and machines sped up the expansion of industry. Consequently, this resulted in a swift urbanization of the areas surrounding factories and steel mills, thereby generating employment prospects [24].

**Employment Creation:** The steel sector was a significant employer, supplying labor for the manufacturing, mining, transportation, and construction industries. It provided support for a sizable labor force, raising many people's standards of living and household incomes.

**Infrastructure Development:** A large number of infrastructure projects, including buildings, bridges, and railroads, were made possible by steel's affordability and strength. This infrastructure promoted trade and commerce in addition to bettering transportation, commercial connections and increased economic interdependence, having a significant impact on the world economy.



**Figure 9:** Statistics report of world steel production by Million Tones, World Steel Association [31]

competitiveness across other industries in addition to increasing industrial efficiency [25].

**Economic Diversification:** The economies of the regions with a strong steel sector saw diversification. Transportation, steel processing, and machinery manufacturing are examples of steel-related industries that support a strong economic environment [26].

**Infrastructure Investment:** To help the steel sector, governments and private investors provided a sizable amount of funding. As a result, there was a cycle of infrastructure investment that accelerated economic growth.

**Global Economic Influence:** Countries with strong steel industries developed become economic superpowers, shaping political and economic trends worldwide.

The expansion of the steel industry in the 19th century stimulated industrialization, employment creation, infrastructural growth, and international trade. It established the foundation for the current industrial and economic environment [12].

## 7. How Urban Development and Society Were Impacted by the Extensive Usage of Steel?

The extensive usage of steel in the 19th century had a significant impact on urban development and society, changing how people lived and how cities were laid out. This is an explanation of these effects:

**Skyscrapers and Modern Architecture:** The advent of structural steel made it possible to build skyscrapers, which completely changed urban environments. Tall skyscrapers shaped metropolitan skylines and became recognizable emblems of modernity and development.

**Population Growth:** Steel was more readily available for building, which resulted in the construction of stronger, taller structures. This served to accommodate the increasing number of individuals moving to cities in search of opportunities and work.

**Industrialization and Job Opportunities:** By attracting laborers and promoting economic expansion, steel mills and industries rose to prominence as important employers in metropolitan regions. There were plenty of work opportunities produced by the steel industry and adjacent sectors. [27]

**Better Transportation:** The building of railroads, bridges, and tunnels required the use of steel. This made it easier for people and products to move between cities and regions.

**Urban Expansion:** Steel buildings' strength allowed cities to grow and evolve. Urban centers expanded in size and complexity, while outdated infrastructure gave way to new.

Urban planning and transportation systems have advanced as a result of the steel industry's stimulation of engineering and building innovation.

**Economic Development:** Attracting investment and bolstering city prosperity, the steel sector emerged as a key economic force.

**Quality of Life:** Housing made of steel was safer and roomier. This provided better living circumstances and enhanced the quality of life for city people.

**Impact on Culture:** The extensive use of steel in urban development led to changes in culture by promoting modernism and a sense of progress.

The extensive usage of steel had far-reaching social and economic effects in addition to altering the physical appearance of cities. It created a lasting legacy in urban development and societal transformation by accelerating urbanization, enhancing living circumstances, and stimulating economic growth.

## **8. The 19th-Century Construction Industry Underwent a Remarkable Transformation Using Steel, with Several Key Developments**

**Skyscrapers:** The use of steel in building construction made it possible to create structures that were both structurally sound and taller. This invention marked a dramatic change in urban design by bringing about the era of skyscrapers, epitomized by famous buildings like the Home Insurance Building in Chicago (1885).

**Urbanization:** Steel construction enabled the development of high-rise buildings, which addressed the issues of urbanization and helped to accommodate the expanding urban population.

**Better Transportation:** The construction of steel railroads, tunnels, and bridges improved the nation's transportation system, spurring economic expansion and facilitating the flow of people and products more effectively. Steel's durability and adaptability gave architects the freedom to explore novel design possibilities. Modern architecture developed as a result of the emergence of creative architectural styles and skeleton frameworks.

**Economic Development:** The steel industry emerged as a primary force behind economic expansion, drawing capital, generating employment opportunities, and promoting industrialization.

**Better Living Conditions:** The extensive use of steel in building produced safer, cozier, and more roomy homes, which enhanced urban residents' quality of life.

**Impact on Culture:** The widespread use of steel in building led to a change in culture that encouraged modernism, optimism, and development.

The use of steel in the 19th-century building boom transformed urban environments, spurred economic expansion, and influenced modern design, all of which had a profound impact on how people lived and worked in metropolitan areas.

The use of steel to revolutionize the 19th-century construction sector left behind a deep and enduring legacy [28].

The use of steel to revolutionize the building industry in the 19th century has left a lasting legacy that continues to influence the cultural, economic, and physical landscapes of the modern world. It is evidence of the inventiveness of people and the long-lasting effects of advancements in building and material science [29].

## 9. How Did the Use of Steel in Construction Impact the Design of Buildings During the 19th Century?

Building architecture in the 19th century was greatly influenced by the usage of steel in construction. Because of steel's strength, flexibility, and durability, larger, more intricate buildings could be built, completely changing the era's architectural scene. The following are some ways that the 19th-century architectural design was influenced by the usage of steel:

1. **Higher skyscrapers:** Steel's strength and durability made it possible to build higher structures that could hold their weight, which in turn allowed for the construction of taller skyscrapers. The first tall structure using a steel frame was the Home Insurance Building in Chicago, which was finished in 1885 and helped to establish the precedent for skyscrapers [14], [15].
2. **Open Floor Plans:** The strength of steel made it possible to create huge, open areas without the need for load-bearing walls, which in turn aided in the development of open floor plans. This made it possible for architects to design rooms that were more versatile and adaptable, which helped to give rise to new architectural movements like modernism and art deco. [30], [15].
3. **Long-Span Roofs:** Steel's versatility and strength in constructing expansive, open areas for a range of uses were shown by the use of steel for long-span roof structures, such as market halls, rail sheds, and exhibition spaces [30].
4. **Innovative Structural Systems:** The building of intricate and audacious structures like the Eiffel Tower was made possible by the development of novel structural systems, such as the cantilever and suspension systems, which were made possible by the use of steel in construction [14], [15].
5. **Efficient building:** Steel's strength and flexibility made it possible to create prefabricated components that could be installed on-site, which allowed for faster and more efficient building processes. The 20th century saw an acceleration in commercial and industrial growth because of this [30], [14].

In conclusion, the 19th-century building boom made possible using steel had a profound effect on architectural design, allowing for the creation of larger, more intricate buildings with open floor plans, long span roofs, creative structural systems, and effective building techniques. These innovations changed the era's architectural scene and made it possible to build famous buildings that still amaze and inspire today.

## 10. Some of the Major Steel Structures Built During the 19th Century

Many significant steel buildings that were constructed in the 19th century demonstrate how steel revolutionized both architecture and construction. Several noteworthy structures are among them:

1. **Bridges:** Throughout the 19th century, a number of innovative steel-framed bridges were built, indicating a dramatic advancement in engineering and building techniques. The Forth Bridge, which was finished in the 1880s, is a famous illustration of a steel bridge that showed off the material's durability and adaptability in engineering projects [15].
2. **High-Rise Buildings:** In cities like New York and Chicago, steel was used more and more to construct the structural frames of high-rise commercial buildings. The 1883 construction of the Home Insurance Company Building in Chicago, which showcased the flexibility of open-plan interiors and allowed for the rapid construction of high-rise steel-framed buildings, was made possible by the use of Bessemer steel for the building's frame [14].
3. **Exhibition Spaces and Market Halls:** Bridges, train sheds, market halls, and exhibition spaces from the 19th century are the origins of the use of steel for long-span roof structures. These buildings showed how steel could be used to create large, open spaces for a variety of uses while maintaining its strength and adaptability [30].
4. **Industrial and Commercial Buildings:** Steel gained popularity in these types of buildings, allowing for the construction of substantial, long-lasting structures. These structures' use of steel promoted the expansion of trade and industry, which aided in both urbanization and economic development [28].

These significant steel buildings from the 19th century demonstrate how steel has revolutionized both architecture and construction by demonstrating its strength, adaptability, and capacity to produce strong, long-lasting structures.

## 11. Conclusion

The utilization of steel in the nineteenth-century construction sector brought about a significant change. During this time in history, steel's strength and adaptability replaced more conventional building materials like wood and stone. The extensive use of steel in building had far-reaching effects. It made it possible to build the famous skyscrapers, bridges, and other imposing constructions that shaped the contemporary world's metropolitan landscapes. Significant economic effects of this shift were also felt because of the thriving steel sector, which fueled both industrial development and economic success.

This change left a legacy that still exists today. City skylines are still dominated by skyscrapers, and steel is still a vital component of building and manufacturing. The Age of Steel brought out many advancements and architectural opportunities that still influence how we construct and design buildings today. Furthermore, steel construction's lasting cultural legacy bears witness to its influence on literature, the arts, and society.

In summary, the Age of Steel marked a significant shift in the history of construction as well as a historical era. The cities we live in, the buildings we respect, and the ongoing economic growth are all examples of its legacy. The use of steel to revolutionize the nineteenth-century construction sector is evidence of human creativity and its long-lasting influence on the built environment.

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