



Concepts and Functions in The Building Engineering

Journal homepage: <https://cfbejournal.abu.ac.ir/>



Economic and regulatory analysis of the use of three options: welding, bolting, or a combination thereof in steel structure connections (In residential, special and minor buildings)

Ebrahim Ahadi

DOI:

M.Sc. Student in Civil Engineering, Ahlul Bayt (a.s.) International University.

* Corresponding author: ebrahmahadi2@gmail.com

ARTICLE INFO

Article history:

Received: 15 September 2024

Revised: 26 October 2024

Accepted: 02 December 2024

Keywords:

Steel Structure, Steel Structure Connections, Welding, Bolting, Economic and Regulatory Analysis.

ABSTRACT

Steel structure connections act as key factors in the overall performance of structures, significantly impacting project cost, construction time, strength, and safety. Selecting the appropriate connection method—whether welded bolted or a combination thereof—depends on various factors, including the project type, environmental conditions, regulatory requirements, and technical specifications. This paper presents an economic and regulatory analysis of these three options. By examining the advantages and disadvantages of each method across different structural contexts, it provides recommendations for selecting the optimal connection method. The results indicate that welding is the optimal choice for complex projects subject to heavy loading, bolting is best suited for simple and cost-effective projects, and a combination of welding and bolting is ideal for specialized structures. Making the correct selection can significantly influence project efficiency, cost, and construction timelines..

E-ISSN: 000-000

© (2024). The Authors. Concepts and Functions in The Building Engineering by Ahlul Bayt International University.

How to cite this article:

E. Ahadi, (2024). M.Sc. Student in Civil Engineering, Ahlul Bayt (a.s.) International University, 1(2), 1-10. <https://>

Introduction

Steel structures are widely used as one of the key components in the construction industry due to their high strength, flexibility in design and fast execution capability. The role of connections in steel structures is of great importance; because the performance of the structure, its safety and stability directly depend on the quality and type of connections. Choosing the right method for connecting steel components not only affects the cost and time of the project, but also has a significant impact on the compliance of the structure with regulations and environmental conditions.

The three main methods for connecting steel components include welding, bolting, and a combination of these two methods, each of which has its own advantages, disadvantages, and applications. Welding is a suitable option for complex connections due to its high strength and proper structural integrity; however, its high cost, time-consuming nature, and sensitivity to environmental conditions are among its challenges. In contrast, bolts are preferred, especially for residential projects and low-value structures, due to their speed of execution, lower cost, and ease of maintenance. Combining welding and bolts is an innovative approach to benefit from the advantages of both methods, which is especially applicable in special structures and complex loadings..

From a regulatory perspective, reputable standards such as AISC[1], Eurocode[2] and the National Building Code of Iran have set precise criteria for the design and implementation of these connections. It is essential to check the compliance of connection methods with these codes to ensure the safety and efficiency of the structure. In this regard, environmental conditions, the type of project and available resources must also be considered so that the final choice is optimal and economical. According to economic analysis and review of regulations, the choice of connection method depends on the type of project. For residential buildings, bolts are recommended due to their economy and ease of implementation. In special buildings that require greater strength and safety, a combination of welding and bolts is the best option. Also, for less important buildings such as poultry houses, the use of bolts is recommended due to their low cost and ease of maintenance. These choices not only improve the performance of the structure, but also have a significant impact on reducing costs and project implementation time.

Ultimately, a civil engineer must make an informed, analytical decision, taking into account the specific needs of each project, budget and time constraints, as well as environmental and regulatory conditions. This article, by providing comprehensive analyses, can be used as a guide to selecting the appropriate connection method for various projects.

2.Connection methods in steel structures

1-2. Boil

Welding is one of the most common joining methods in steel structures, for which comprehensive guidelines are provided in Iranian regulations, including Chapter 10, Topic 10 of the National Building Regulations (Design and Implementation of Steel Structures). Welding is used especially in critical and complex connections because it creates proper integrity in the structure and effectively transfers loads.. The regulations emphasize weld quality, selection of appropriate electrodes, and adherence to design principles. Electrode specifications must be selected based on the type of steel and loading conditions, and this selection is detailed in the regulations. In addition, continuous monitoring of the welding process, quality control tests, a(such as non-destructive testing (UT and RT) and compliance with internationally recognized standards such as (AWS D1.1) are essential to ensure the quality and durability of the connection.

Environmental conditions are also another factor that is considered in the regulations. For example, in humid or low-temperature environments, the use of special welding methods and materials resistant to environmental conditions is recommended. However, welding requires advanced equipment and a skilled workforce, which can increase the cost and time of project implementation.

2-2. Screw

Bolted connections have a special place in the design of steel structures due to their speed of implementation, lower cost and ease of maintenance. The National Building Code of Iran has set precise criteria for the design, selection and installation of bolts. The bolts used in structural connections must have mechanical specifications in accordance with international standards such as ASTM A325 and ASTM A490 These screws are usually used in two categories: normal and high-strength, which are selected depending on the type of structure and loading.

One of the main advantages of bolted connections mentioned in the regulations is that they are easier to control and inspect than welding. This feature allows for the repair and replacement of defective parts. The regulations also recommend the use of galvanized bolts or corrosion-resistant coatings in corrosive environments to increase the durability of the structure. In the installation section, observing correct prestressing and ensuring the tightness of the connections are key issues explained in the regulations.

3-2. Combination of welding and bolting

The combination of welding and bolting methods, due to the advantages of both methods, is used in projects with complex loading and special conditions. The National Building Code of Iran has also provided guidelines for this type of

connection. In this method, welding is usually used to create initial integrity and transfer axial loads, and bolts are used to restrain shear and moment loads.

According to the regulations, the design and implementation of composite joints require careful coordination between welding standards and bolted joints. For example, the weld and bolt locations must be designed so that they do not negatively affect each other's performance. It is also essential to observe the appropriate distance between bolts and welds and select materials that are resistant to environmental conditions.

The challenges of this method, as mentioned in the regulations, include the time-consuming implementation process and the need for more detailed planning. However, this method can be a very effective and sustainable option in certain structures, such as bridges and heavy industrial structures.

In Iranian regulations, the main emphasis is on meeting quality requirements, safety, and matching connection methods to the type of project and environmental conditions. The choice between welding, bolting, or a combination of them depends on several factors such as the type of structure, loading, environmental conditions, and economic costs. The National Building Code assists civil engineers in selecting and implementing the best connection method by providing precise criteria and detailed instructions.

3. A review of economic considerations of connection methods

1-3. Welding: Costs and Economic Requirements

Welding is more economically expensive than other methods due to the need for advanced equipment, skilled labor, and strict quality controls. National regulations, especially in the section on cost management of construction projects, provide recommendations for optimizing welding costs. This includes the use of modern welding methods such as automatic welding. Submerged arc welding (SAW) is for reducing manpower and increasing productivity.

The cost of welding includes the purchase of electrodes, shielding gases, welding equipment, and quality control tests. Also, the longer lead time for welding compared to bolting can increase the overall cost of the project. However, the high strength of welded joints can reduce the need for maintenance in the long term, which is an economic advantage.

2-3. Bolted connections: an economical and cost-effective approach

Bolted connections are recognized as a more economical method compared to welding in many construction projects. Iranian regulations emphasize the selection of standard bolts and proper management of the installation process to minimize costs. Due to the high speed of execution and the reduction in the need for complex

equipment, bolted connections are a more suitable option in terms of time and implementation cost.

One of the economic advantages of this method is the possibility of mass production of pre-drilled parts in the factory and reducing installation time on the project site. Also, the ability to easily replace defective parts reduces maintenance costs. However, in projects with heavy loads or special conditions, the need for high-strength bolts and anti-corrosion coatings may increase costs.

3-3. Combining welding and bolting: a cost-benefit analysis

The use of a combination of welding and bolting is usually used in projects requiring high strength and precision, such as bridges and heavy industrial structures. This method is more expensive than either method alone due to the complexity of designing and implementing the two types of connections simultaneously.

Iranian regulations recommend that welding be used in critical areas and bolts in less stressed areas to reduce costs in this method. Also, combining these two methods can reduce maintenance costs in the long term because failure in one connection usually does not completely disrupt the performance of the structure. However, the need for careful planning, longer implementation time, and continuous technical supervision are factors that increase the cost of this method.

Given economic considerations and Iran's regulatory requirements:

Welding is suitable for projects where high strength and durability are important, despite the high costs.

Bolted connections are a cost-effective option for routine, low-profile projects due to their lower cost and shorter implementation time.

The combination of welding and bolting is used for special and high-value projects, which, despite higher costs, provides optimal safety and durability.

Proper cost management and appropriate selection of connection methods based on the type of project and economic conditions are among the main tasks of civil engineers in the design and implementation of steel structures.

Table 1. Comparison of welding, bolting and its combination in steel structures

Combination of welding and bolting	Boil	Screw	Feature
High (combination of cost of both methods)	Medium to high (depending on electrode type and equipment)	Low to medium (relatively inexpensive screws and plates)	Cost of materials

High (coordination requires specialist and appropriate technical force)	High (requires skilled professionals and advanced equipment)	Medium (quick and simple implementation possible by semi-skilled labor)	Labor cost
Medium to long (requires multi-stage implementation and more coordination)	Long (depends on the complexity and location of the job)	Short (due to simple assembly and quick installation)	Runtime
Average (depending on the contribution of each method to the connection)	High (difficult and expensive repairs)	Bottom (easy replacement and inspection)	Maintenance cost
Optimal for more complex conditions (if designed correctly and using durable materials)	Sensitive to humidity and temperature (more resistant electrodes can reduce this sensitivity)	Resistant to various environmental conditions (galvanized screws)	Resistance to environmental conditions
Need for more attention to the details of the regulations for both methods	Requires careful review based on specific guidelines for each regulation.	Often has detailed and comprehensive instructions for use	Compliance with regulations

In selecting the type of connection for civil engineering projects, special attention should be paid to economic, technical and regulatory compliance criteria. Welding is a suitable option for projects with complex connections and heavy loads, as it provides high strength and structural integrity, although it is costly. Bolting, as an economical method for simple and fast projects, is a suitable choice that is optimal in terms of time and cost. The combination of welding and bolting can be a comprehensive solution for complex connections and special conditions, offering the advantages of both methods together. In general, the choice of connection type should be made according to the needs of the project, its technical and economic conditions, and it is recommended that designers and civil engineers, in consultation with experts, choose the best option for each specific project.

4. Investigating connection methods for three types of buildings (residential, special, low-value) and selecting the best method

4-1. Residential buildings

Table 3. Comparison of this method for residential buildings

Feature	Boil	Screw	Combination of welding and bolting
Cost	Top	Down	Medium
Runtime	Long	Short	Medium
Strength	Top	Medium	Medium
Ease of maintenance	Low	Top	Medium
Final offer	✗	✓	✗

The best option: Screw. Simple implementation, reasonable cost and compliance with the needs of residential buildings.

4-2. Special buildings

Table 4. Comparison of connection methods for special buildings

Feature	Boil	Screw	Combination of welding and bolting
Cost	Top	Medium	Top
Runtime	Medium	Short	Long
Strength	Top	Down	Very high
Ease of maintenance	Low	Medium	Low
Final offer	✓	✗	✓

The best option: Combination of welding and bolting. Providing strength and safety in complex loadings.

4-3. Minor buildings (such as poultry houses)

Table .5 Comparison of connection methods for low-value buildings

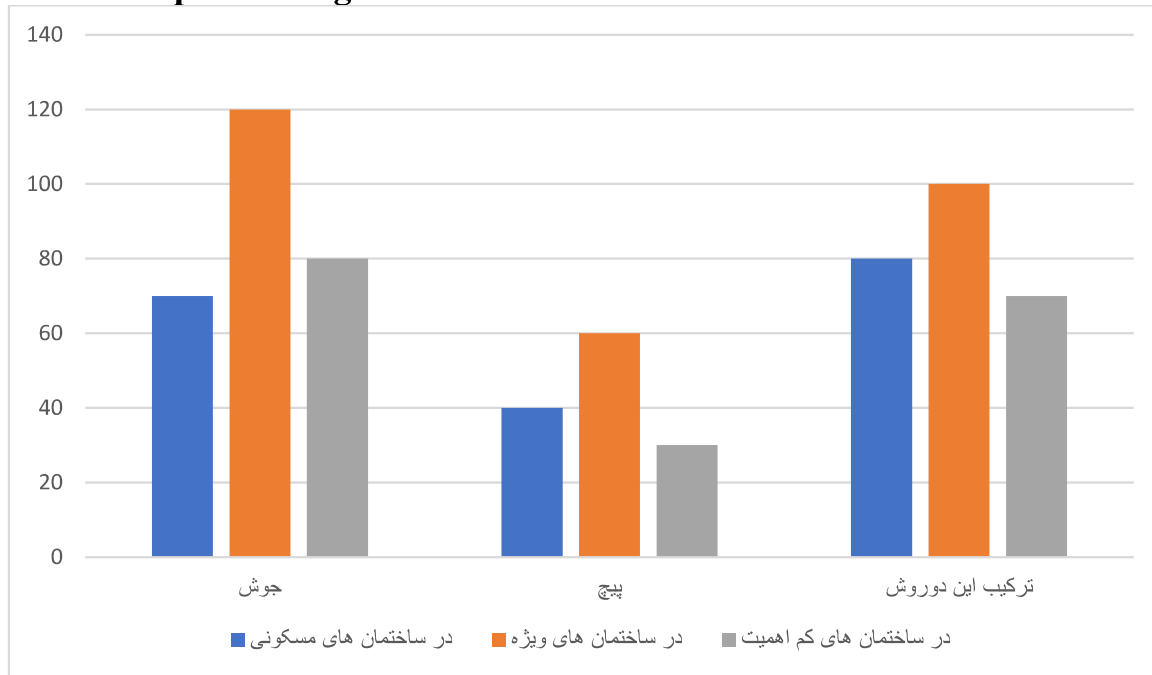
Feature	Boil	Screw	Combination of welding and bolting
Cost	Top	Down	Top
Runtime	Long	Short	Long
Strength	Top	Medium	Top
Ease of maintenance	Low	Top	Medium

Final offer	×	✓	×
-------------	---	---	---

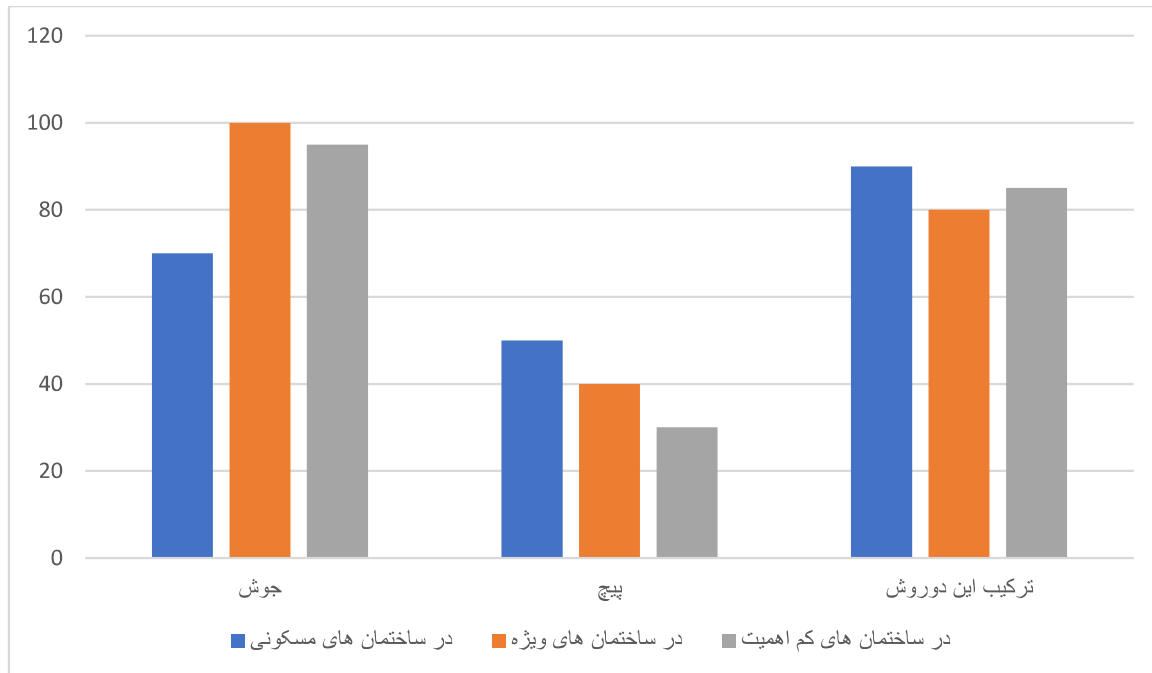
The best option: Screw. Simple, fast and economical.

5. Comparison chart Between three connection methods

Cost of implementing the methods



Method execution time



6. Overall conclusion

The overall conclusion of this study shows that the choice of connection method should be made carefully and based on the specific needs and characteristics of each type of building. In different construction projects, the appropriate choice between welding, bolting, and a combination of the two can have a great impact on the cost, execution time, and overall performance of the structure. For residential and low-value buildings, the use of bolts is recommended due to cost and time savings, while special buildings with heavy loads and complex connections require the use of welding or a combination of welding and bolts to ensure the strength and integrity of the structure. The combination of welding and bolts is considered an optimal and comprehensive solution, especially in special conditions and projects with complex technical requirements. Finally, it is recommended that civil engineers choose the appropriate method according to the specific conditions of each project, detailed economic and technical analyses, and consultation with experts to achieve optimal performance in projects.

This study shows that the choice of connection method in steel structures should be made according to the characteristics of each project and its technical needs. For residential and low-value buildings, the use of bolts is recommended due to lower cost and faster execution speed. In contrast, for special buildings and projects with heavy loads, a combination of welding and bolts or welding is considered the best option to ensure optimal structural strength and safety. The correct choice of connection method not only affects the performance of the structure, but can also be effective in reducing costs and execution time. Therefore, civil engineers should make informed decisions by carefully analyzing the technical and economic conditions of the project and consulting with experts to select the best option for each specific project.

7. references

- [1] AISC. (2021). AISC 360-16: Specification for Structural Steel Buildings. American Institute of Steel Construction.
- [3] Eurocode 3: Design of Steel Structures. (2005). European Committee for Standardization. EN 1993-1-1:2005.
- [4] Ghafoori, M., & Mirdamadi, SH (2014). Performance comparison of bolted and welded connections under cyclic loading. *Engineering Structures*, 69, 169-178.
- [5] Lee, CH, & Kim, JH (2018). A study on the economic and safety comparison of welded and bolted steel connections. *Journal of Structural Engineering*, 144(5), 04018135.
- [6] Sadeghi, A. (2020). Design of hybrid bolted-welded connections for improved seismic performance. *Journal of Structural Engineering*, 146(12), 04020194.
- [7] Shokravi, M., & Rahimi, M. (2016). Economic analysis of bolted vs. welded connections in large-scale steel structures. *Construction and Building Materials*, 120, 533-540.
- [8] Wang, Y., & Zhang, L. (2019). Economic comparison of welded and bolted connections in steel structures. *Journal of Constructional Steel Research*, 158, 203-211.

- [9] Wylie, WJ, & Moody, M. (2017). Structural Steel Design: A Practice-Oriented Approach. McGraw-Hill Education.
- [10] Iran. Ministry of Roads and Urban Development. (2015). National Building Regulations, Chapter Ten: Design and Implementation of Steel Structures. Natio