CHAPTER 116

Review on Comparision between Properties of Tor and Stainless-Steel

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ABSTRACT

Choice of Materials Is important as It significantly affects the strength, safety, durability of the structures. This paper presents a comparative study of Tor-Steel and Stainless-Steel known for its remarkable resistance to corrosion. This research investigates the mechanical properties for both materials including tensile strength, ductility, hardness and fatigue resistance as well as their chemical compositions and corrosion resistance. By analysing these factors paper provides insights into the appropriate material selection based on specific engineering requirements where each material may offer superior performance. This study offers valuable guidance for engineers in selecting between Tor-Steel and Stainless-Steel for optimal results in structural design.

Keywords: Stainless Steel 1; Tor Steel 2; Materials 3.

1.0 Introduction

Material selection is critical in engineering and construction. Among the many available options, Tor-Steel and Stainless-Steel are notable for their unique properties, each suited to different engineering needs. This research paper provides comparative analysis for these two widely used materials focusing on their mechanical, chemical, and environmental characteristics. Tor-Steel a high-strength variant of carbon steel is valued for its exceptional tensile strength and fatigue resistant. That makes it perfect for applications that require maintaining structural integrity under high stress. It is commonly found in the automotive, construction and manufacturing industries, particularly in parts like bolts, gears and shafts that experience significant torsional stress. Despite its mechanical strength Tor-Steel has drawbacks, primarily its vulnerability to corrosion. Without adequate protection, it can degrade quickly when exposed to moisture, chemicals or other corrosive elements potentially leading to structural failure (Han *et al.*, 2023). In contrast Stainless-Steel is an alloy mainly composed of iron, chromium and nickel which is well-known for its outstanding corrosion resistance which is achieved through the formation of a protective oxide layer that prevents rust (Zheng *et al.*, 2024). Its strength, durability and resistance to oxidation make it a preferred material in a wide

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range of applications including construction, medical instruments and maritime environments (Rabi *et al.*, 2020). Its versatility is further enhanced by its ability to retain structural integrity across extreme temperatures making it suitable for both high-temperature and sub-zero conditions (Chen *et al.*, 2024).

1.1 Tor-Steel

TOR steel short for Torsional Steel is a HYSD steel bar widely used for reinforced concrete construction due to its excellent tensile strength and strong bonding with concrete(Islam *et al.*, 2020). It is available in various strength grades to suit different construction needs i.e. Fe (415,500, 550, and 600) along with their specialized variants like Fe (415D, 415S, 500D, 500S and 550D) which offer enhanced properties for specific applications. The material's chemical composition is tailored to meet the requirements of durability and performance in concrete reinforcement. Table 1 Represents Chemical Composition of Tor-Steel.

Table 1: Chemical Composition of Tor-Steel (Amend No. 1 to IS 1786: 2008)

Constituent	Percent Maximum								
	Fe415	Fe415D	Fe415S	Fe500	Fe500D	Fe500S	Fe550	Fe550D	Fe600
C	0.30	0.25	0.25	0.30	0.25	0.25	0.30	0.25	0.30
S	0.060	0.045	0.045	0.055	0.040	0.040	0.055	0.040	0.040
P	0.060	0.045	0.045	0.055	0.040	0.040	0.050	0.040	0.040
S and P	0.110	0.085	0.085	0.105	0.075	0.075	0.100	0.075	0.075

Table 2: Chemical Composition of Stainless-Steel (IS 16651: 2017)

Sr No.	Steel Designation Number		International standard designation	C Max	Si Max	Mn Max	S Min/ Max	Cr Min/ Max	Ni Min/ Max	Mo Min/ Max	P Max	Cu Min/ Max	N Min/ Max
1	A	Austenitic	1.4301	0.07	1.0	2.0	0.030	17.00/ 19.50	8.00/ 10.50	-	0.045	-	0.0/ 0.11
2	B		1.4311	0.03	1.0	2.0	0.030	17.50/ 19.50	8.50/ 11.50	-	0.045	-	0.12/ 0.22
3	C		1.4436	0.05	1.0	2.0	0.030	16.50/ 18.50	10.50/ 13.00	2.50/ 3.00	0.045	-	0.0/0.11
4	D	Austenitic-Ferritic	1.4162	0.04	1.0	4.0to6.0	0.015	21.00/ 22.00	1.35/ 1.70	0.10/ 0.80	0.040	0.10/ 0.80	0.20/0.25
5	E		1.4362	0.03	1.0	2.0	0.015	22.00/ 24.50	3.50/ 5.50	0.10/ 0.60	0.035	0.10/ 0.60	0.05/ 0.20
6	F		1.4462	0.03	1.0	2.0	0.015	21.00/ 23.00	4.50/ 6.50	2.50/ 3.50	0.035	-	0.10/ 0.22
7	G	Ferritic	410L	0.03	1.0	1.0	0.030	11.00/ 13.50	0.0/ 0.60	-	0.040	-	-

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1.2 Stainless-Steel

Stainless steel is a corrosion-resistant alloy composed primarily of iron, chromium and other elements valued for its strength, durability & aesthetic appeal (Chen *et al.*, 2024). When used as concrete reinforcement stainless steel is available in various high-strength grades such as SS (500,550,600 and 650) each further categorized into subgrades (A to G). These grades are designed to meet specific performance criteria and undergo standardized tests to ensure quality and reliability. Table 2 Represents Chemical Composition of SS.

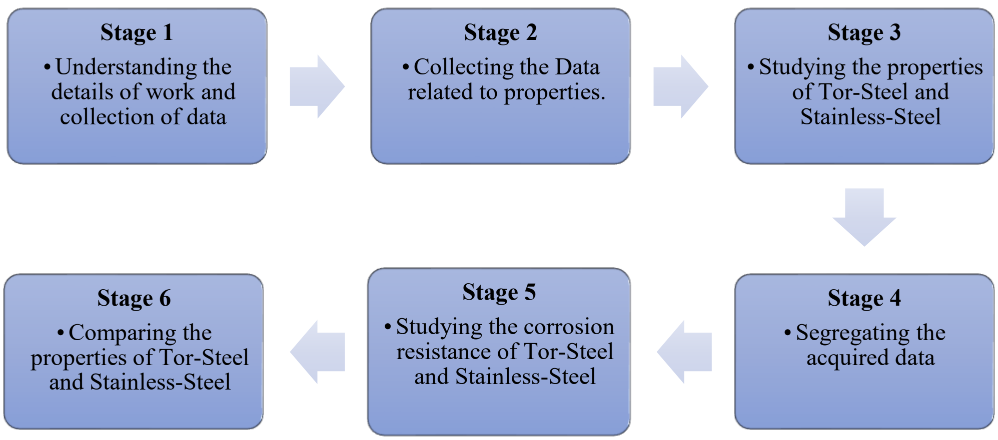
2.0 Methodology

Figure 1 illustrates methodology in this research, which is detailed in the following section:

Stage 1: Understanding the details of work and collection of data:

Understanding the details of work and data collection means fully comprehending the research scope and objectives, ensuring clear tasks. It involves systematically collecting data from experiments, observations, or literature. This approach ensures the research is based on accurate information, supporting thorough analysis and valid conclusions.

Figure 1: Flow of Work



Stage 2: Collecting data related to properties:

Acquiring the properties of Tor-Steel and Stainless-Steel means investigating their essential characteristics, like strength, ductility and corrosion resistance. This involves analyzing their performance under various conditions with the help of different research papers. The goal is to understand how each material behaves and compare their suitability for different uses.

Stage 3: Studying the properties:

Studying the properties of Tor-Steel and Stainless-Steel using different research papers involves reviewing scientific studies to gather detailed information about their characteristics.

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By comparing findings on factors like strength and corrosion resistance, a broader understanding of the materials is achieved. This ensures a well-supported comparison based on diverse research

Stage 4: Segregating the acquired data

Segregating the acquired data means sorting and organizing the collected information into categories. This process helps in structuring the data for easy analysis and comparison. It ensures that the information is clear and relevant for drawing accurate conclusions about the materials.

Stage 5: Studying the corrosion resistance of Tor-Steel and Stainless-Steel

Corrosion is deterioration of materials. It mainly happens when metals come into contact with oxygen, moisture, or other chemicals, which leads to the formation of oxides or other compounds. This process weakens the metal, diminishing its mechanical strength and durability over time. So, studying the corrosion property of Tor-Steel and Stainless-Steel independently is important. This helps determine which material offers better long-term protection in corrosive settings.

Stage 6: Comparing the properties of Tor-Steel and Stainless-Steel

After collecting all data and data segregation we will compare the data and will present in the paper in tabular format.

3.0 Literature Review

- *Corrosion Resistance:* Stainless steel provides enhanced corrosion resistance due to its passive oxide layer which protects it from rusting in aggressive environments. Studies highlight its superior performance in chloride-rich conditions compared to Tor steel (Guo *et al.*, 2024; Moodley *et al.*, 2024; Wang *et al.*, 2024). The ability to resist pitting and crevice corrosion makes stainless steel an ideal choice for infrastructure exposed to moisture and chemicals.
- *Mechanical Strength:* Research shows that stainless steel exhibits higher mechanical strength than Tor steel with improved yield strength and ultimate tensile strength (Ding *et al.*, 2024; Yoo *et al.*, 2024; Zheng *et al.*, 2024). Its superior strength-to-weight ratio makes it an efficient material for high-load applications, reducing structural weight without compromising performance.
- *Ductility:* Ductility is essential in seismic-resistant structures, and stainless steel demonstrates an increased strain-hardening capacity compared to Tor steel (Chen *et al.*, 2024; Duan *et al.*, 2024; Xing *et al.*, 2024). This characteristic ensures better energy dissipation and flexibility under extreme loading conditions reducing the risk of sudden failure.
- *Hardness:* While hardness influences wear resistance studies show that stainless steel maintains a balance between hardness and ductility preventing brittleness while ensuring

durability (Hwang *et al.*, 2024; Meza *et al.*, 2024; Zhang *et al.*, 2023). This makes it a suitable material for applications requiring impact resistance.

- *Toughness:* Toughness is critical in dynamic loading conditions and stainless steel has been shown to outperform Tor steel in energy absorption and resistance to fracture (Han *et al.*, 2023; Li & Aoude, 2023; Rabi *et al.*, 2022). Its superior impact toughness makes it ideal for structural applications in bridges and earthquake-prone regions.
- *Thermal Conductivity:* Compared to Tor steel, stainless steel has a lower thermal conductivity making it a better insulator in high-temperature environments (Fu *et al.*, 2022; Huang *et al.*, 2022). This property enhances its performance in fire-resistant and heat-exposed structures.
- *Weldability:* Stainless steel exhibits good weldability with proper techniques though some grades require preheating to prevent cracking (Chen *et al.*, 2022; Chen *et al.*, 2022). Tor steel while easier to weld may suffer from loss of strength in the heat-affected zone requiring additional precautions.
- *Elastic Modulus:* Studies indicate that the Young's modulus of stainless steel is comparable to that of Tor steel ranging from 200 to 208 GPa (Han *et al.*, 2022; Yang *et al.*, 2022). However stainless steel demonstrates better consistency in elastic behavior reducing long-term deformation in structures.
- *Fatigue Resistance:* Fatigue resistance is crucial in cyclic loading applications such as bridges and high-rise buildings. Stainless steel has shown better resistance to fatigue failure compared to Tor steel improving structural longevity (Xin *et al.*, 2021; Xu *et al.*, 2021).
- *Density:* Stainless steel has a slightly higher density than Tor steel but its enhanced strength offsets this weight increase making it efficient in load-bearing applications (Chen *et al.*, 2021).
- *Applications:* Stainless steel is widely used in bridge piers, marine structures and seismic reinforcements due to its superior mechanical properties and corrosion resistance (Li *et al.*, 2021). Meanwhile Tor steel remains a cost-effective option for general reinforcement in concrete structures.

4.0 Observations

Table 4 contrasts the different properties of Tor-Steel and Stainless-Steel, highlighting their respective suitability for various applications. Table 5 emphasizes the notable contrast in corrosion resistance between Tor-Steel and Stainless-Steel, illustrating how Stainless-Steel's enhanced durability makes it a more dependable option for extended use in corrosive settings.

5.0 Conclusion

Stainless-Steel recognized for its exceptional resistance to corrosion, high strength, and excellent ductility, offers clear advantages over Tor-Steel, particularly in environments prone to corrosion.

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Table 3: Properties Table

Property	Tor-Steel	Stainless-Steel
Corrosion Resistance	Moderate; requires protective coatings or treatments for corrosion resistance.	High; inherently resistant due to chromium content forming a passive oxide layer.
Mechanical Strength	High tensile strength; often used in high-stress applications.	Varies by type; austenitic grades have good strength, duplex grades offer higher strength.
Ductility	Moderate to high; ductility decreases with increased carbon content.	High, especially in austenitic grades.
Hardness	Generally high; can be increased through heat treatment processes.	Varies by grade; martensitic Stainless-Steels can be hardened significantly.
Toughness	Good, but may decrease at low temperatures.	Generally excellent, especially in austenitic grades, which remain tough at low temperatures.
Thermal Conductivity	Moderate; varies depending on alloying elements.	Lower than carbon steel; varies by grade but generally lower thermal conductivity.
Weldability	Good; certain grades may require preheating or post-weld heat treatment.	Varies; austenitic grades are typically easy to weld, while others may require special techniques.
Elastic Modulus	Approx. 210 GPa (similar to Stainless-Steel).	Approx. 190-200 GPa; varies slightly by grade.
Fatigue Resistance	High; often used in applications where cyclical loading is present.	Varies; duplex and martensitic grades generally have good fatigue resistance.
Density	Approximately 7.85 g/cm^3.	Typically: 7.7-8.0 g/cm^3, depending on the alloy.
Applications	Tools, fasteners, springs, and other high-strength applications.	Structural applications, automotive parts, medical devices, and more.

Table 4: Corrosion Resistance

Parameter	Tor-Steel	Stainless-Steel
Corrosion Resistance	Moderate - Prone to rust in high-chloride environments	High - Excellent resistance due to the presence of chromium and nickel
Corrosion Protection Measures	Requires regular maintenance, coatings, or galvanization to prevent rust	Naturally corrosion-resistant, minimal maintenance required
Environmental Suitability	Suitable for low-chloride environments; high-chloride conditions require additional protection	Ideal for high-chloride environments (e.g., coastal areas, chemical industries)
Long-Term Durability	Susceptible to corrosion over time, leading to reduced structural integrity	Superior durability with minimal corrosion over time
Cost Implications	While the initial cost is lower, there may be higher maintenance and repair expenses over time due to corrosion.	Although the initial cost is higher, the overall life cycle cost is lower because of reduced maintenance requirements
Impact of Corrosion on Mechanical Properties	Corrosion reduces strength and ductility, raising the likelihood of structural failure.	Preserves its mechanical properties even in corrosive conditions, guaranteeing reliable performance.
Common Applications	General construction where corrosion is not a primary concern	Critical structures exposed to harsh environments (e.g., bridges, marine structures)

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Although Tor-Steel may be more cost-effective and provide adequate strength for some uses, Stainless-Steel's superior durability, aesthetic value, and minimal maintenance needs make it the preferred option for crucial structural elements, especially in challenging environments.

6.0 Future Scope

- Advanced Mechanical Properties Analysis: Future research can delve deeper into the microstructural changes of Tor-Steel and Stainless-Steel under different loading conditions. This could provide a better understanding of the fatigue resistance, ductility, and strain-hardening characteristics unique to each material.
- A comparative analysis with different environments like marine and industrial conditions could provide valuable insights into their long-term durability and maintenance requirements.
- New Alloy Developments: The creation of new steel alloys that blend the properties could be a potential area of research. These new materials could be tailored for specific applications where a balance of high strength, corrosion resistance, and cost-effectiveness is required.

This future scope is designed to address gaps in current knowledge, expand the potential applications of Tor and Stainless-Steel, and contribute to the development of new materials and technologies.

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