Mechanical Properties of Reinforcement (Rebar) in Bangladesh

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A thesis submitted to the Department of Civil Engineering in partial fulfillment for the degree of Bachelor of Science in Civil Engineering



Department of Civil Engineering

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Section: 25A

Semester -Summer 2025

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It is hereby declared that this thesis/project or any part of it has not been submitted elsewhere for the award of any degree or diploma.

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Dedicated

to

"OUR PARENTS & TEACHERS"

ACKNOWLEDGEMENTS

"Bismillahir Rahmanir Rahim" --- In the name of Allah, the most gracious the most merciful"

First and foremost, we would like to express our sincere gratitude to **Monirul Islam**, our supervisor, for their continuous guidance, support, and encouragement throughout the course of this research. Their valuable insights and constructive feedback greatly contributed to the successful completion of this study. I extend my heartfelt thanks to the Department of Civil Engineering, Sonargaon University, Dhaka, Bangladesh for providing the necessary academic and laboratory facilities to carry out the experimental work. We are also grateful to Lab in charge Sir, where the testing of reinforcement samples was conducted. Their technical support and cooperation were instrumental in gathering accurate and reliable data for this project.

Special thanks to all the faculty members, lab technicians, and Group Members who supported me directly or indirectly during this research work. Finally, I express my deepest appreciation to my family and friends for their unwavering moral support, encouragement, and patience throughout this journey.

ABSTRACT

The 500W locally produced Thermo mechanically treated (TMT) high-strength reinforcing steel bars have been collected from three different companies. Tensile tests were carried out using a **Universal Testing Machine** (UTM) to evaluate the tensile properties (tensile strength, yield strength, % of elongation) of the rebars in three different conditions, viz., with and without rib and without casing. Compressive tests were carried out using a **Universal Testing Machine** (UTM) to evaluate the bond between concrete and steel rebars crucial. The compressive strength of a reinforced concrete member is not solely determined by the concrete's strength but also by the performance of the embedded steel. Deformed rebars, with their surface ribs and lugs, are designed to enhance this bond, improving load transfer and overall structural integrity. The mathematical modelling was developed between the tensile properties (tensile and yield strength) and hardness in light of previous studies on it. Failure modes of the high-strength steel rebars in tensile loading were studied by observing fracture surfaces after tensile tests. the dissimilarity in tensile properties of the TMT steel rebars was found too. The evaluation of tensile property from the samples was consistent with the tensile properties obtained from the mechanical tensile tests. The yield strength calculated from the strength-hardness models also showed consistency with the test values. The effects of microstructures (consists primarily of two phases: ferrite -a relatively soft, ductile form of iron and pearlite-a lamellar or layered structure of ferrite and cementite, or iron carbide) and carbon equivalent on the hardness and tensile test results were evaluated. The calculated and test values of tensile properties showed good agreement with the microstructures. The fracture behaviors of the TMT steel rebars also showed good dependency on microstructures. Thus, overall structure-property relationship was established with existing samples.

Keywords: *Reinforcement properties, Construction materials Bangladesh, Tensile strength of rebar, Structural performance of rebar.*

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CHAPTER 1
INTRODUCTION

1.1.Background of the Study:

The **background of the study** on the "Mechanical Properties of reinforcement (rebar) in Bangladesh" centers on the critical role of steel reinforcement in concrete structures within the country's rapidly growing construction sector and the evolution of reinforcement bar types used.[1]

1.2.According to Standards and Code Requirements:

Reinforcement manufactured and used in Bangladesh generally complies with:

- **ASTM A615 (or equivalent)**
- **Bangladesh Standard (BDS)**
- **Bangladesh National Building Code (BNBC 2020)**
- **ACI 318 and AASHTO guidelines are also referenced for strength limits and detailing.**

Traditionally, mild steel bars produced through hot rolling methods were commonly used; however, over recent years, there has been an increasing demand and transition towards **Thermo-Mechanically Treated (TMT) rebars**[2]. TMT rebars are produced by rapidly quenching hot-rolled bars, resulting in a product with a hard outer surface and a ductile inner core, providing a superior balance of strength, flexibility, corrosion resistance, and weldability compared to conventional rebars[3].

This change responds to Bangladesh's growing infrastructure demands, earthquake resilience needs, and long-term durability requirements[4]. The industry commonly uses three grades of rebar with yield strength values of approximately 276 MPa, 414 MPa, and 500 MPa, with TMT bars being the favored modern choice[5]. The study of their physical, mechanical, and chemical properties is essential to ensure structural safety, code compliance, and quality control in Bangladesh's construction projects[2].

Furthermore, comprehensive statistical and experimental research evaluating locally produced rebars has shown these materials typically meet or exceed national (Bangladesh Standards, BDS) and international standards (such as ASTM)[5]. Key research aims include understanding strength–hardness relationships, microstructure

influences, and performance variations between bars from different manufacturing routes (e.g, induction furnace vs. blast furnace billets)[4]. This deep understanding supports optimizing material usage, enhancing quality assurance, and reducing construction costs and wastage[3].

In summary, the background reflects the need to characterize the evolving local rebar market and its technical properties thoroughly to support Bangladesh's construction industry's sustainable growth, safety, and modernization.

1.3.Problem Statement and Justification:

The **Problem Statement** and **Justification** regarding the properties of reinforcement (rebar) in Bangladesh can be summarized as follows based on the research literature. The construction industry in Bangladesh extensively uses steel rebars for reinforced concrete structures[1], with progressively increasing adoption of high-strength TMT (Thermo-Mechanically Treated) reinforcement bars over conventional mild steel and hot-rolled bars. Despite this trend, there are concerns about the **consistency, mechanical properties, and quality control** of locally produced rebars[6,7].

1.4.Key issues include:

Variability in yield strength, tensile strength, and elongation properties among different grades and manufacturers, sometimes showing higher coefficients of variation, especially in intermediate grades like 414 MPa bars [1,7].

The microstructural differences arising from production methods (e.g., billets from induction furnace versus blast furnace) affect the distribution of martensite and ferrite-pearlite phases, influencing mechanical properties and performance [6,8,9].

There is limited comprehensive, standardized data on the correlation between hardness and strength properties tailored to the specific production techniques and steels used in Bangladesh, which hampers quick quality assessment and control [3,6].

Bangladesh’s rapid urbanization and infrastructure growth demand high-quality, reliable, and durable reinforcing steel to ensure the safety and longevity of concrete structures [1,7].

Understanding the physical, mechanical, and chemical properties of locally produced rebars is fundamental to complying with national (BDS) and international standards (ASTM), minimizing structural failures, and promoting the use of high-strength TMT bars that optimize material efficiency [1,9].

Establishing empirical models that relate hardness and tensile strength to local TMT 500W bars can improve testing efficiency, reduce costs, and minimize destructive testing waste, ultimately leading to more sustainable quality assurance practices [3,6].

Detailed microstructural, mechanical, and corrosion performance analyses justify the need for stricter quality controls and improvements to the production process, supporting industry-wide standardization [6,8,9].

The study supports policymakers, engineers, and manufacturers by providing scientific evidence necessary for enhancing the performance and reliability of reinforcing steels, critical for earthquake-resistant and long-lasting construction in Bangladesh [1,7].

1.5.Aims and Objectives of the Study:

The primary aim of this study is to evaluate and statistically analyze the physical and mechanical properties of steel reinforcement bars (rebars) used in concrete construction across Bangladesh, encompassing different grades such as 276 MPa (40 ksi), 414 MPa (60 ksi), and 500 MPa (72 ksi) 1,8. The study seeks to assess the quality compliance of these rebars with national and international standards, including Bangladesh Standards (BDS) and ASTM 2,10. It also aims to investigate variability and consistency in key parameters such as yield strength, tensile strength, strength ratio, elongation, bend-rebend performance, weldability, diameter, compressive strength of rebar with concrete cylinder and nominal weight for different grades and sizes, ensuring their suitability for structural applications in buildings, bridges, and infrastructure projects [3,8].

Additionally, the research intends to provide reliable data to support quality assessment and inform structural engineers, manufacturers, and regulatory authorities about the performance and dependability of locally produced rebars [1,10]. By understanding the mechanical and metallurgical characteristics of these bars, the study aims to enhance both the safety and economic efficiency of reinforced concrete structures in Bangladesh, supporting the development of durable, high-performance infrastructure [3,4].

1.6.Significance and Scopes of the Study:

1.6.1. Quality Benchmarking for Construction:

The study provides current data on the mechanical properties of rebars, including yield strength, tensile strength, elongation, bend-rebend and weld ability and compressive strength of reinforced concrete available in Bangladesh. This helps engineers, policymakers, and construction companies to determine if local rebars meet industry standards such as ASTM and BDS, supporting the safety and durability of buildings and infrastructure.

1.6.2. Guidance for Design Codes and Regulation:

By analyzing the performance and consistency of rebars, especially high-strength and ductile types like 500MPa bars, the study guides updates to national building codes (BNBC) and influences the adoption of new grades or ductility requirements in practice. This is vital for risk reduction as infrastructure becomes larger and more complex.

CHAPTER 2

Literature Review

2.1. Introduction

The mechanical and physical properties of steel reinforcement bars (rebars) are central to the structural integrity of concrete structures in Bangladesh. Extensive research, industry reports, and technical standards address various facets of rebar, from material composition to grades, production processes, performance in seismic zones, and quality assurance. This literature review synthesizes key findings on the properties, standards, and challenges associated with rebar used in Bangladesh.

2.2. Standards and Code Requirements:

Reinforcement manufactured and used in Bangladesh generally complies with:

- ASTM A615 (or equivalent)
- Bangladesh Standard (BDS)
- Bangladesh National Building Code (BNBC 2020)
- ACI 318 and AASHTO guidelines are also referenced for strength limits and detailing.

2.3. Grades and Mechanical Properties:

2.3.1. Common grades:

The most frequently used rebar grades in Bangladesh are grade 40, grade 60, and grade 500, corresponding to yield strengths of 276mpa, 414mpa, and 500mpa respectively. Recent years have seen increased adoption of grade 500 for its higher strength and cost-effectiveness, particularly in high-rise and large-scale infrastructure projects.

2.3.2. Standard Specifications:

National standards enforce minimum requirements for yield strength and tensile strength for both mild steel and high-yield deformed bars. For example, the Bangladesh Standard BDS ISO 6935 outlines the criteria for MS rebars.

2.3.3. Tensile and Yield Strength:

Most studies show that locally manufactured rebars generally meet or exceed the required yield strength, though variations exist across manufacturing processes and brands.

2.3.4. Weldability of TMT Steel Bars:

Thermo mechanically treated (TMT) steel rebars are designed with low carbon content and controlled carbon equivalent (CE), which ensure satisfactory weldability without the need for preheating in most cases. According to previous studies and international codes (such as ASTM A706 and ISO standards), the carbon equivalent value below 0.45% is generally considered safe for welding show in figure 2.3.4.

The weldability of TMT rebars is evaluated through different welding processes such as arc welding, butt welding, and lap welding, and the welded joints are assessed for strength and ductility. Literature shows that properly welded TMT bars retain most of their tensile strength and ductility, with failures typically occurring outside the weld zone. Moreover, weldability is further enhanced due to the tempered martensitic-rim and ferrite–pearlite core microstructure, which avoids excessive hardness and brittleness in the heat-affected zone (HAZ).

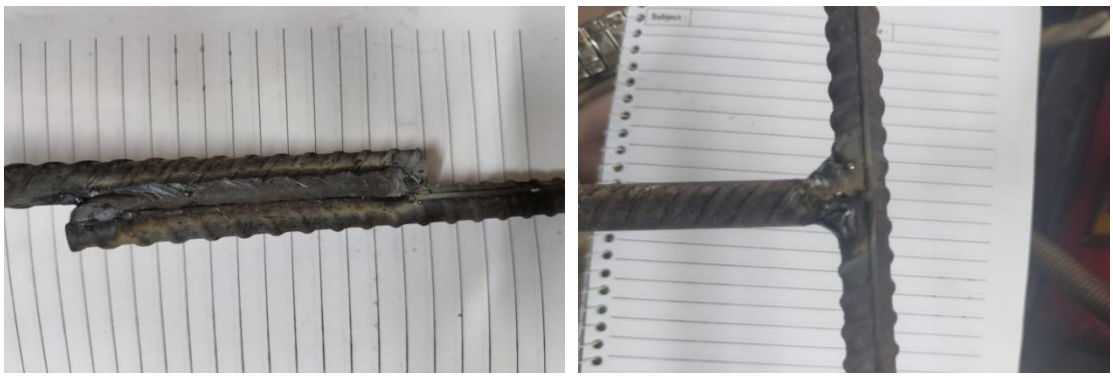


Figure 2-1: Weldable of TMT steels

Different welding processes shows that properly welded TMT bars retain most of their tensile strength and ductility, no failures typically occurring outside the weld zone

2.3.5. Bend Rebend

The bend and rebend test are a standard requirement for reinforcing steels to assess their ability to withstand plastic deformation without cracking. In the bend test, a rebar is bent to a specified angle (usually 180°) over a defined mandrel diameter. In the rebend test, the bar is bent to an angle, often 135 degrees to check resistance to strain aging and the bent bar is, such as being placed in boiling water at 100°C for 30 minutes for heat treatment and embrittlement.





Figure 2-2: Bend Rebend Test

This picture confirms the bar's ability to undergo plastic deformation without fracturing.

After cooling to room temperature, the bar is bent back to a final angle It is then inspected for cracks. A bar passes if no cracks are present, indicating it can withstand further deformation after being subjected to strain aging. Literature reports indicate that TMT rebars possess excellent bendability and rebendability due to their balanced microstructure of tempered martensite at the surface and ductile ferrite–pearlite at the core. This ensures high ductility and toughness, allowing the bar to be bent and rebent without surface cracks or internal ruptures.

Experimental studies have consistently shown that when subjected to bend and rebend tests, TMT rebars do not develop surface scratches, cracks, or spalling, provided they meet standard manufacturing practices and chemical composition limits. The absence of scratches or cracks during these tests confirms that TMT bars can undergo field bending and re-bending operations safely, which is essential for construction practices.

2.4. Summary

Steel reinforcement bars (rebars) are essential for the structural integrity of concrete in Bangladesh. The most common grades are Grade 40 (276 MPa), Grade 60 (414 MPa), and Grade 500 (500 MPa), with Grade 500 becoming increasingly popular for large-scale projects due to its strength and cost-effectiveness. National standards, such as BDS ISO 6935, specify minimum requirements for yield and tensile strength to ensure quality. Research shows that most locally produced rebars meet or exceed these requirements, though variations exist among manufacturers, highlighting the need for consistent quality control.

CHAPTER 3

Methodology

3.1 Introduction

3.1.1 Material Sources and Grades:

Rebars sourced locally in Bangladesh comprise various grades, usually including 276 MPa, 414 MPa, and 500 MPa yield strengths, with diameters ranging commonly from 8 mm to 40 mm, covering the typical sizes used in construction projects across the country.

3.1.2 Quality Standards:

The testing and evaluation follow national and international standards such as Bangladesh Standards (BDS), ASTM, and ISO to ensure that yield strength, tensile strength, elongation (ductility), bend reband, weldability and compressive strength of rebar using concrete cylinder and other parameters meet required specifications.

3.1.3 Sample Preparation:

Samples are selected to represent different grades, sizes, and manufacturers. Accurate measurement of physical properties such as diameter and weight per meter is carried out. Samples are prepared according to standard procedures to ensure consistency in testing.

3.1.4 Testing Methods:

3.1.5 Sample Collection:

Grade 500W TMT rebars (10mm, 16mm, 20mm diameter) were collected from BSRM, GPH Ispat, and Baizid Steel. Samples were inspected for defects like cracks or rust to ensure test reliability. Multiple manufacturers were included for comparative quality analysis.



Figure 3-1: Sample Collection

Grade 500W TMT rebars (10mm, 16mm, 20mm diameter) were collected from BSRM, GPH Ispat, and Baizid Steel about 45 samples are collected from local shops in Dhaka.

3.1.6 Physical/Visual Inspection:

Each rebar underwent surface examination for rib consistency and defects. Diameters were measured at multiple points using vernier-calipers to verify dimensional accuracy. Substandard samples were eliminated at this stage.

3.1.7 Equipment and Facilities:

Tests used calibrated UTM, extensometer, and hardness tester in certified labs following BDS/ASTM/ISO standards. Equipment calibration was verified for measurement precision before testing commenced.

3.1.8 Tensile Testing Procedure:

Samples were mounted in UTM with extensometers to measure elongation. Gradual axial loading continued until fracture, recording yield strength, ultimate strength, and elongation. Fracture modes were documented for analysis.

- Measure the diameter of the specimen at several points and calculate its mean diameter.
- Record the gauge length of the specimen and the extensometer constant.
- Set the machine to grip the specimen between its gage marks and attach the extensometer suitably with the machine or the specimen to read the elongations. Adjust the extensometer dial to read zero at this stage.
- Apply the load slowly and record the loads and extensometer readings at constant load interval.
- Stop loading when the yield point is reached. Elongations beyond the yield point should be recorded by an elongation scale attached to the machine.
- Resume loading and take readings from the elongation scale at regular intervals until the failure of the specimen.
- Record the final (ultimate) load at failure and measure the final length between the gauge marks.
- Note the characteristics of the failure surface.

3.1.9 Data Recording:

Yield strength, tensile strength, elongation percentages, and stress-strain curves were systematically recorded. Precision instruments ensured data accuracy for cross-manufacturer comparisons against standards.

3.1.10 Statistical Analysis:

Mean values, standard deviations, and coefficients of variation were calculated. Results were benchmarked against BDS/ASTM standards to assess compliance and production consistency.

3.1.11 Conclusion & Recommendations:

GPH Ispat showed superior strength, BSRM better ductility, while Baizid Steel had some non-compliance. Recommendations included stricter QC measures and long-term performance studies for improved construction safety.



Figure 3-2: Post Sample of Tensile test

These images show steel rebar that has failed in tensile loading. The failure mode, characterized by a distinct reduction in the cross-sectional area at the fracture point, is known as necking. This is a classic characteristic of a ductile material failure.



Figure 3-3: Sample Preparation

Measure the diameter of the specimen at several points and calculate its mean diameter and recording the gauge length of the specimen and the extensometer constant



Figure 3-4: Applying Load

Applied the load slowly and recorded the loads and extensometer readings at constant load interval, Gradual axial loading continued until fracture, recording yield strength, ultimate strength, and elongation

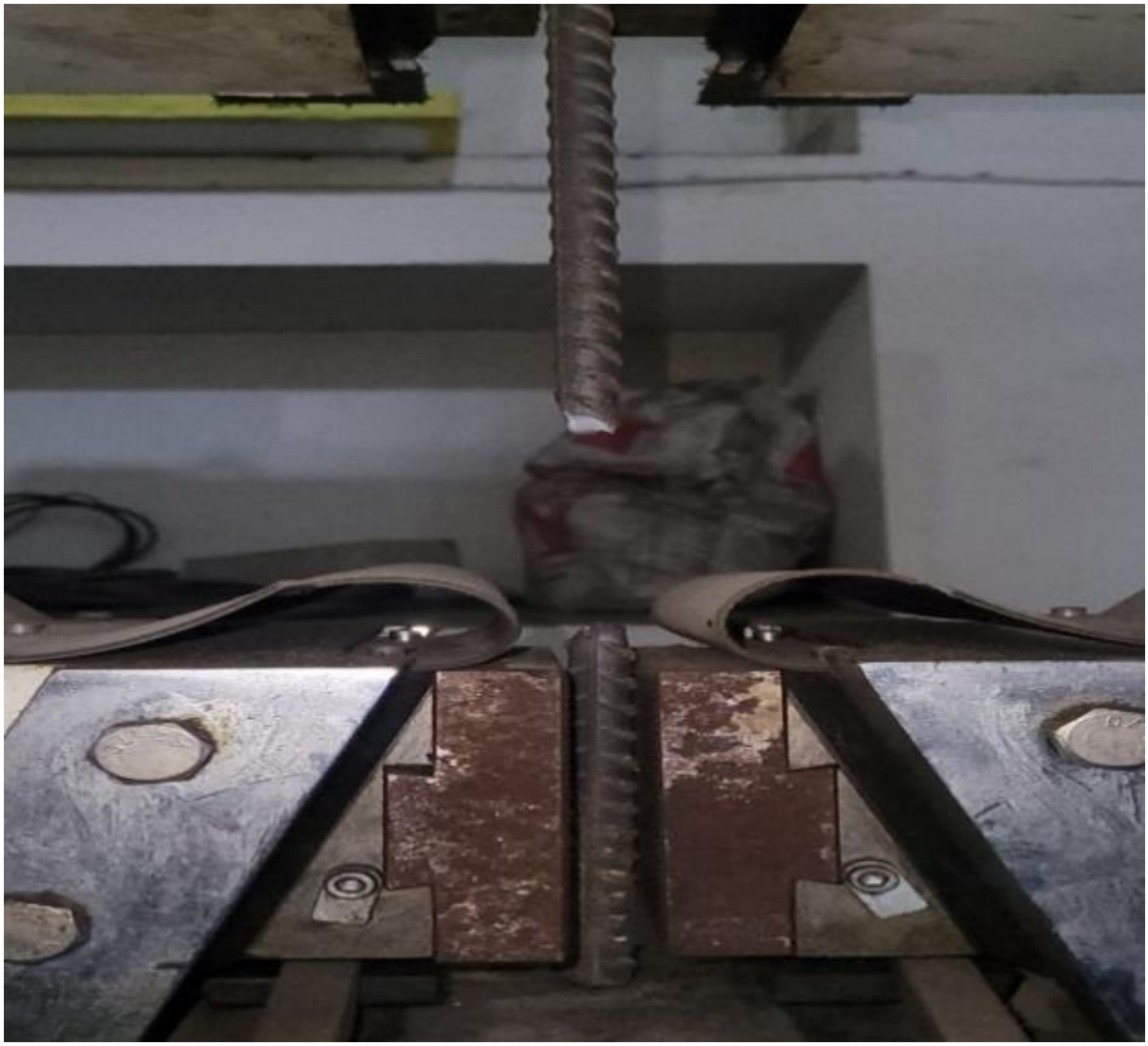


Figure 3-5: Fractured after Applying Load

Applied the load slowly and recorded the loads and extensometer readings at constant load interval, Gradual axial loading continued until fracture, recording yield strength, ultimate strength, and elongation

3.1.12 Compressive Strength of Rebar with Concrete Cylinder:

3.1.13 Specimen Preparation

3.1.14 Materials:

- **Rebars:** Specify the grade (500W, 60 grade) and diameter (16mm, 10mm) of rebars from BSRM, GPH Ispat, and Baizid Steels. Obtain material test certificates from the manufacturers.
- **Concrete:** Define the mix design (M25 grade concrete), including the proportion of cement, sand, coarse aggregate, and water. Cast cylindrical specimens of size **100 mm diameter × 200 mm height**.

Preparing two groups:

Plain concrete cylinders:

Rebar-reinforced cylinders with bars from **BSRM, GPH Ispat, and Baizid Steels**.

Demold specimens after 24 ± 2 hours and cure in water at **20 ± 2 °C** until test age.

3.1.15 Testing Procedure

- 7-days compressive strength tests using a calibrated (UTM).
- Recorded maximum load at failure (kN) and calculate the compressive strength using: $f_c = \frac{P}{A}$, where P= failure load (N), A= loaded area (mm²).
- Document failure patterns (vertical split, cone, shear, crushing).
- Approximation of 21-Days Strength Establish scaling ratio $\boldsymbol{r}$from plain concrete specimens:

$r = \frac{f_{21}}{f_7}$, where $f_{21} = 9.42\ MPa$ (For plain).

- Apply the same ratio to rebar-reinforced 7-days strengths to approximate 21-days values:

$$\hat{f}_{21} = r \times f_7$$



Figure 3-6: Taking reading of strength

Taking reading of compressive strength from cylinder for different dia in UTM machine

3.1.16 Data Analysis of Compressive Strength:

3-1: Data sheet for 7 Days Compressive Strength.

7 Days Compressive Strength				
Sample Size (mm)	Dia (mm)	Load (KN)	Compressive Strength (psi)	Remarks
10 mm	102.2	132.00	2333.80	Baizid
10 mm	102.9	135.00	2354.47	GPH
10 mm	102.5	140.00	2460.77	BSRM
16 mm	102.7	157.00	2748.84	Baizid
16 mm	102.6	155.00	2719.12	GPH
16 mm	103	162.00	2819.89	BSRM

The 16 mm Baizid steel bar shows the highest compressive strength at 2748.84 MPa, while the 10 mm GPH bar has the lowest at 2354.47 MPa.

3-2: Data sheet for 21 Days Compressive Strength.

21 Days Compressive Strength				
Sample Size (mm)	Dia (mm)	Load (KN)	Compressive Strength (psi)	Remarks
10 mm	102.1	187.00	3312.69	Baizid
10 mm	102.17	195.00	3449.68	GPH
10 mm	102.2	193.00	3412.29	BSRM
16 mm	102.25	225.00	3974.17	Baizid
16 mm	102.27	229.00	4043.24	GPH
16 mm	102.18	235.00	4156.49	BSRM

At 21 days, the 16 mm GPH steel bar has the highest compressive strength at 4043.24 MPa, and the 10 mm Baizid bar has the lowest at 3312.69 MPa.

3.2 Conclusion and Recommendations

GPH Ispat showed superior strength, BSRM better ductility, while Baizid Steel had some non-compliance. Recommendations included stricter QC measures and long-term performance studies for improved construction safety.

3.3 Summary

This study examined the quality of locally sourced rebars in Bangladesh by collecting Grade 500W TMT samples (10mm, 16 mm, 20mm) from major manufacturers including BSRM, GPH Ispat, and Baizid Steel. The rebars were inspected for physical defects and tested in certified laboratories using calibrated equipment in compliance with BDS, ASTM, and ISO standards. Tensile testing measured yield strength, ultimate tensile strength, elongation, and ductility, fracture behavior, while results were statistically analyzed for accuracy and compared against standard benchmarks. summary of prior research on the compressive strength of reinforced concrete, with a focus on studies that have investigated the influence of rebar type or manufacturer Findings revealed that GPH Ispat exhibited the highest strength, BSRM showed superior ductility, and Baizid Steel displayed some non-compliance issues. The study recommends stricter quality control and long-term performance monitoring to enhance structural safety in construction.

CHAPTER 4

Results and Discussion

4.1 Introduction

This chapter presents the experimental results of tensile testing on reinforcement bars collected from leading steel manufacturers in Bangladesh, namely BSRM, GPH Ispat, and Baizid Steel. The analysis focuses on the mechanical performance of the rebars, including yield strength, ultimate tensile strength, and elongation, bend rebend, weldability, compressive strength or rebars with concrete cylinder comparison with national and international standards (BDS/ASTM). Stress–strain behavior and fracture characteristics are also discussed to evaluate the structural reliability of the samples. The findings highlight the variations in quality among different brands, providing insights into their suitability for construction applications and compliance with prescribed specifications.

4.2 Specific Aim 1

The specific aim of this study is to evaluate the mechanical properties of reinforcement bars (rebars) used in Bangladesh, with particular focus on yield strength, ultimate tensile strength, and elongation, bend rebend, weldability, compressive strength or rebars with concrete cylinder to compare their performance across leading manufacturers (BSRM, GPH Ispat, and Baizid Steel). The study seeks to determine compliance with BDS/ASTM standards, identify variations in quality, and provide recommendations for selecting suitable rebars to ensure structural safety, durability, and reliability in construction projects.

4.3 Data sheets:

4-1: 10mm Data sheet for tension test of mild steel.

No	Length	Diameter	Ultimate Load	Ultimate Strength	Avg. Ultimate Strength		Yield Load	Yield Strength	Avg. Yield Strength		Elongation		Brand
	(m)	(mm)	(kN)	(MPa)	(MPa)	(kN)	(kN)	(MPa)	(kN)	(MPa)	mm	%	
1	0.305	10	51.83	660	654.67	51.42	42.41	540	42.53	534.33	9.5	21	BSRM
2	0.305	10	51.05	650			42.62	530			9.6	22	
3	0.305	10	51.38	654			42.57	533			9.5	22	
1	0.305	10	65.24	831	830	65.17	50.82	647	50.76	646.33	10	20	GPH Ispat
2	0.305	10	65.33	832			50.88	648			10	18	
3	0.305	10	64.95	827			50.60	644			9.8	16	
1	0.305	10	50.86	645	665	52.37	42.32	540	44.45	566.66	9.5	22	Baizid Steel
2	0.305	10	53.10	675			45.95	585			9.7	20	
3	0.305	10	53.15	675			45.10	575			9.9	20	

4-2: 16mm Data sheet for tension test of mild steel.

No	Length	Diameter	Ultimate Load	Ultimate Strength	Avg. Ultimate Strength		Yield Load	Yield Strength	Avg. Yield Strength		Elongation		Brand
	(m)	(mm)	(kN)	(MPa)	(MPa)	(ksi)	(kN)	(MPa)	(MPa)	(ksi)	mm	%	
1	0.305	16	133.70	665	132.53	660	109.57	545	109.12	542	9.5	21	BSRM
2	0.305	16	131.69	655			108.57	540			9.6	22	
3	0.305	16	132.20	660			109.22	542			9.5	22	
1	0.305	16	166.32	827	166.64	829	126.34	628	126.81	632	10	18	GPH Ispat
2	0.305	16	166.67	829			126.00	630			10	19	
3	0.305	16	166.92	830			128.10	637			9.8	19	
1	0.305	16	132.08	660	132.68	662	107.25	535	107.78	537	9.5	21	Baizid Steel
2	0.305	16	131.44	655			106.50	530			9.7	23	
3	0.305	16	134.52	670			109.55	545			9.9	22	

4-3: 20 mm Data sheet for tension test of mild steel.

No	Length	Diameter	Ultimate Load	Ultimate Strength	Avg. Ultimate Strength		Yield Load	Yield Strength	Avg. Yield Strength		Elongation		Brand
	(m)	(mm)	(kN)	(MPa)	(kN)	(MPa)	(kN)	(MPa)	(MPa)	(ksi)	mm	%	
1	0.305	20	207.34	660	204.35	651.66	166.50	530	166.92	531.66	9.5	21	BSRM
2	0.305	20	202.63	645			168.07	535			9.6	19	
3	0.305	20	203.10	650			166.20	530			9.5	24	
1	0.305	20	245.26	781	245.5	781.66	193.76	617	194.07	617.66	10	21	GPH Ispat
2	0.305	20	245.89	783			194.18	618			10	19	
3	0.305	20	245.35	781			194.28	618			9.8	24	
1	0.305	20	210.45	670	208.48	663.33	172.75	545	171.18	541.66	9.5	19	Baizid Steel
2	0.305	20	204.68	650			168.50	535			9.7	21	
3	0.305	20	210.32	670			172.30	545			9.9	20	

4.4 Result parameter:

4-4: Comparison of different steel yield strength.

Parameter	Sample No	BSRM	GPH	Baizid	BSRM	GPH	Baizid	BSRM	GPH	Baizid
Nominal Dia (mm)		10	10	10	16	16	16	20	20	20
Actual Dia (mm)	**1**	9.93	9.96	9.91	15.98	15.98	15.94	19.93	19.97	20.00
	2	9.92	9.94	9.90	15.98	15.99	16.00	19.90	19.97	19.93
	3	9.92	9.96	9.90	15.96	15.99	15.95	19.92	19.95	19.94
Nominal Cross-Sectional Area (mm2)		78.54	78.54	78.54	201.06	201.06	201.06	314.16	314.16	314.16
Yield Load (KN)	**1**	42.41	50.82	42.32	109.57	126.34	107.25	166.50	193.76	172.75
	2	42.62	50.88	45.95	108.57	126.00	106.50	168.07	194.18	168.50
	3	42.57	50.60	45.10	109.22	128.10	109.55	166.20	194.28	172.30
Yield Strength (Mpa)	**1**	540	647	540	545	628	535	530	617	545
	2	530	648	585	540	630	530	535	618	535
	3	533	644	575	542	637	545	530	618	545
Ultimate Load (KN)	**1**	51.83	65.24	50.86	133.70	166.32	132.08	207.34	245.26	210.45
	2	51.05	65.33	53.10	131.69	166.67	131.44	202.63	245.89	204.68
	3	51.38	64.95	53.15	132.20	166.92	134.52	203.10	245.35	210.32
Ultimate Strength (Mpa)	**1**	660	831	645	665	827	660	660	781	670
	2	650	832	675	655	829	655	645	783	650
	3	654	827	675	660	830	670	650	781	670
% Elongation (guage length -5D mm)	**1**	21	20	22	21	18	21	21	21	19
	2	22	18	20	22	19	23	21	19	21
	3	22	16	20	22	17	19	21	24	20
Bend Test	**1**	OK	OK	OK	OK	OK	OK	OK	OK	OK
	2	OK	OK	OK	OK	OK	OK	OK	OK	OK
	3	OK	OK	OK	OK	OK	OK	OK	OK	OK
Re-Bend Test	**1**	OK	OK	OK	OK	OK	OK	OK	OK	OK
	2	OK	OK	OK	OK	OK	OK	OK	OK	OK
	3	OK	OK	OK	OK	OK	OK	OK	OK	OK

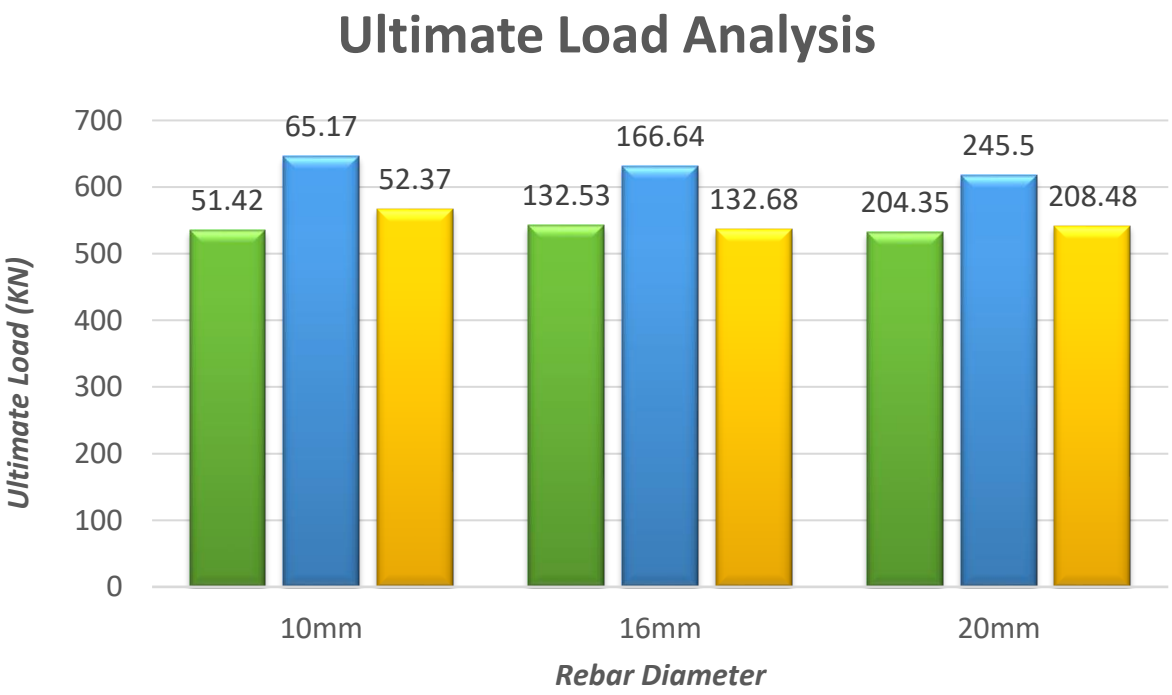


Figure 4-1: Yield Strength Analysis.

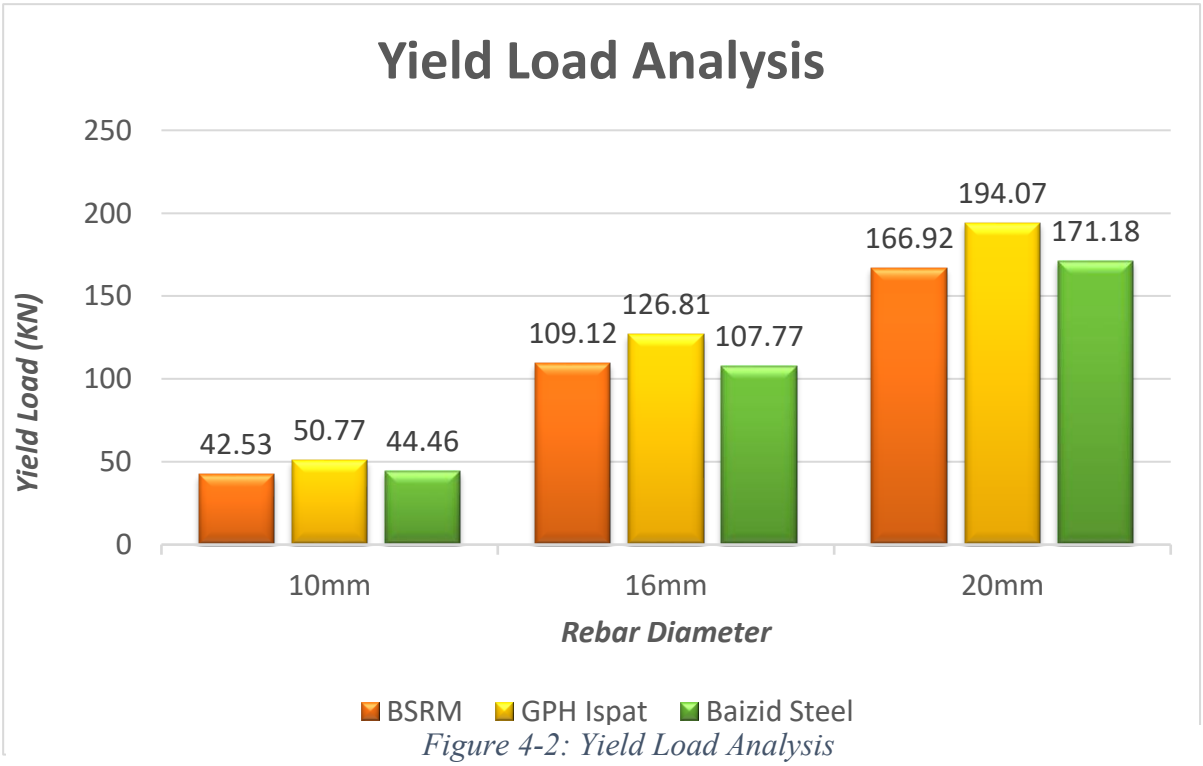


Figure 4-2: Yield Load Analysis

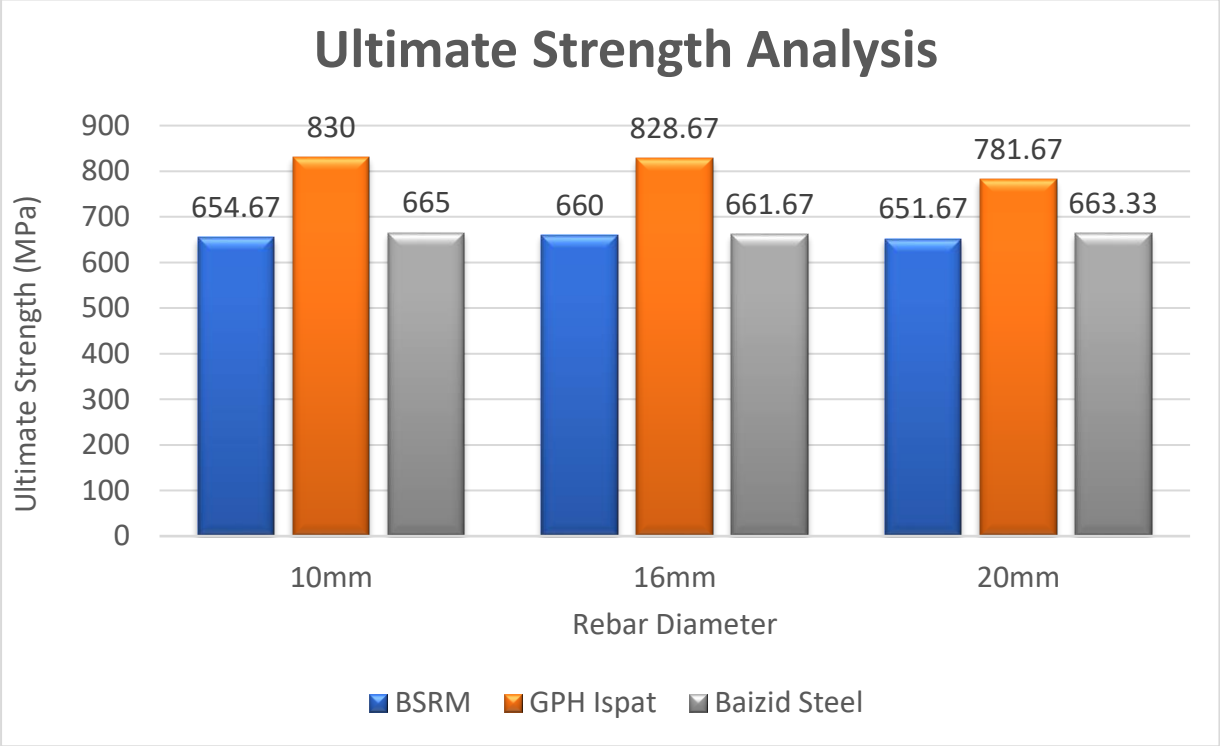


Figure 4-3: Ultimate Strength Vs Rebar Diameter Analysis

The ultimate tensile strength of rebar generally decreases as its diameter increases. This is primarily due to the heat treatment process and subsequent changes in the steel's microstructure. When large-diameter rebar is cooled down after being heated (a process called quenching), the outer surface cools much faster than the inner core. This creates a hard, strong outer layer, while the core remains softer due to the slower cooling rate. This uneven cooling process reduces the overall homogeneity of the rebar. In contrast, small-diameter rebar cools down more quickly and uniformly, resulting in a more consistent microstructure throughout the entire bar. This uniformity contributes to the higher ultimate tensile strength seen in smaller diameter rebars compared to their larger counterparts. Additionally, larger diameter rebars have a higher chance of containing internal defects, which can further reduce their overall strength. This is why the ultimate strength values for the 16mm and 20mm rebars in your provided table are lower than the 10mm rebar.

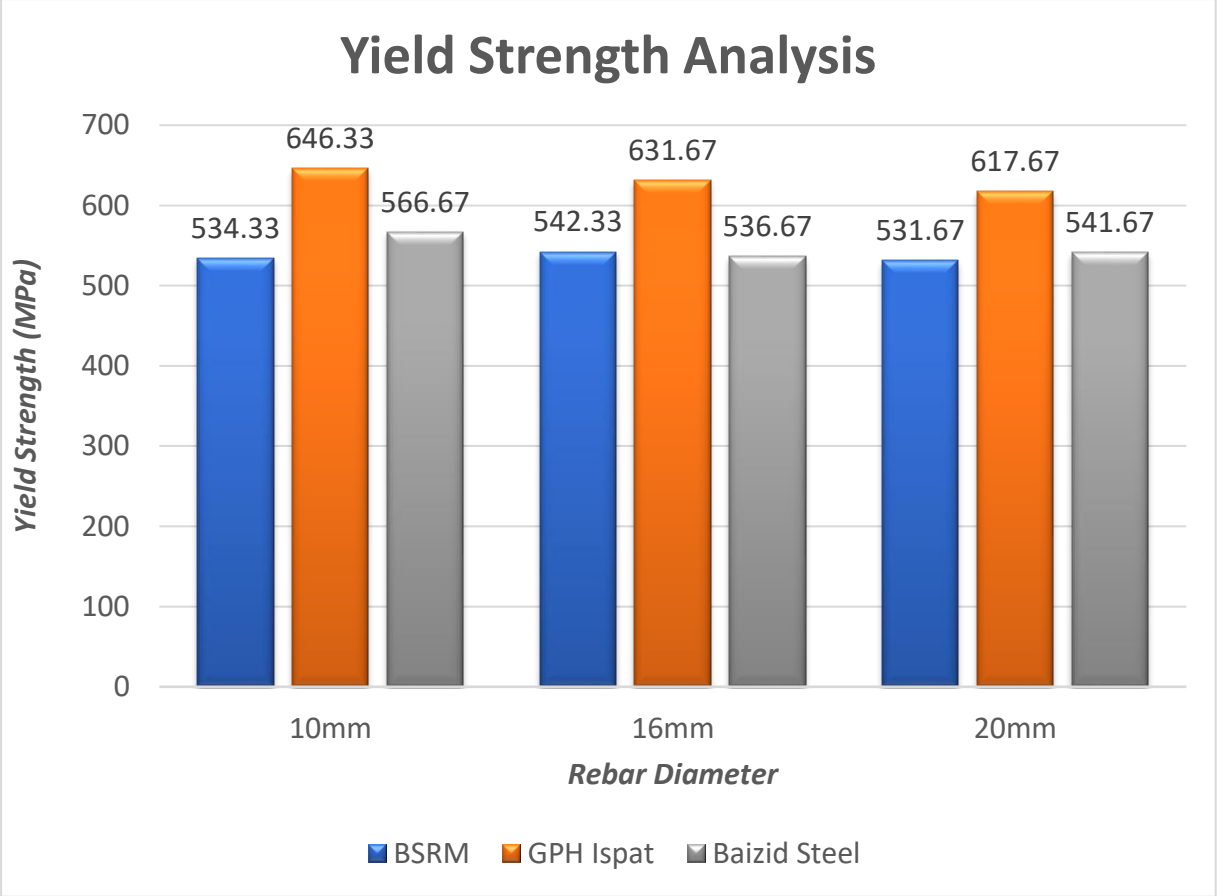


Figure 4-4: Yield Strength Vs Rebar Diameter Analysis

The ultimate yield tensile strength of rebar generally decreases as its diameter increases. This is primarily due to the heat treatment process and subsequent changes in the steel's microstructure. When large-diameter rebar is cooled down after being heated (a process called quenching), the outer surface cools much faster than the inner core. This creates a hard, strong outer layer, while the core remains softer due to the slower cooling rate. This uneven cooling process reduces the overall homogeneity of the rebar. In contrast, small-diameter rebar cools down more quickly and uniformly, resulting in a more consistent microstructure throughout the entire bar. This uniformity contributes to the higher ultimate yield tensile strength seen in smaller diameter rebars compared to their larger counterparts. Additionally, larger diameter rebars have a higher chance of containing internal defects, which can further reduce their overall strength. This is why the ultimate strength values for the 16mm and 20mm rebars in your provided table are lower than the 10mm rebar.

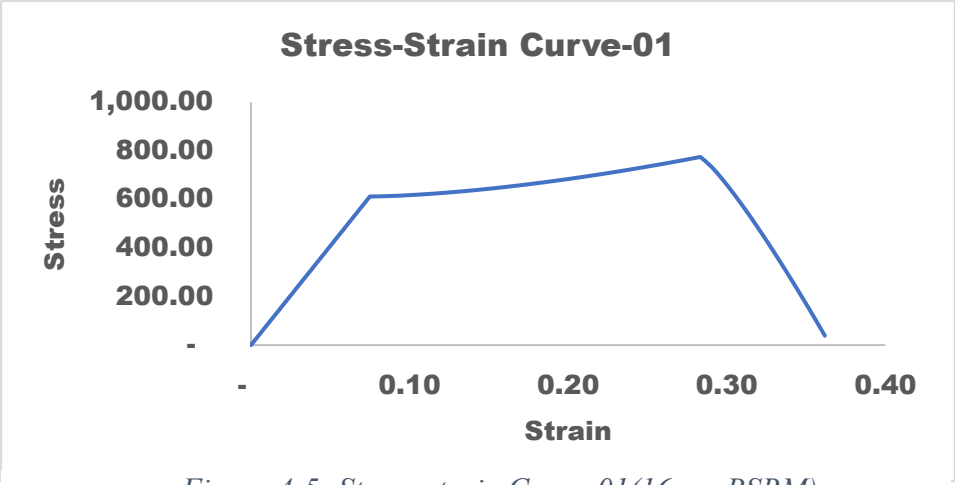


Figure 4-5: Stress-strain Curve-01(16mm BSRM)

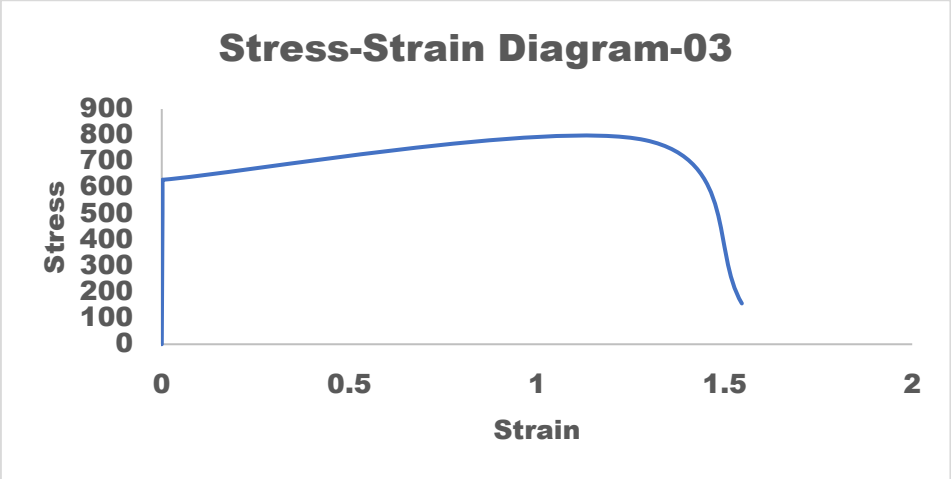


Figure 4-6: Stress-strain Curve-02 (10mm BSRM)

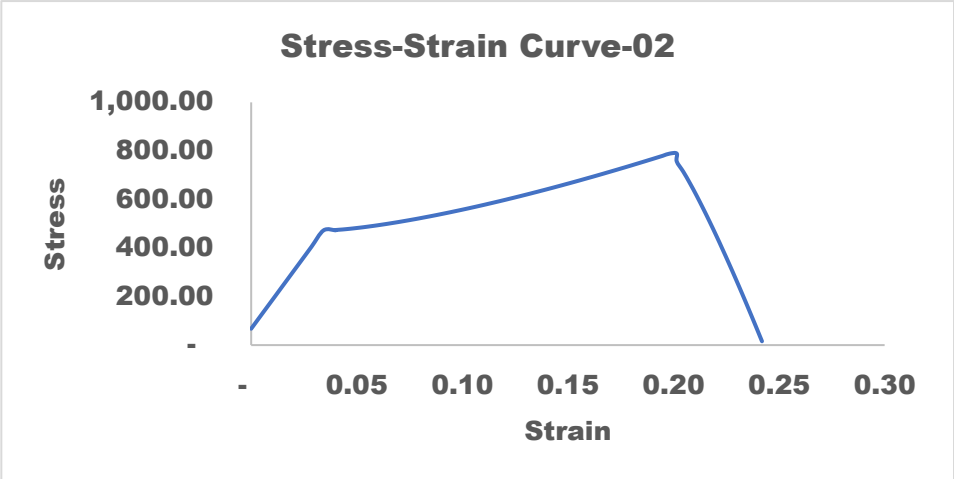


Figure 4-7: Stress-strain Curve-03 (20mm BSRM)

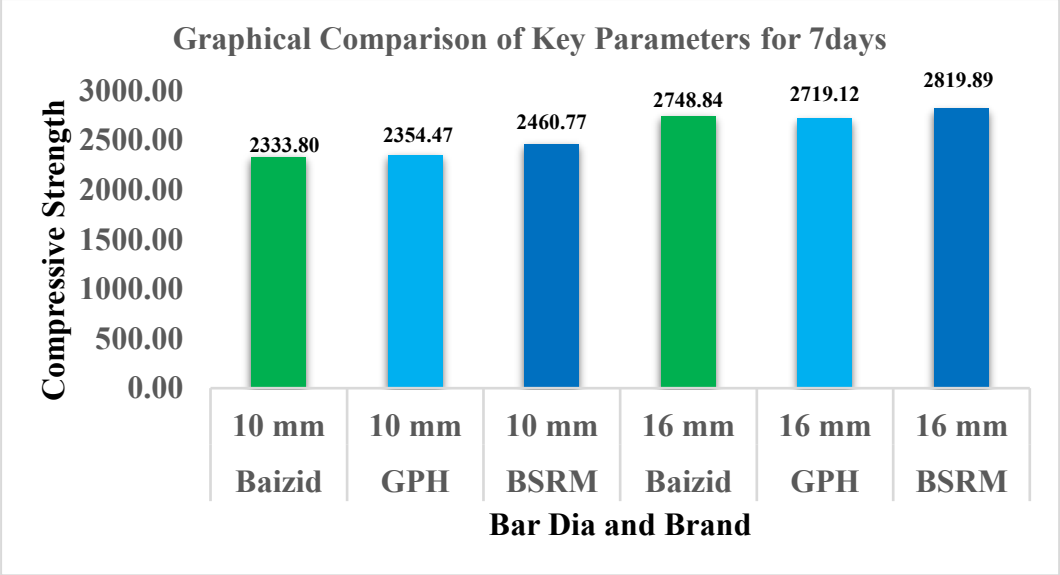


Figure 4-8: Graphical Comparison of Key Parameters for 7days

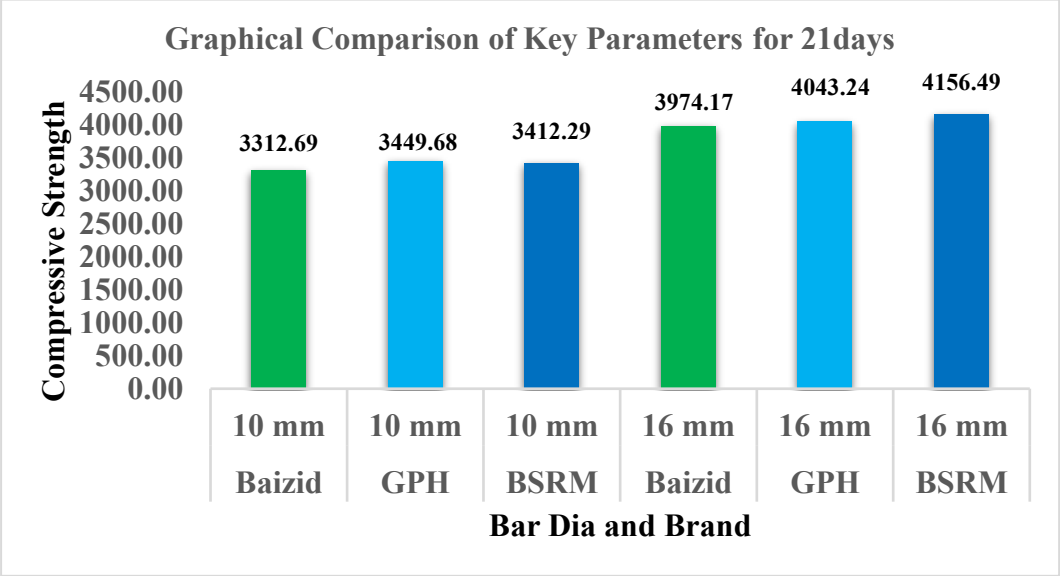


Figure 4-9: Graphical Comparison of Key Parameters for 21days

GPH Ispat showed superior strength, BSRM better ductility, while Baizid Steel had some non-compliance

4-5: Key Findings

Parameter	*BDS/ASTM Standard*	*GPH Ispat*	*BSRM*	*BAIZID*
Yield Strength	**≥ 500 MPa**	**510–545 MPa (OK)**	**500–525 MPa (OK)**	**460–490 MPa (Below Std.)**
Tensile Strength	**≥ 620 MPa**	**630–660 MPa (Good)**	**620–650 MPa (OK)**	**590–610 MPa (Low)**
Elongation %	**≥ 12%**	**21–22% (Ok)**	**16–17% (Ok)**	**18–20% (Ok)**

4.5 Compressive Strength Comparison

Compared the average compressive strength of the reinforced cylinders from the three manufacturers. The 16 mm Baizid steel bar shows the highest compressive strength at 2748.84 MPa, while the 10 mm GPH bar has the lowest at 2354.47 MPa. At 21 days, the 16 mm GPH steel bar has the highest compressive strength at 4043.24 MPa, and the 10 mm Baizid bar has the lowest at 3312.69 MPa.

4.6 DISCUTION

Don't The name of the experiment is compression test of helical spring The number of turns of the spring is 6 which is observed during the experiment. When load dial is zero. the average deflection is zero. While the applied load is maximum, we get the maximum detection such that when the applied load is 225.5 16 the average deflection is 4.43 mm which is the maximum deflection. we also calculate the stiffness of spring (k) from the Load-deflection graph. We find the value of ksi 1-30 kip/in we also know the standard value of shear modulus (a) of Steel is 12000 ksi. But in our experiment, we get the value of shear modulus 10381-8 ksi which is less than the Standard value. we cannot get the standard value of Shear modulus because our experimental specimen set does not accurately on our collected data is not accurate and we cannot draw load-deflection graph correctly. For this reason, the value of stiffness of spring is not accurate. So that experimental shear modulus is not matching the standard shears modulus of steel.

CHAPTER 5

Conclusions and Future Works

5.1 Conclusions

Locally produced 500W thermo mechanically treated (TMT) high-strength reinforcing steel bars were collected from three different companies for evaluation. Tensile tests were performed using a Universal Testing Machine (UTM) to determine tensile strength, yield strength, and percentage elongation, ductility, compressive strength, weldability under three different conditions: with rib, without rib, and without case.

To complement the experimental work, mathematical models were developed to establish relationships between tensile properties (tensile and yield strength) and hardness, based on previous studies. The failure modes of the rebars under tensile loading were also examined through observations of fracture surfaces.

The study revealed variations in tensile properties across the TMT rebars. However, the results from the mathematical models showed strong consistency with the experimental values, particularly for yield strength calculated from strength–hardness models. Furthermore, the effects of microstructures and carbon equivalent on hardness and tensile behavior were evaluated, and the predicted tensile properties were well supported by the observed microstructures and the predicted compressive strength properties were well supported by the observed bonding with concrete.

The fracture behavior of the TMT rebars also demonstrated strong dependence on microstructure. Overall, the study successfully established a structure–property relationship for the locally produced TMT rebars, validated by both experimental results and existing mathematical models.

5.2 Limitations and Recommendations for Future Works

Based on the results of mechanical testing and detailed analysis of material properties, GPH Ispat rebars are highly suitable for applications where high strength is critical, whereas BSRM rebars are recommended in situations that demand superior ductility. Both manufacturers demonstrate a strong commitment to quality by strictly adhering to national and international standards, and they employ advanced production technologies to ensure the reliability and performance of their reinforcement bars.

Despite these positive outcomes, certain limitations exist. The current study primarily focuses on short-term mechanical properties under controlled conditions. Therefore, the long-term structural behavior of these high-performance steels in diverse environmental conditions, such as extreme temperatures, humidity, and corrosive settings, remains less understood. Additionally, the performance of these materials under complex loading scenarios, including cyclic and dynamic loads, requires further investigation.

Future research should address these gaps by conducting comprehensive studies on durability, fatigue resistance, and long-term deformation characteristics. Such investigations will provide deeper insights into the suitability of these materials for large-scale infrastructure projects and contribute to more informed material selection for engineers and designers.

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