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Comparison of Yield and Tensile Strengths of Reinforcing Steel Bars Produced in Kabul with ASTM A615/A615M Requirements

Mudasir Durani*¹, and Syed Javid Azimi ²

^{1,2,3} *Afghan International Islamic University, Department of Industrial Engineering, Faculty of Engineering, Kabul, AF*

Abstract

Reinforcing steel is a critical material in concrete structures, and its mechanical properties directly affect structural performance and safety. This research compared the yield and tensile strengths of Grade 60 reinforcing steel bars produced by Khan, Meli, and Melat Steel Industries in Kabul, Afghanistan. This study used a quantitative, comparative research design based on laboratory test records collected in 2024 from Karkon Afghan, BAES, and Accurate Construction Materials Testing Laboratories. We analyzed 390 reinforcing steel test results from 188 laboratory reports, covering nominal bar diameters of 12, 14, and 16 mm. The results were organized and analyzed in Microsoft Excel and OriginPro 2024, and the mean, standard deviation, coefficient of variation, and comparative differences were compared with the minimum requirements of ASTM A615/A615M for Grade 60 steel. The findings showed that the mean yield and tensile strengths of all three manufacturers were generally above the ASTM minimum requirements of 420 MPa and 620 MPa, respectively. For 12 mm bars, Meli recorded the highest mean yield and tensile strengths, while Khan and Melat showed lower values. For 14 mm bars, Khan had the highest mean yield strength, whereas Melat had the highest mean tensile strength. For 16 mm bars, Melat recorded the highest mean yield and tensile strengths. Statistically significant differences among manufacturers were observed for some bar diameters, while other differences were not significant. Individual specimens below the specified minimum values were also observed, indicating variability in mechanical performance.

Keywords: Steel Industry, Reinforced Steel, Tensile Strength, Yield Strength, ASTM A615/A615M

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Introduction

This research paper compares the yield and tensile strength of Grade 60 reinforcing steel bars manufactured by MELI, KHAN, and MELAT Steel Industries. The study focuses on 12 mm, 14 mm, and 16 mm diameters to determine whether locally produced reinforcing steel meets ASTM A615/A615M international standards. Steel bars are used not only in construction but also in the automotive, manufacturing, energy, and aerospace industries because they have

*Email: mudasirmohammadi04@gmail.com (corresponding author)

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excellent bonding qualities, a low thermal expansion coefficient compared to concrete, and high weldability for on-site production (Aldabagh, 2020). The ultimate and yield strengths of steel reinforcement are key quality-defining metrics. The steel industry in Afghanistan faces significant challenges, including inconsistent adherence to international standards, nonstandard mechanical testing processes and outcomes, and the presence and production of non-original bars. Nonstandard reinforcement steel products distributed to clients and donors cause building collapses and structural failures and increase construction project costs and timelines due to repeated testing, engineers' limited knowledge, the use of different raw materials, and inadequate regulatory control (Aimaq, 2021; Mudaser, 2023).

Kabul, Afghanistan's capital, has many steel production facilities; among them, Khan Steel, Meli Steel, and Milat Steel are pioneers. Based on our findings, these three industries differ in production capacity, control systems, and technological performance. Steel's desirable properties, such as weldability, strength, ductility, and environmental sustainability, prove that steel is an important engineering material. The unique mix of steel properties, such as strength and mechanical behavior, is influenced by its microstructure, production process, and other components, which also contribute to its performance (Beshah, 2022; Dhoska, 2019).

Concrete and reinforcement steel form a composite structural system that concentrates pressure in several directions (Zhou, 2022). For modern infrastructure, steel reinforcement is essential to ensure safety, longevity, economics, and durability (Mander, 2007; Rafi, 2018). Bringing steel bars and concrete together offers many benefits; thermal compatibility is among the most important. This means that when the two materials are used together, internal forces caused by temperature differences do not occur; instead, the materials accommodate each other easily (Osarenmwinda, 2013). To provide sufficient bond strength in the matrix, steel bar surfaces are ribbed to interlock with the concrete mix (Achamyeleh, 2019).

Many studies suggest that reinforcing bars are quite resilient to seismic activity, especially in seismically active regions such as Asia and North America (Byrd, 2023). Research findings from different parts of the world suggest that steel consumption, especially in developing economies, has been increasing rapidly as urbanization and infrastructure development continue to rise (Kawabata, 2012). Demand is higher in the Middle East, Africa, and Asia because of government-sponsored infrastructure projects and other development initiatives (Arcila, 2020; Abdel-Magid, 2017).

To reduce project amounts and improve structural efficiency, high-strength steels such as ASTM A1035 and Grades 60 and 80 are used more than ever before (Aldabagh, 2020). To improve quality control, developed nations use data analytics and smart automation (Arnu, 2017; Zhou, 2022). After 2001, reconstruction, rehabilitation, and rebuilding efforts resulted in the establishment and expansion of steel production facilities in Afghanistan, especially in Kabul Province (Wahedi M. I., 2023; Gardizi, 2025; Khan, 2026). To maintain consistent steel bar quality, international standards provide detailed requirements for compliance (ASTM, 2022; ISO, 2016; AASHTO, 2015).

Many factors affect steel quality, including thermomechanical treatment, cooling rate, impurities, bar deformation patterns, and chemical composition (Dhoska, 2019; Abdel-Magid, 2017). Products from national companies can differ significantly, as mechanical

characteristics, structural performance, and the use of scrap-based materials affect production quality (Atsbeha, 2017; Beshah, 2022). Findings show that locally produced steel in many countries may not always meet these norms because of contaminants and inconsistent production control (Ede, 2014; Beshah, 2022; Achamyeleh, 2019). Reinforcing bars do not meet the 420 MPa minimum yield strength requirement. This problem caused structural safety concerns in Ethiopia (Beshah, 2022). Moreover, because scrap-based steel bars in Nigeria have high contamination levels, the reinforcing samples could not meet ASTM yield strength requirements (Ede, 2014).

Steel made from scrap has predictable chemical characteristics. Because it does not have a controlled melting point, copper, tin, sulfur, and phosphorus can mix into the final product (Abdel-Magid, 2017; Beshah, 2022; Atsbeha, 2017). Improper and uncontrolled mixing of scrap materials and contamination often cause unpredictable mechanical behavior, such as reduced ductility, low yield strength and UTS, and premature fracture during bending. These factors can cause inconsistency among different batches (Mudaser, 2023).

Mechanical performance varies from batch to batch because the product's chemical composition varies widely, especially manganese and carbon content (Salman, 2018). A recent study shows that steel produced in Afghanistan has low structural reliability, as most mills lack process monitoring and automated rolling-temperature control systems (Mudaser, 2023). Prior to these studies, previous research showed that reinforcing bars made in Afghanistan often suffer from poor refining processes and the use of inappropriate scrap material (Mudaser, 2023). Another study found that bars are too small, not very ductile, perform poorly, and contain too many impurities (Ede, 2014; Nwakaire, 2021).

Because of inadequate regulatory oversight, reinforcement bars produced in Ghana varied in yield strength and mass per unit length (Yalley, 2016). Many samples were collected and tested to check deviations and yield strength ratios; it was noted that brittle failure under service loading is possible, raising concerns (Yisa, 2017). Research in Pakistan, Nigeria, and Ethiopia suggests significant variation in yield strength and UTS, even when steel bars are produced by the same manufacturing facility (Ede, 2014; Atsbeha, 2017).

Over the past decades, Afghanistan's infrastructure has developed significantly, and reinforcement steel products have played an important role. Although the steel sector has improved and expanded significantly, many obstacles remain. These obstacles include building collapse and difficulty distinguishing standard from nonstandard steel products. Furthermore, construction projects are delayed, and multiple tests for the same material waste significant money; inexperienced engineers and inadequate regulatory oversight are also concerns.

To select a standard reinforcement steel, one must evaluate the required steel's primary properties in a lab to determine yield strength and ultimate strength. Without these measures, building collapses and structural failures may occur, causing human and material losses. Therefore, it was important to study the mechanical properties (tensile and yield strengths) of steel bars. This study focuses on reinforcement steel results from three laboratories (Karkon Afghan, Accurate, and BAES) in Kabul that are under the direct oversight of the Ministry of Commerce and Industries and Afghanistan national authorities.

This research provides a comprehensive assessment by comparing three major local manufacturers directly with ASTM A615/A615M requirements, whereas the previous Afghan study focused on one local manufacturer and compared it with imported products.

Methods and Materials

This study will examine the yield strength and tensile strength of Grade 60 reinforcing steel bars using a quantitative, comparative research design based on existing laboratory test records from 2024. The study is quantitative because it uses numerical laboratory measurements, including yield strength and tensile strength, which are analyzed and compared using numerical and descriptive methods. The study is also comparative because it compares the mechanical properties of reinforcing steel across the Melat, Khan, and Meli steel industries, different nominal bar diameters (12, 14, and 16 mm), and applicable international standard requirements, particularly ASTM A615/A615M. Data were collected at Accurate, Karkon Afghan, and BAES construction materials testing laboratories. Methods for collecting and analyzing numerical data, such as test results, were fundamental to the quantitative design. The three Kabul-based manufacturers' specifications adhered to the ASTM A615/A615M standard.

Step 1: Gathered data from various sources, including Khan Steel, Meli Steel, and Melat Steel, on the sizes of reinforcement steel bars (12 mm, 14 mm, and 16 mm), and from three laboratories (Karkon Afghan, BAES, and Accurate).

Step 2: Sorting and reviewing test reports in Microsoft Excel.

Step 3: Analyzing the test reports, including finding the mean and standard deviation, checking the results against ASTM limits, and conducting factory-to-factory comparisons.

Step 4: Compiling findings and observations using summary tables and OriginPro 2024 software to generate comparative charts.

Reinforcing bars from the Khan Steel, Meli Steel, and Melat Steel industries were studied. The most common nominal bar diameters used in Afghan building projects are 12 mm, 14 mm, and 16 mm, and all bars were Grade 60. To conduct tests in accordance with international standards, these laboratories use calibrated equipment, such as Universal Testing Machines (UTMs). We created a master database in Microsoft Excel using data from the individual laboratory test reports. For every test record in the database, the following fields were included: Laboratory Name, Testing Date, Yield Strength, Tensile Strength, Effective Diameter, and Nominal Diameter. MPa and mm were used as the units for yield strength and effective diameter, respectively. The aforementioned laboratories used standardized test methods to generate the data.

We analyzed 390 reinforcing steel test results covering three manufacturers, three nominal bar diameters (12, 14, and 16 mm), and the mechanical properties (yield strength and tensile strength). These results were obtained from 188 laboratory reports collected from three construction materials testing laboratories in Kabul. Table 1 presents the distribution of the test results.

Table 1: *Distribution of Reinforcement Steel Test Results*

Manufacturer	12 mm	14 mm	16 mm	Total
Melat Steel	49	28	32	109
Khan Steel	20	13	18	51
Meli Steel	16	8	4	28

Table 2 summarizes the important tests and the equipment needed for them.

Table 2: *Laboratory Test Methods and Equipment*

Property Tested	Standard Test Method	Equipment Used	Key Procedure
Tensile & Yield Strength, Elongation	ASTM A615 / A370	Universal Testing Machine (UTM)	Grip a rebar sample at both ends and apply a continuously increasing tensile load until fracture. The yield strength (stress at which plastic deformation begins), ultimate tensile strength (maximum stress sustained), and percentage elongation (increase in gauge length at fracture) are recorded.

Table 3: *Tensile and Yield Strength Requirements (ASTM, 2022; AASHTO, 2015).*

	Grade 40 [280] ^A	Grade 60 [420]	Grade 75 [520]	Grade 80 [550]
Tensile strength, min, psi [MPa]	60 000 [420]	90 000 [620]	100 000 [690]	105 000 [725]
Yield strength, min, psi [MPa]	40 000 [280]	60 000 [420]	75 000 [520]	80 000 [550]
Elongation in 8 in. [200 mm], min., % Bar Designation No. 3 [10]	11	9	7	7
4, 5 [13, 16]	12	9	7	7
6 [19]	12	9	7	7
7, 8 [22, 25]	...	8	7	7
9, 10, 11 [29, 32, 36]	...	7	6	6
14, 18 [43, 57]	...	7	6	6

**Figure 1.** *Tensile test specimen in grips.*

Table 4: Bend Test Requirements (ASTM, 2022; AASHTO, 2015).

Bar Designation No.	Pin Diameter for Bend Tests			
	Grade 40 [280]	Grade 60 [420]	Grade 75 [520]	Grade 80 [550]
3, 4, 5 [10, 13, 16]	$3\frac{1}{2} d^B$	$3\frac{1}{2} d$	$5d$	$5d$
6 [19]	$5d$	$5d$	$5d$	$5d$
7, 8 [22, 25]	...	$5d$	$5d$	$5d$
9, 10, 11 [29, 32, 36]	...	$7d$	$7d$	$7d$
14, 18 [43, 57] (90°)	...	$9d$	$9d$	$9d$

**Figure 2:** Load-elongation test display

Data Analysis

Everything was done systematically and in a planned manner to ensure the highest level of accuracy, consistency, and comparability in the outcomes. Karkon Afghan, BAES, and Accurate Construction Materials Testing Laboratories are three laboratories in Kabul Province that provide test certificates or laboratory test results. Before any action, we carefully reviewed all data and test reports in PDF format. The test results were extracted from the PDFs and organized using Excel. The steel data were organized by producer (Khan Steel, Meli Steel, and Melat Steel) and nominal steel diameter (12 mm, 14 mm, and 16 mm). Statistical analysis of the yield and tensile strength data was performed by calculating the average value for each parameter and tabulating the nominal rebar diameters for each specified nominal rebar size. The calculated values were compared with the minimum criteria in ASTM A615/A615 M. Using the aforementioned reference values for each bar diameter, bar charts were generated in OriginPro 2024 software to illustrate and compare the performance of the steel manufacturers Melat, Khan, and Meli. This analysis allows examination of the Kabul-based manufacturers' performance, identification of differences among them, and assessment of compliance with international standards such as ASTM A615/A615 M. Excel and OriginPro 2024 were used for all data analysis calculations; descriptive statistics included range, standard deviation, and mean. Graphical comparisons were made between manufacturers and bar sizes.

Graphical Comparative Analysis

Using the yield strength and tensile strength of 12 mm, 14 mm, and 16 mm reinforcement steels and comparing the products manufactured by Khan Steel, Meli Steel, and Melat Steel with the ASTM standard, bar charts were created. The bar charts for 12 mm steel, showing the yield strengths of KHAN (480.3), MELAT (466.3), and MELI (582.7), were compared with the ASTM standard (420). Bar charts comparing the tensile strengths of KHAN (711.3), MELAT (691.5), and MELI (762.7) steel at 12 mm with the ASTM standard (620). Bar charts for 14 mm showed the yield strengths of KHAN (511.39), MELAT (487.19), and MELI (505.38) and compared them with the ASTM standard (420). Bar charts showing the tensile strengths of KHAN (647.42), MELAT (717.88), and MELI (650.46) steel at 14 mm were compared with the ASTM standard (620). The bar charts for 16 mm showed the yield strengths of KHAN (477.07), MELAT (589.22), and MELI (546.74), compared with the ASTM standard (420). Bar charts showing the tensile strengths of KHAN (661.68), MELAT (760.02), and MELI (701.38) steel at 16 mm were compared with the ASTM standard (620). To display the results clearly, the collected data were summarized in tables. Table 5 shows one example:

Table 5: Mechanical Properties and ASTM compliance.

Nominal Dia. (mm)	Factory	Mean Effective Dia. (mm)	Mean Yield Strength (MPa)	Mean Tensile Strength (MPa)	T/Y Ratio	Complies with ASTM? (Y/N)
12	KHAN	11.585	480.31	711.29	1.48	Y
12	MELAT	12.015	466.30	691.48	1.48	Y
12	MELI	11.942	582.74	762.72	1.31	Y
14	KHAN	14.016	511.39	647.42	1.27	Y
14	MELAT	14.009	487.19	717.88	1.47	Y
14	MELI	13.664	505.38	650.46	1.29	Y
16	KHAN	16.065	477.07	661.68	1.39	Y
16	MELAT	15.929	589.22	760.02	1.29	Y
16	MELI	15.981	546.74	701.38	1.28	Y

Note: Compliance is based on a pass/fail assessment against the minimum yield (420 MPa) and tensile (620 MPa) strengths.

Findings

This section presents the analysis and discussion of laboratory test results collected from three construction materials testing laboratories in Kabul. KHAN, MELAT, and MELI steel industries produced the reinforcement steel bars. The results for yield strength and tensile

strength were compared with the relevant ASTM specifications to determine the samples' effectiveness for their intended application.

Yield Strength of 12 mm Reinforcing Bars

According to the ASTM minimum requirement of 420 MPa, the yield strength results were compared. The yield strength of Melat was 466.301 MPa, Khan was 480.383 MPa, and Meli was 582.744 MPa. Among the three compared manufacturers, Meli Steel had the highest yield strength.

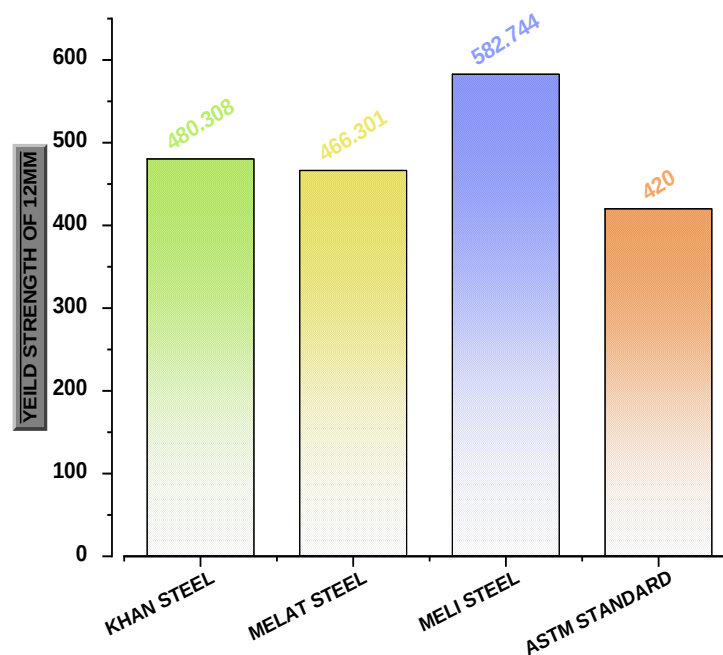


Figure 3: Bar chart of Yield strength of 12mm bars.

After testing, the material's elastic behavior for structural applications was satisfactory, as all samples met or exceeded the ASTM minimum yield strength. Comparatively, MELI's yield performance indicated greater resistance to plastic deformation than the other two manufacturers. KHAN steel performance was also satisfactory; it met all requirements but had a lower yield strength than the other two manufacturers. The available data show that all manufacturers provide Grade 60 reinforcement with satisfactory yield properties.

Yield Strength of 14 mm Bars

According to the ASTM minimum requirement of 420 MPa, the yield strength results of 14 mm reinforcement steel bars were compared. The yield strength of Melat was 487.19 MPa, Khan was 511.389 MPa, and Meli was 505.381 MPa. Among the three compared manufacturers, Khan Steel had the highest yield strength.

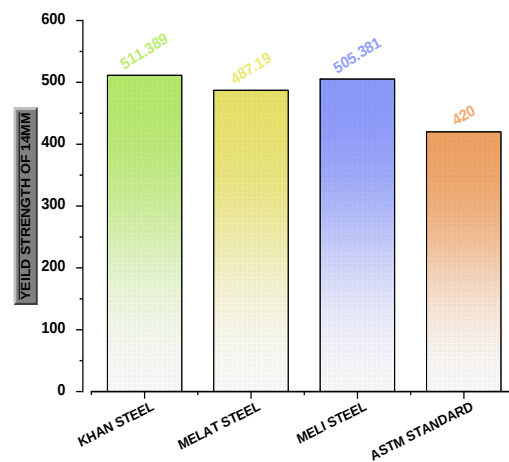


Figure 4: Yield strength of 14mm bars.

All tested samples considerably exceeded the ASTM-required minimum yield strength, indicating satisfactory performance in terms of resistance to plastic deformation. KHAN had the highest yield strength, indicating greater resistance to plastic deformation among the three manufacturers. MELI and MELAT were relatively close behind. The results show that the 14 mm bars had sufficient yield strength for structural applications.

Yield Strength of 16 mm Bars

According to the ASTM minimum requirement of 420 MPa, the yield strength results of 16 mm reinforcement steel bars were compared. The yield strength of Melat was 589.218 MPa, Khan was 477.067 MPa, and Meli was 546.743 MPa. Among the three compared manufacturers, Melat Steel had the highest yield strength.

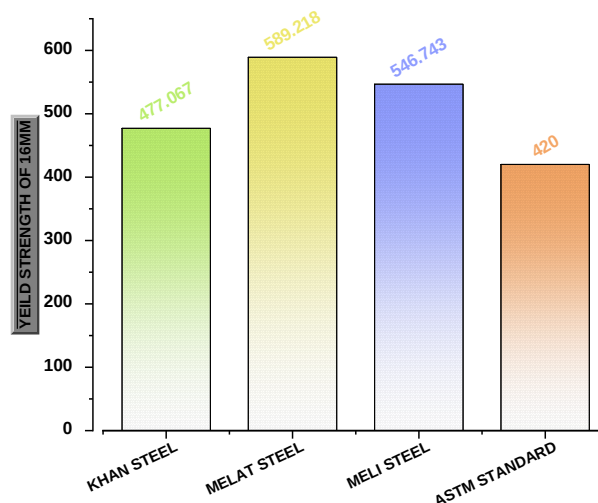


Figure 5: Yield strength of 16mm bars.

Compared with the ASTM minimum yield strength, all tested bars had higher values. MELAT had the highest yield strength, indicating greater resistance to plastic deformation among the three manufacturers. Although KHAN's value was the lowest of the three, it was still

significantly higher than the ASTM limit. The findings demonstrate that the reinforcing bars exhibited sufficient yield strength for use in structural design.

Comparison (YS) of Grade 60 Steel Bars: 12, 14, and 16 mm

In this section, we compare three different suppliers, KHAN, MELAT, and MELI, of Grade 60 reinforcing steel bars in three different diameters (12, 14, and 16 mm) and their geometrical and mechanical properties. The yield strength is the main topic of discussion, and all measured values are compared with ASTM requirements. Comparing the different bar diameters provides more information on material consistency, manufacturing quality, and stability. All of the tested bars fulfilled the criteria for Grade 60 because their yield strengths were significantly greater than the ASTM standard's minimum of 420 MPa. With 12 mm bars, MELI had the highest yield strength among the three manufacturers. KHAN reported the highest yield strength for 14 mm bars, followed by MELI and MELAT. MELAT exhibited the highest yield strength for 16 mm bars, while both MELI and KHAN were higher than the ASTM minimum requirement. Variation in yield strength by diameter and manufacturer may relate to differences in chemical composition, thermo-mechanical treatment, and cooling conditions. However, this study did not measure these factors. The reinforcement consistently met the minimum yield-strength requirement across all tested sizes.

Tensile Strength of 12 mm Bars

According to the ASTM minimum requirement of 620 MPa, the tensile strength results of 12 mm reinforcement steel bars were compared. The tensile strength of Melat was 691.48 MPa, Khan was 711.287 MPa, and Meli was 762.724 MPa. Among the three compared manufacturers, Meli Steel had the highest tensile strength.

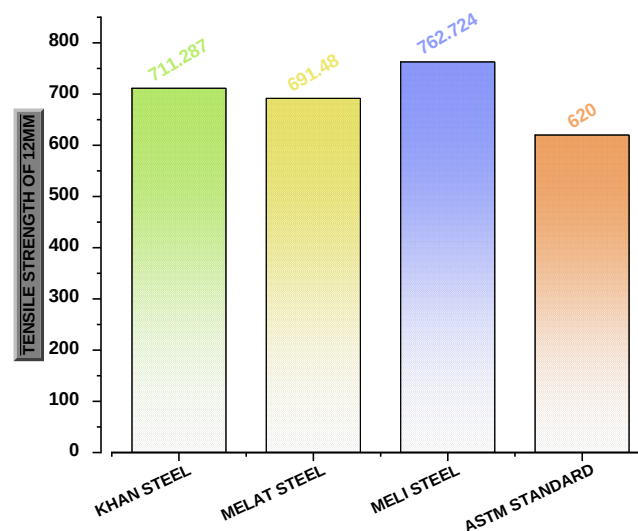


Figure 6: Tensile strength of bars of 12mm diameter.

The tensile strength values of all samples exceeded the ASTM minimum criterion, indicating that they met the Grade 60 tensile-strength requirement. The higher tensile strength of MELI was associated with greater strain-hardening capability based on the measured tensile-strength values. While MELAT satisfied the requirement despite having the lowest tensile strength,

KHAN fell between the other two manufacturers. Higher tensile strength can contribute to structural resistance under high tensile loading.

Tensile Strength of 14 mm Bars

According to the ASTM minimum requirement of 620 MPa, the tensile strength results of 14 mm reinforcement steel bars were compared. The tensile strength of Melat was 717.883 MPa, Khan was 647.418 MPa, and Meli was 650.457 MPa. Among the three compared manufacturers, Melat Steel had the highest tensile strength.

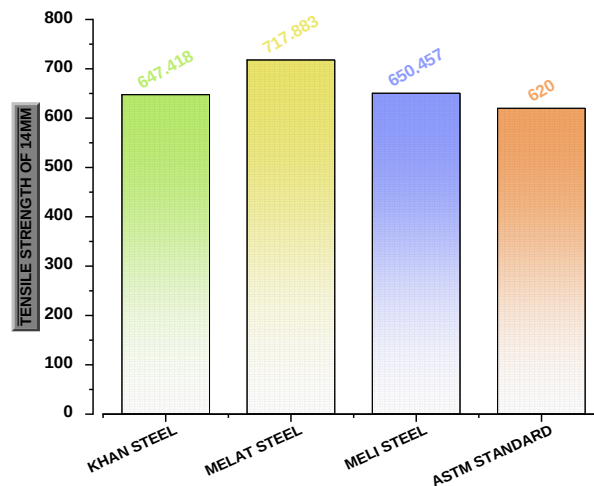


Figure 7: Tensile Strength of Bars with a Diameter of 14 mm

All of the producers met the ASTM requirements for tensile strength. MELAT had the highest tensile strength, while KHAN and MELI recorded relatively similar values. Higher tensile strength may indicate greater resistance to tensile loading.

Tensile Strength of 16 mm Bars

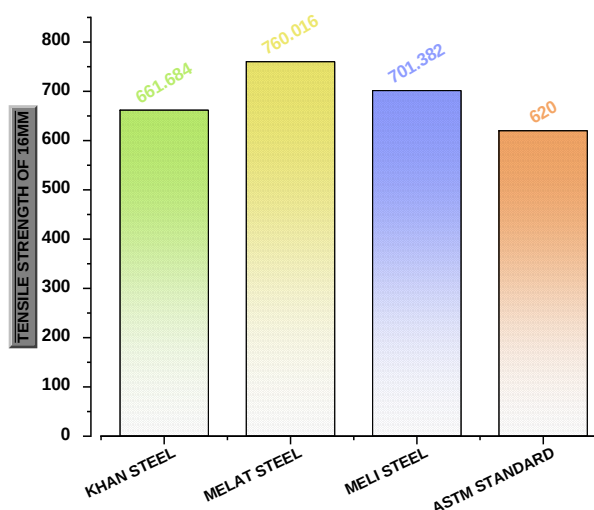


Figure 8: Tensile strength of 16mm bars

Against the ASTM minimum requirement of 620 MPa, the tensile strength results for 16 mm reinforcement steel bars were compared. The tensile strength of Melat was 760.016 MPa, Khan was 661.684 MPa, and Meli was 701.382 MPa. Among the three compared manufacturers, Melat Steel had the highest tensile strength.

All brands' tensile strength test results were in accordance with the ASTM requirements. The results showed that MELAT had the highest tensile strength among the three manufacturers. Higher tensile strength values indicate greater resistance to tensile stresses after yielding.

Comparative (TS) of Grade 60 Steel Bars: 12, 14, and 16 mm

In this section, we compare three different producers' Grade 60 reinforcing steel bars, KHAN, MELAT, and MELI, based on their geometrical and mechanical properties. The bars in question measure 12, 14, and 16 mm in diameter. All of the measured values were evaluated according to the applicable ASTM standards, and the analysis focused on tensile strength. Comparing different bar diameters provides information about structure, production quality, and material consistency. Acceptable ultimate-strength behavior was observed, with all bar diameters recording tensile strength levels exceeding the ASTM minimum strength requirement of 620 MPa. Of the three types of 12 mm bars tested, MELI had the highest tensile strength, followed by KHAN and MELAT. In tensile testing with 14 mm bars, MELAT had the highest tensile strength, while KHAN and MELI had comparable values. Among the 16 mm bars tested, MELAT showed the highest tensile strength, followed by MELI and KHAN. Variations in tensile strength across diameters may relate to differences in manufacturing and material properties. When post-yield performance matters, tensile strength reflects reinforcement behavior under high loading.

Discussion

This section discusses the tensile and yield strengths of Grade 60 reinforcing bars. To assess structural suitability, reliability, and quality, the discussion integrates the test results with ASTM specifications. The results showed that all steel bars met the ultimate-strength and yield-strength requirements set by ASTM standards. For consistency in reinforced concrete structures, the mechanical properties of the reinforcement steel used in construction are important. Results varied among steel manufacturers, but all met the ASTM requirements. The mechanical properties of steel bars are influenced by raw-material quality, chemical composition, manufacturing processes, and cooling conditions. Researchers in Ethiopia (Achamyeleh, 2019; Beshah, 2022), Nigeria (Ede, 2014; Nwakaire, 2021), Pakistan (Rafi, 2018), and Ghana (Yalley, 2016) reported that locally produced steel bars generally satisfy the required mechanical strength while exhibiting variability among companies. This study aligns with Mudasir and Wahidi, who found that Khan Steel reinforcement bars showed satisfactory tensile capacity and elongation compared with imported steel from Esfahan and Tashkent. This research provides a comprehensive assessment by directly comparing three major local manufacturers against ASTM A615/A615M requirements, whereas the previous Afghan study focused on one local manufacturer and compared it with imported products.

The statistical analysis demonstrated that yield strength varied among the tested manufacturers and bar diameters. For 12 mm bars, Meli recorded the highest mean yield strength (582.74

MPa), followed by Khan (480.31 MPa) and Melat (466.30 MPa). The relatively high coefficient of variation for Meli (18.92%) indicates greater variability among its tested specimens compared with Khan (7.09%) and Melat (10.43%). Welch's one-way ANOVA indicated a statistically significant difference among manufacturers for the 12 mm bars ($F = 8.453$, $P = 0.0011$). Post-hoc analysis further showed that Meli differed significantly from both Khan and Melat, whereas the difference between Khan and Melat was not statistically significant. For 14 mm bars, the mean yield strengths were 505.38 MPa for Meli, 487.19 MPa for Melat, and 511.39 MPa for Khan. Although Khan had the highest numerical mean, the differences were not statistically significant ($F = 0.741$, $P = 0.4919$). For 16 mm bars, Melat exhibited the highest mean yield strength (589.22 MPa), followed by Meli (546.74 MPa) and Khan (477.07 MPa). The differences among manufacturers were statistically significant ($F = 6.390$, $P = 0.0151$), and the post-hoc analysis indicated a significant difference between Melat and Khan. These findings demonstrate that manufacturer-related differences in yield strength were not consistent across all diameters.

The tensile strength results also varied by manufacturer and bar diameter. For 12 mm bars, Meli recorded the highest mean tensile strength (762.72 MPa), followed by Khan (711.29 MPa) and Melat (691.48 MPa). However, the difference among manufacturers was not statistically significant according to Welch's ANOVA ($F = 1.362$, $P = 0.2714$). The relatively high coefficient of variation observed for Meli (26.45%) indicates substantial variability among its tested specimens. For 14 mm bars, Melat showed the highest mean tensile strength (717.88 MPa), whereas Meli and Khan recorded 650.46 MPa and 647.42 MPa, respectively. The manufacturer effect was statistically significant ($F = 11.126$, $P = 0.0012$). Post-hoc analysis indicated that Melat had significantly higher tensile strength than both Meli and Khan. For 16 mm bars, Melat again recorded the highest mean tensile strength (760.02 MPa), followed by Meli (701.38 MPa) and Khan (661.68 MPa). Differences among manufacturers were statistically significant ($F = 13.737$, $P = 0.0016$), particularly between Melat and Khan. Differences in yield and tensile strength may relate to variations in raw materials, chemical composition, rolling temperature, cooling rate, and manufacturing processes. However, this study did not measure these factors and therefore cannot confirm them as direct causes. Further research is needed to verify their effects.

Conclusion

This research compared the yield and tensile strengths of Grade 60 reinforcing steel bars manufactured by Melat, Khan, and Meli Steel industries with nominal diameters of 12 mm, 14 mm, and 16 mm, respectively. Accurate, BAES, and Karkon Afghan laboratories tested the steel in 2024, and the results were compared with ASTM A615/A615M standards. The mean yield and tensile strengths of Melat, Khan, and Meli reinforcing steel industries were generally above the ASTM A615/A615M minimum Grade 60 requirements. However, some specimens fell below the specified minimum values, indicating variability in mechanical performance. The claimed ductility performance is less reliable when certain parameters are not met, such as gauge length control, loading rate, mandrel diameter, bending angle, and inspection requirements. Lastly, Grade 60 reinforcing steel in Kabul has acceptable strength properties, but noncompliance with testing procedures and practices could compromise structural

performance. Improving regulatory oversight, standardizing testing techniques, and expanding laboratory capabilities are essential to ensure that reported mechanical properties accurately reflect the behavior of reinforcement steel used in Afghan construction projects.

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