

Analysis of the mechanical properties and chemical composition of recycled reinforcement bars used in the construction industry in Kenya

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Abstract

To ascertain compliance with regional and international standards, this study investigated the mechanical and chemical properties of recycled reinforcement bars produced by Kenyan steel manufacturers. Tensile testing was performed using universal testing, and the results obtained evaluated against KS EAS 412 requirements. Elemental composition was conducted using an optical emission spectrometer to determine carbon and other alloying elements in the samples. Results indicated that manufacturer A rebars with YS and UTS values exceeding minimum thresholds, whereas Manufacturer B samples recorded lower yield strength (~475.0 MPa). Percentage elongation results indicated that 85.71% of the manufacturers met the minimum threshold set by KS EAS 412. All manufacturers, except F, failed to meet the minimum UTS/YS ratio of 1.08 required by KS EAS 412; Manufacturer F recorded a ratio of 1.07, slightly below the threshold. Overall mechanical properties conformity of the tested samples revealed that five (5) out of seven (7) manufacturers complied with the KS EAS 412 standard. Samples from Manufacturer T displayed elevated carbon content. The study concludes that while most locally manufactured recycled rebars complies with regional and international standards, persistent variations in mechanical and chemical properties highlight the need for stricter quality control in Kenyan steel production.

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1. Introduction

An increase in global population has brought about industrialization and urbanization. This has led to a rapid increase in the number and scale of infrastructural development projects, ultimately increasing demand for different types of engineering materials [1]. The building materials commonly in use include timber, sand, gravel and metal among others. Steel remains the predominant engineering material owing to its favorable mechanical properties, versatility, and economic advantages [2-4].

The demand for steel in Africa is met by local production and importation [5, 6]. However, there is a lack of trust in locally available rebars among stakeholders, that stems from documented concerns regarding their quality and reliability [7, 8]. This erosion of public confidence in locally manufactured rebar has been exacerbated by rising cases of building collapses reported in Kenya and other African countries such as Cameroon, Ethiopia, Nigeria, Uganda, Senegal, Tanzania, Rwanda, South Africa and Ghana [9-17]. While these failures have been attributed to improper design, poor workmanship among other critical causes of failure, attention has been drawn on the quality of the reinforcing steel bars used in the construction industry [18].

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In many countries around the globe, scrap metal is widely utilized in production of rebar for use in construction sector. Studies have highlighted the importance of using scrap metal in the manufacturing of products such as rebars over the new (primary) alloy [19]. This is as a result of environmental benefits of recycling such as reduction in landfills, CO₂ emissions and energy requirements [20-22]. Despite the push for sustainability, Kenya's construction sector has demonstrated laxity in the adoption of reinforcement bars manufactured from scrap [23]. This is largely attributed to limited recycling infrastructure, change of policy and governance, lack of effective regulatory frameworks, and quality concerns, as reflected in Kenya's Scrap Metal Act (2015) and the Scrap Metal Council's Strategic Plan (2023–2027) [23-25].

Several studies have been conducted, particularly in African countries, in a bid to assess the quality of rebars produced from recycled metals through performance and suitability evaluation of materials utilized in the construction sector [9-15]. This has been ignited by numerous reported incidents of building collapse in these countries [8, 9, 26-28]. This study is motivated by the need to explore the quality of recycled reinforcing bars (RRBs) used in Kenya's construction sector by critically analyzing suitability and conformity to the regional and international standards. Findings from this study attempt to provide evidence on the quality and compliance of reinforcement bars with established regional and international standards, given their critical role in structural safety.

2. Materials and Methods

2.1. Source of Samples

The test samples were sourced from seven (7) manufacturers designated hereafter as A, B, C, D, E, F and T. Samples from each source corresponded to the variations in steel milling conditions among manufacturers depending on raw materials. Details regarding the steel milling processes employed by the manufacturers were not available for inclusion in this study, as the relevant information was not provided.

2.2. Mechanical Testing of Rebar

Test pieces of length 200mm were cut from the seven (7) specimens obtained from various independent manufacturers using a hacksaw; the test pieces were prepared in accordance with ISO 6892-1 and ISO 6935-2 standards. Tensile testing of the samples was conducted using an Enkay Universal Testing Machine with a capacity of 100 kN, integrated with Mat Bench V.3 software for machine control and data acquisition. The machine was operated in force-controlled mode at a loading rate of 0.4 kN/s, applied across D10 cross-sections. The specimen gauge length was 50 mm, and tests were carried out under ambient laboratory temperature (25 ± 2 °C). Testing procedures adhered to BS EN ISO 6892-1 standards for tensile testing of metallic materials. The gauge length of samples was computed from Equation 1 in accordance with ISO 6892-1[29] and ISO 6935-2 [30] standard.

$$\text{Gauge length (test length)} = 5.65\sqrt{A} \quad (1)$$

where A denotes the cross-sectional area of the specimen. Thus, for samples with diameter 10 mm (D10), $A = 78.54 \text{ mm}^2$, the gauge length was 50 mm.

Table 1. Test samples and their designation

Designation of Manufacturer	Numbering and designation of test samples	
	Tensile strength	Elemental composition
A	AT1, AT2, AT3, AT4, AT5, AT6, AT7	AC1, AC2, AC3
B	BT1, BT2, BT3, BT4, BT5, BT6, BT7	BC1, BC2, BC3
C	CT1, CT2, CT3, CT4, CT5, CT6, CT7	CC1, CC2, CC3
D	DT1, DT2, DT3, DT4, DT5, DT6, DT7	DC1, DC2, DC3
E	ET1, ET2, ET3, ET4, ET5, ET6, ET7	EC1, EC2, EC3
F	FT1, FT2, FT3, FT4, FT5, FT6, FT7	FC1, FC2, FC3
T	TC1, TC2, TC3, TC4, TC5, TC6, TC7	TC1, TC2, TC3

The corresponding load and extension data were recorded in order to generate load-extension graphs needed for analysis. Properties such as ultimate tensile strength (UTS) and percentage elongation, and yield strength was computed from the obtained data. The force and extension graphs were automatically generated with the computer connected to the machine. The results were compared with KS EAS 412[31] to check for conformity with regional standards. Figure 1 shows Enkay Universal Testing Machine with a capacity of 100 kN used in this study. The samples were grouped in designated experimental batches ready for tensile testing as shown in Figure 2. At least seven samples from each source were tested as summarized in Table 1.



Fig. 1. Enkay Universal testing machine at multimedia university of Kenya used in this study



Fig. 2. Typical set of samples before testing

2.3. Determination of Elemental Composition

The chemical composition from each of sampled specimen bars was determined by Optical Emission Spectrometer (SpectroMAXx-Ametek) model in accordance with ASTM E415[32] at the Numerical Machining Complex NMC spectrometry lab. The OES method was selected due to its high accuracy, rapid output, and ability to simultaneously detect multiple elements without altering the specimen, making it particularly suitable for rapid checking compliance with BS 4449 and ASTM A615 standard of chemical composition. From each source, a test specimen of 20mm length was cut and ground flat for spectrometry in accordance with ISO 14284:1996 [33] to ensure uniformity and reliability of results. Each test piece was marked with a code such as AC1 for identification purposes as presented in Table 1. The steps for preparation of specimen for chemical analysis are outlined in Table 2.

The prepared samples were placed in the spark hole to ensure that the polished surface was well positioned. This excitation caused the atoms in the specimen to generate characteristic emission lines of their elemental identity. The emitted spectra were detected and results obtained post processed using SPECTRO Analytical Software (iCAL 2.0 system), providing quantitative results for

major alloying elements such as Fe, Mn, Si, C, Cr, Ti, V, Cu, Al, Mo, Ni, P, S. The procedure was repeated for the 21 samples shown in Table 1 and results obtained recorded in MS Excel 2019 for subsequent statistical analysis. Figure 3 shows OES set up.

Table 2. Protocol for preparation of specimens for OES elemental analysis

Step	Process	Equipment/material used	Purpose
1	Sectioning	Hack saw and flat metal file	Extracts a flat cross-sectional D10 specimen.
2	Coarse grinding	Belt sander-(Φ 250 mm silicon carbide (SiC) abrasive wheel, spindle speed: 1400–2800 rpm, water coolant)	Removes rust, and surface oxidation to expose the bare steel matrix. Improves surface finish.
3	Surface flattening	Disc grinder-(Coarse Silicon Carbide (SiC) paper belts (80–120 grit)	Ensures a perfectly flat surface to establish a proper airtight seal over the spectrometer's spark hole. Improves surface finish.
4	Chemical cleaning	Absolute Ethanol (>99.9% purity) or Acetone	Removes finger oils, lubricants, or residues that alter carbon and Sulphur readings
5	Drying	High-pressure compressed air	Removes excess solvent moisture to prevent air pocket contamination within the spectral plasma arc.

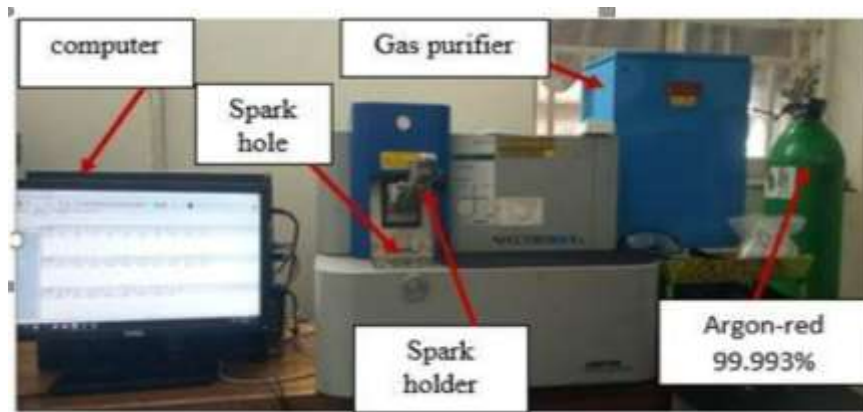


Fig. 3. The setup of optical emission spectroscopy used in this study at Numerical Machining Complex (NMC) spectrometry lab

Carbon equivalent value (CE) as expressed in Equation 2, was used to express the maximum percentage of mass of the residue elements present in steel scrap and was calculated from the formula obtained from the standard BS 4449:2005 [34] as:

$$CE = C + \frac{Mn}{6} + \frac{Cr+Mo+V}{5} + \frac{Ni+Cu}{15} \quad (2)$$

where C, Mn, Cr, V, Ni, Cu, Mo denotes percentage composition of carbon, manganese, chromium, vanadium, nickel, copper and molybdenum, respectively.

3. Results and Discussion

3.1. Tensile Strength, Yield Strength and Elongation

The mechanical properties of the tested rebar from the seven (7) sources were analyzed to assess their conformity with KS EAS 412, focusing on yield strength, ultimate tensile strength, ultimate tensile strength/ yield strength ratio and percentage elongation. The samples were tested in

designated experimental batches and resulting data tabulated for analysis. Figure 4 shows a typical set of samples after testing.

Table 3 provides comparative breakdown of mechanical properties including both averaged experimental (measured) value of each manufacturer and corresponding threshold specified in KS EAS 412. The results presented in Table 3 are further illustrated in Figures 5–7 to facilitate the observation of trends and support the ensuing discussion.



Fig. 4. Rebar samples after fracture

Table 3. Statistical comparison of the mechanical properties of tested rebar against KS EAS 412 standard.

Manufacturer	Property							
	Yield Strength YS (MPa)		Average UTS (MPa)		Avg Elongation (%)		Avg. Stress ratio	
	Measured value	KS EAS 412	Measured value	KS EAS 412	Measured value	KS EAS 412	Measured value	KS EAS 412
A	535.0±24.0	500.0	616.1±31.0	550.0	16.1±2.43	14.0	1.15±0.03	≤ 1.08
B	475.0±35.1	500.0	554.3±23.4	550.0	18.25±1.37	14.0	1.16±0.06	≤ 1.08
C	612.0±20.4	500.0	715.7± 25.3	550.0	22.3±1.83	14.0	1.17±0.03	≤ 1.08
D	522.0±15.4	500.0	600.0±12.5	550.0	19.25±1.80	14.0	1.15±0.03	≤ 1.08
E	504.0±9.0	500.0	586.0±16.1	550.0	18.62±1.28	14.0	1.16±0.02	≤ 1.08
F	481.8±16.4	500.0	517.0±18.3	550.0	23.1±3.42	14.0	1.07±0.03	≤ 1.08
T(virgin- material)	577.0±18.3	500.0	663.3±32.5	550.0	21.9±1.45	14.0	1.14±0.03	≤ 1.08

Target limits for each parameter tested are also indicated in Table 3 as specified in KS EAS 412 standard. The averaged values indicate that 71% of the manufacturers used in this study met the minimum threshold of YS (≥ 500.0 MPa) set in KS EAS 412 as shown in Figure 5. Only samples from manufacturers B and F exhibited mean values below the threshold. Nevertheless, the upper bounds of their standard deviation (STD) ranges overlapped with the minimum threshold value, indicating partial compliance within the observed variability. Additionally, all the samples from the seven manufacturers attained the minimum threshold of UTS (≥ 550.0 MPa).

Figure 6 compares the mean percentage elongation values across different manufacturers alongside their respective standard deviations, evaluated against KS EAS 412 threshold (indicated by the solid horizontal target line in the bar). It is observed that all the seven (7) manufactures satisfied the threshold of minimum percentage elongation. A clear distinction in experimental scatter is observed as represented by error bars. The ductility values range between 16.1% and 23.1%, with standard deviation spanning from 13.67 % to 26.52%. The average values of elongation for most manufacturers fall within 18–22%, showing broadly comparable elongation behavior. Manufacturer A (16.1 ± 2.43) represents the lower bound, while Manufacturer F ($23.1 \pm$

3.42) marks the upper bound with the largest scatter. The measure of dispersion remains within acceptable limits, reinforcing the reliability of the observed ductility behavior.

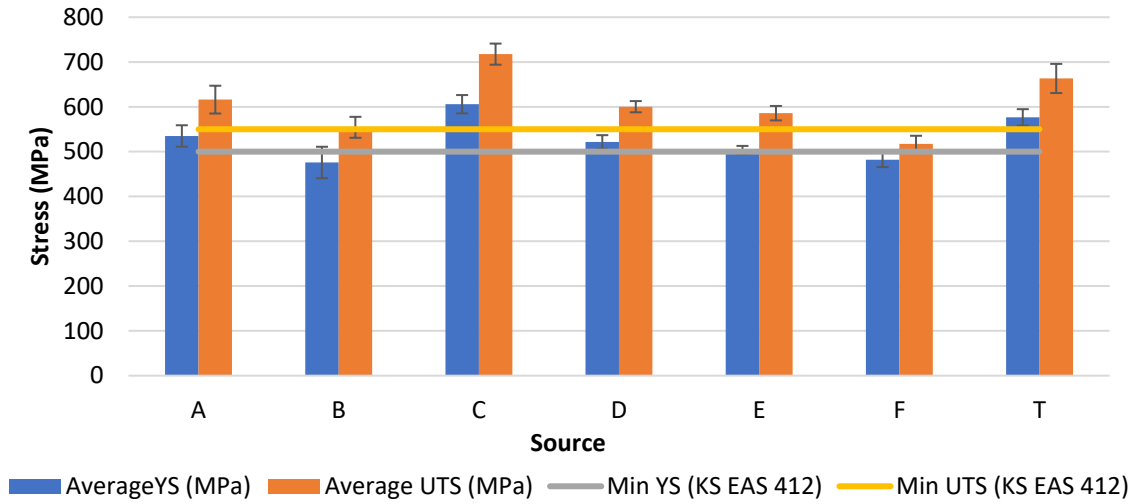


Fig. 5. Average values of YS and UTS of samples from different manufacturers

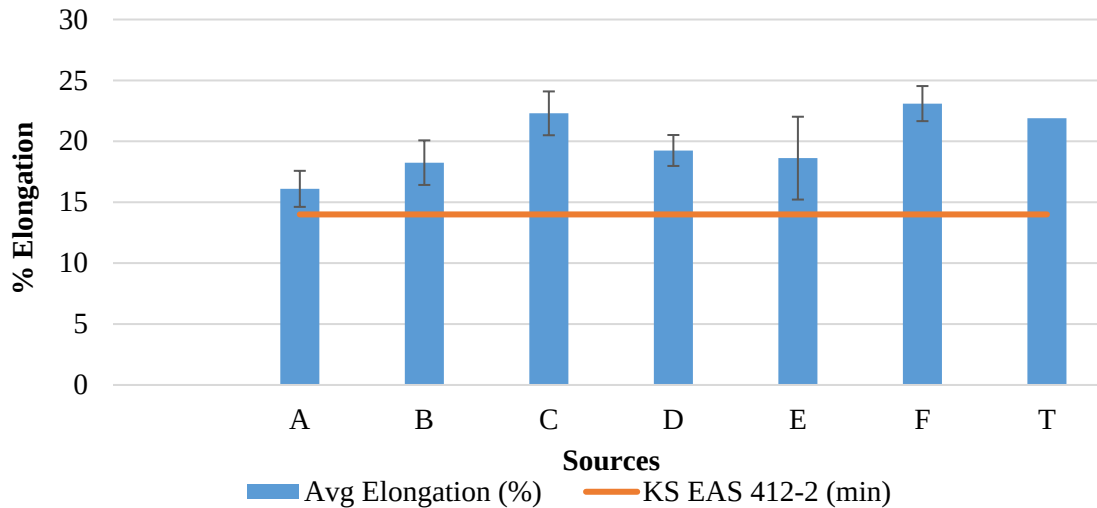


Fig. 6. Average percentage elongation of rebar from different manufacturers

Figure 7 presents the averaged stress ratios (UTS/YS) of the tested manufacturers against the minimum threshold (≥ 1.08) indicated by the solid horizontal orange baseline on the graph. The comparative analysis revealed that six out of seven manufacturers denoted by (A, B, C, D, E, and T) surpassed the minimum threshold, demonstrating secure margin between yielding point and ultimate tensile failure. Manufacturer C samples exhibit highest ratio, implying the greatest capacity for energy absorption during post-yielding deformation. The high values of UTS/YS suggest that the material exhibit significant plastic deformation and distribute stress before failure. On the contrary, a critical failure in compliance is noted in manufacturer F samples, whose mean ratio largely falls below the target baseline on the chart. This deficiency implies a narrow margin between YS and UTS making the material experience rapid strain localization post-yielding with limited plastic deformation before fracture.

Overall compliance status in the dataset was computed using a logical AND condition: a source is marked $\checkmark$ only if yield strength, UTS, stress ratio, and elongation all meet KS EAS 412 thresholds. The results from these analyses are presented in Table 4. Results in Table 4 show that five (5) out of seven (7) rebar sources satisfied all the requirement for KS EAS 412 standards, demonstrating major conformity. The findings further reveal that scrap-derived bars can achieve acceptable

performance when properly processed. Billet-derived bars (source T) remain benchmark for consistent compliance.

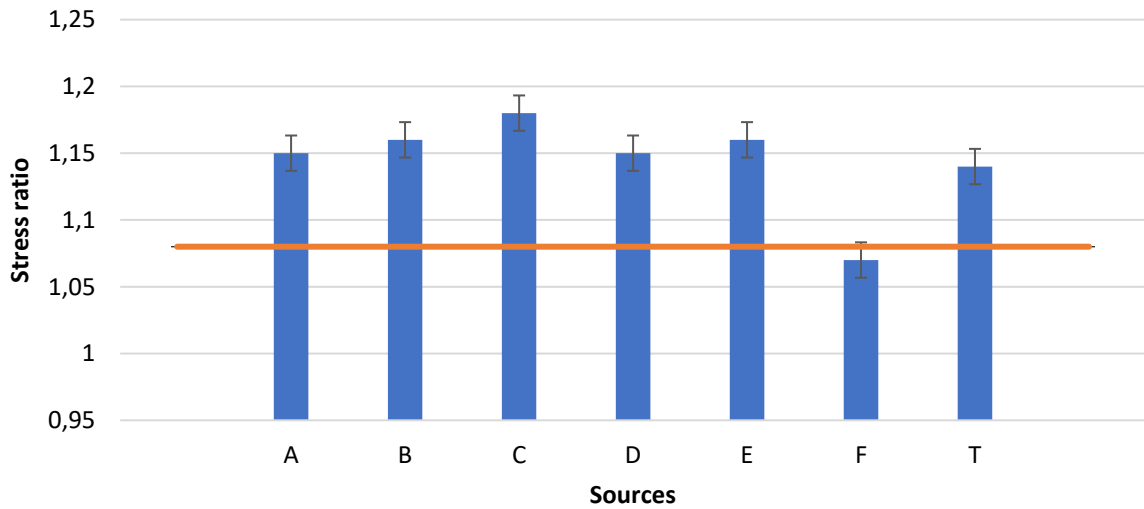


Fig. 7. Average stress ratio of samples from different manufacturers

Table 4. Summary of compliance of mechanical properties with the requirements of KS EAS 412

Source	Property				Overall status
	YS ($\geq 500.0\text{MPa}$)	UTS ($\geq 550.0\text{ MPa}$)	% Elongation ($\geq 14.0\%$)	Stress ratios (≥ 1.08)	
A	✓	✓	✓	✓	✓ Compliant
B	✗	✓	✓	✓	✗ Non-compliant
C	✓	✓	✓	✓	✓ Compliant
D	✓	✓	✓	✓	✓ Compliant
E	✓	✓	✓	✓	✓ Compliant
F	✗	✓	✓	✗	✗ Non-compliant
T (billet)	✓	✓	✓	✓	✓ Compliant

The findings demonstrate that conformity with Grade B500 requirements is achievable not only in billet-based production routes but also in steel plants utilizing scrap metal as the main feedstock. This accentuates the critical role of stringent quality control practices in ensuring compliance with the relevant standards, irrespective of the production route employed.

3.2. Elemental Composition

A total of twenty-one (21) samples were prepared and analyzed for their elemental composition using Optical Emission Spectroscopy (OES) as per BS 4449 and ASTM A615 standards. Figure 8 shows representative samples before and after OES test. The spectrometer analyzed results of major elements by percentage such as Fe, C, Si, Mn, P, S, Cr, Mo, Ni, Cu, and V in steel. Table 5 presents the measured average composition of each element from samples obtained from different manufacturers. The primary elemental composition analysis across all the seven (7) manufacturers confirmed Iron (Fe) as the dominant element in rebar at a percentage in a range of 98.24 % - 98.93% as shown in Table 5. This is followed by Manganese (Mn) in the range of 0.4-0.53%. Manganese acts as a deoxidizer to eliminate harmful effects of sulfur oxide. In addition, Mn contributes to solid-solution strengthening and enhances high-temperature performance, supporting the observed mechanical reliability [27]. The percentage carbon content is in the range between 0.17-0.25% for majority of the samples such as (AC-FC groups) but for TC series, a higher

percentage carbon content in the range of 0.29-0.32% is recorded, while Manganese in this group of samples was at 0.45-0.6%. The higher carbon-manganese contents in the TC series are consistent with virgin material, as confirmed by their superior yield and tensile strength values compared to others processed from scrap.

Table 5. Average elemental composition per manufacturer

Manufacturer /Element	A	B	C	D	E	F	T	ASTM A615	KS EAS 412
C	0.2417 ±0.002	0.2227 ±0.026	0.2120 ±0.032	0.2073 ±0.006	0.1817 ±0.006	0.2153 ±0.003	0.3033 ±0.0125	0.30–0.50	0.22
Si	0.1523 ±0.019	0.1810 ±0.078	0.1897 ±0.032	0.1877 ±0.052	0.1363 ±0.002	0.1837 ±0.069	0.1380 ±0.038	Not specified	-
Mn	0.4433 ±0.012	0.4197 ±0.028	0.4270 ±0.026	0.5290 ±0.119	0.4123 ±0.013	0.5323 ±0.140	0.5077 ±0.073	0.60-1.50	1.60
P	0.0347 ±0.002	0.0357 ±0.004	0.0413 ±0.006	0.0280 ±0.004	0.0333 ±0.001	0.0167 ±0.005	0.0317 ±0.005	≤0.05	0.050
S	0.0417 ±0.002	0.1647 ±0.166	0.0417 ±0.005	0.0293 ±0.009	0.0313 ±0.002	0.0237 ±0.004	0.0373 ±0.003	≤0.06	0.050
Cr	0.1380 ±0.070	0.1290 ±0.019	0.1497 ±0.040	0.0923 ±0.045	0.0933 ±0.015	0.1060 ±0.054	0.1890 ±0.069	Not specified	≤ 0.30
Ni	0.0733 ±0.002	0.0770 ±0.001	0.0787 ±0.006	0.0850 ±0.016	0.0583 ±0.007	0.0623 ±0.012	0.1163 ±0.058	Not specified	-
Mo	0.0106 ±0.002	0.0106 ±0.001	0.0213 ±0.009	0.0103 ±0.001	0.0120 ±0.001	0.0123 ±0.003	0.0160 ±0.003	Not specified	-
Al	0.0119 ±0.004	0.0157 ±0.010	0.0263 ±0.019	0.0132 ±0.006	0.0081 ±0.002	0.0163 ±0.005	0.0207 ±0.006	Not specified	-
Cu	0.1020 ±0.013	0.1397 ±0.0123	0.1393 ±0.016	0.0780 ±0.057	0.1047 ±0.006	0.0572 ±0.041	0.1027 ±0.017	Not specified	-
Ti	0.0009 ±0.000	0.0033 ±0.003	0.0012 ±0.001	0.0021 ±0.001	0.0013 ±0	0.0020 ±0.002	0.0096 ±0.013	Not specified	-
V	0.0001 ±0.000	0.0011 ±0.001	0.0001 ±0	0.0002 ±0	0.0001 ±0	0.0028 ±0.004	0.0001 ±0	Not specified	-
Fe	98.6467 ±0.144	98.570 0±0.12	98.6333 ±0.06	98.683 3 ±0.087	98.9000 ±0.025	98.700 0 ±0.136	98.5533 ±0.233	Not specified	-
CE	0.3693 ±0.016	0.3347 ±0.033	0.3320 ±0.036	0.3280 ±0.006	0.2763 ±0.015	0.3570 ±0.026	0.4437 ±0.033	0.5000 ±0.02	-

Copper (0.08-0.15wt%) and chromium (0.02-0.15wt%) serves as primary micro-alloying elements to prevent oxidation and corrosion [35]. Titanium (0.001-0.003 wt%) and Vanadium (~0.0001wt%) act as grain refiners and promote uniform microstructure therefore enhancing grain boundary stability and yield strength [36]. The comparison of the percentage composition of the key element vis carbon, manganese, phosphors and Sulphur is presented in Figure 9.

From the obtained results of elemental composition, carbon, phosphorus, and sulfur are within the standards specified in ASTM A615. Conversely, manganese levels varied, with most values falling below the ASTM recommended range of 0.60–1.50 wt%. Percentage carbon composition in rebars greatly influences the microstructure and mechanical properties of the rebar [37,38]. All manufacturers achieved the ASTM A615 requirement of carbon content ≤ 0.22%, confirming compliance with the international standard. However, manufacturers A and T fall short of the KS EAS 412 standard, with values exceeding the recommended maximum of 0.22 wt%. Manganese and

phosphorus levels are all within specified limits. Sulphur levels recorded were within limits, except for manufacturer B in which the tested samples were short of both KS EAS 412 ($\leq 0.050\%$) and ASTM A615 ($\leq 0.060\%$) requirements, indicating non-compliance with the permissible limits for this element.

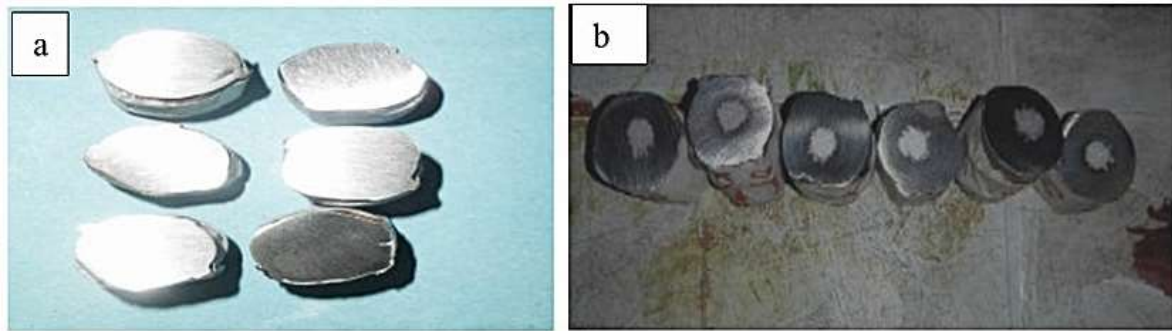


Fig. 8. Typical specimens before (a) and after (b) OES testing. All the 21 specimens were analyzed under OES and their results are presented in the tables

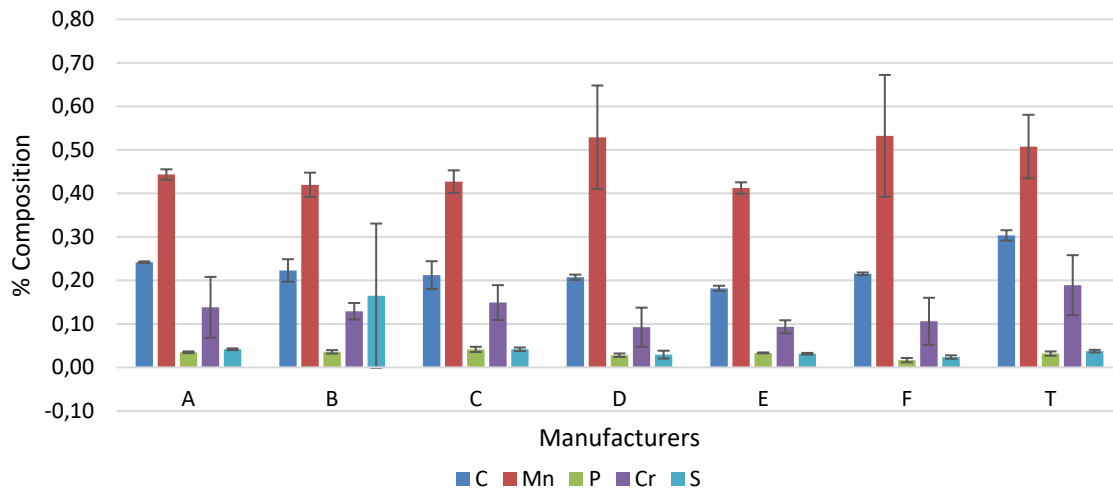


Fig.9. Percentage composition of key alloying elements

The Carbon equivalent (CE) is critical metric used to predict weldability and susceptibility to cracking for reinforcement steel bars. Literature indicates that CE values below 0.4 ensure good weldability, while values above 0.45 are more susceptible to cold cracking [39]. Figure 10 shows obtained CE values from this study that were in a range of 0.256-0.492 for rebar obtained from scrap, confirming their weldability and compliant with ASTM A615 and ISO 6935-2 standards. The findings from this study highlights that the steel rebars from different manufacturers' exhibit acceptable chemical balance for structural applications.

Figure 11 shows the relationship between percentage composition of carbon and carbon equivalent (CE) values for bars obtained from different sources. It is clear from this figure that composition of carbon significantly influences CE where high carbon contents increase the value of CE. According to KS EAS 412, the maximum allowable wt% C for reinforcement bar is 0.25, while Carbon equivalent threshold is 0.4. The results in Figure 11 demonstrate that majority of the manufacturers produce rebar with carbon content below 0.22% and calculated CE ranging between 0.3 and 0.4. However, the CE values for rebar obtained from manufacturer T exceed the set threshold value of 0.4 (indicated by the solid target line on the chart). The variability exhibited by manufacturer T warrants closer monitoring to prevent adverse effects on weldability.

The elemental composition results indicate that majority of the reinforcement bars in Kenyan construction market conform to the limits prescribed by KS EAS 412-2 and ASTM A615 standard, with minor deviations in carbon and Sulphur contents from selected manufacturers. Carbon is the

most influential element due to its direct influence on Carbon Equivalent (CE) whose values remained below 0.5 for all the seven (7) manufacturers. In general, the compliance analysis confirms that Kenyan recycled rebar meets essential requirements in chemical composition. The slight variations observed underscore the importance of conducting thorough quality assessments to ensure that reinforcement bars conform to the required standards before being released to the market.

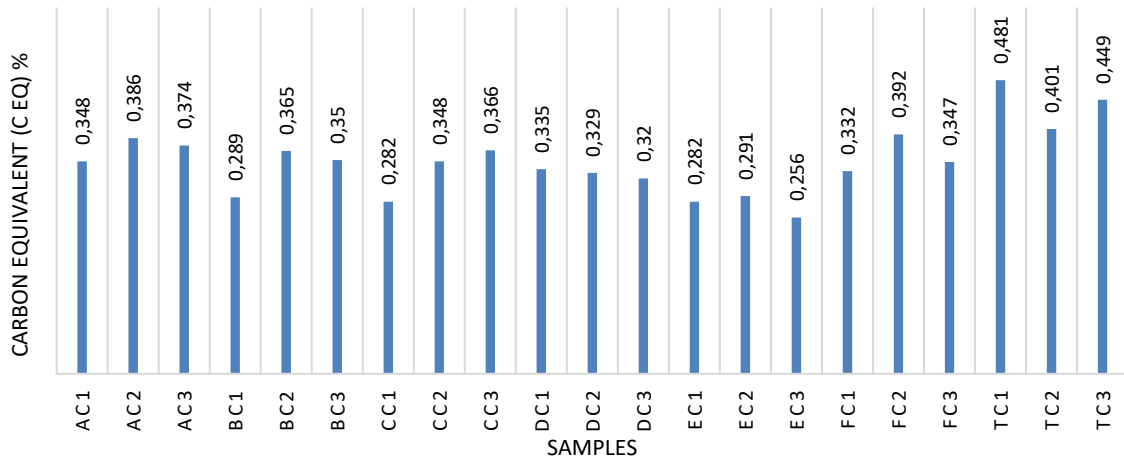


Fig. 10. Carbon equivalent values for various samples

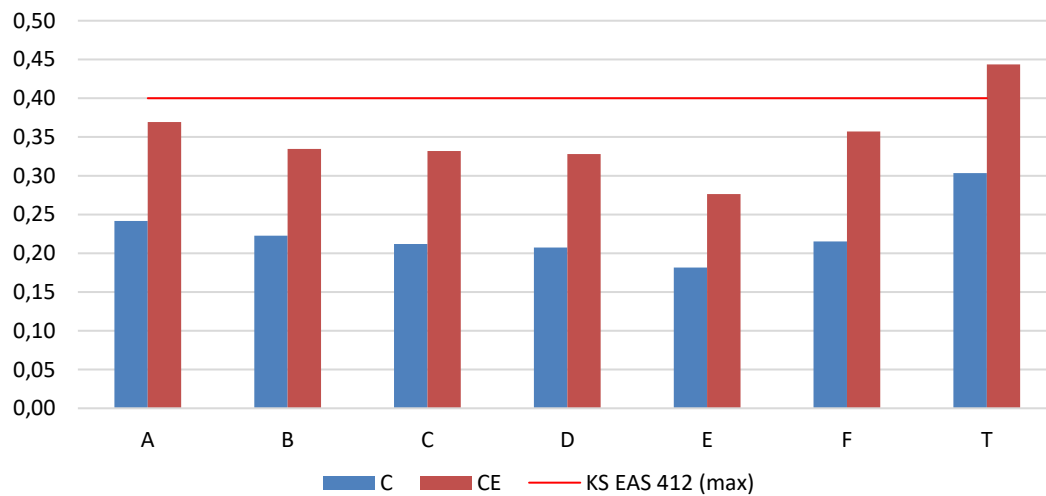


Fig. 11. Percentage carbon content vs carbon equivalent (CE) across rebar from different manufacturers

4. Conclusions

The study revealed varying levels of compliance among reinforcement bar manufacturers in the Kenyan construction market. The majority of the sampled manufacturers (A, C, D, E, and T) satisfied the minimum threshold of ≥ 500.0 MPa as specified in KS EAS 412 and ASTM A615 standard. In contrast, manufacturers B and F recorded values below the specified limit and were therefore deemed non-compliant with the standard. Despite this variation in yield strength, all manufacturers achieved the ultimate tensile strength requirement of ≥ 550.0 MPa, confirming that the bars possess adequate tensile capacity to withstand applied loads. Additionally, all the manufacturers exceeded the percentage elongation requirement of $\geq 14.0\%$. This attribute demonstrated ductile behavior essential for structural resilience. Stress ratio analysis showed that all manufacturers, except manufacturer F, recorded values above 1.08. This suggests that the

majority of the reinforcement bars had sufficient strain-hardening capacity, allowing them to sustain additional stress beyond yielding before reaching ultimate tensile failure, which is important for ductile structural behavior. The elemental composition results showed that most reinforcement bars generally complied with the chemical composition requirements, although minor deviations in carbon and Sulphur contents were observed in some samples. Overall, the findings demonstrate that scrap-based steel production is technically viable in Kenya, but improved quality control and continuous compliance monitoring are required to ensure consistent structural performance.

Future research should consider expanding the region and manufacturer coverage of reinforcement bars sampled in Kenya and investigate the causes of variations in mechanical and chemical properties. Microstructural characterization and evaluation of additional properties, including fatigue, fracture, bending, and corrosion performance is also recommended to provide deeper insight into the structural reliability and durability of scrap-based reinforcement bars. Further research should also examine the influence of scrap sources, processing parameters, and alloying practices on product quality and support the development of improved quality-control and continuous market-surveillance mechanisms to ensure consistent compliance with KS EAS 412.

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