

## International Journal of Innovative Research in Science, Engineering and Technology

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# Quality Assessment and Control of Steel Reinforcing Bars Used in Rwandan Construction Industry

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**ABSTRACT:** Rwanda is now in the process of reconstruction and more particularly construction sector is at its climax to meet sustainable development envisaged in its vision 2020, and consequences of this high construction sector growth is the high demand for construction materials more particularly steel reinforcing bars.

According to RDB 2014, construction material is the largest and fastest growing component of Rwanda's manufacturing sector and steel products represent 4 of the 11 largest building material imports at 34 million USD/yr in imports. Rwanda Revenue Authority (RRA) also recorded imported steel reinforcing bars 9,613 tons in 2006 which grew to 28,617 tons in 2016, addition to local production of 25,000 tons per year.

Most of buildings and other civil engineering structures today are being constructed of reinforced concrete of which steel bars are main reinforcing elements. The quality of these steel bars which are actually backbone of every reinforced concrete structure is not given its due weight in the sense of quality consciousness as most times are used in buildings without being subjected to any quality test. Some building have collapse in Rwanda, while others have developed serious cracks as a sign of structural failure setting huge population of occupants into fears with consequent forced vacation. In addition said failures, there has been quite a number of collapsed buildings in our neighboring countries where these steel reinforcing bars are imported from and investigations conducted have pointed at substandard re-bars as still at large. This in itself causes suspicion in quality of steel reinforcing bars being used in Rwanda. Generally, demand for re-bars is very high and the higher the demand the higher the risk of importing or producing substandard products, and the higher the need for quality assessment and control

The study therefore assess quality of re-bars available in Rwanda and examines quality control methods and from lessons and experience learnt from other countries and cities more especially Africa and Asia which are similar to Rwanda, identifies strategies that may be deployed to strengthen quality control systems. The study is limited to 12mm and 10 mm diameter samples of steel reinforcing bars from four main sources available in Rwanda and concentrates in Kigali the capital city of Rwanda.

**KEYWORDS:** steel reinforcing bars, quality assessment and control, tensile properties.

### I. INTRODUCTION

Rwanda is currently undergoing intensive development following many years it has lagged behind in different aspects of development, construction industry and research related inclusive. Reconstruction process and more particularly construction sector is at its climax and consequences of this this high construction sector growth is the high demand for construction materials more particularly steel reinforcing bars. With construction material on highest demand, majority of which are imported from neighboring countries namely Kenya, Uganda, Tanzania and other far countries like South Africa and Turkey, although of recent Turkey seem to have taken over from South Africa while Tanzania takes over from Uganda.

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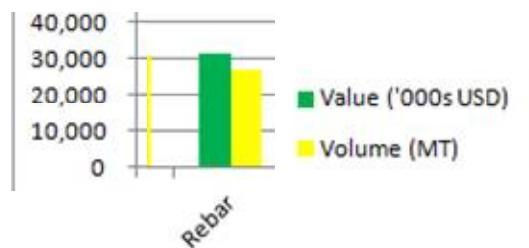
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In line with reconstruction, Rwanda has also adopted a land use planning policy of vertical development which calls for high rise buildings (Rwanda vision 2020, 2000). Like in most developing countries, high rise buildings are predominantly constructed with reinforced concrete and main reinforcing material of concrete being reinforcing steel bars. This makes this unique material very important based on the role it plays in reinforcing structural elements in particular high rise buildings and other civil engineering infrastructures.

According to African Development Bank in its annual meeting of 19<sup>th</sup> - 23<sup>rd</sup> May 2014 held in Rwanda, there is a high demand for housing units and high rate of urbanization which is 4%pa that has resulted into faster rate growth of construction spending of 24% between 2008- 2011 which is USD 500 million (RDB, 2014), this has seen a high demand for steel reinforcing bars in construction industry.

RDB 2014 reported construction material as the largest and fastest growing component of Rwanda's manufacturing sector, 51% of recent investments which grew to 24% (to 500 million USD) between 2010 and 2011. Steel products represent 4 of the 11 largest building material imports coming into Rwanda, Rebars products represent 34 million USD/yr, in imports.



### Source: RDB, 2014

According to Rwanda Revenue Authority (RRA), there has been feasible increment of imported steel reinforcing bars, in 2006 total imports were recorded as 9,613 tons which grew to 28,617 tons in addition to local production of 25,000 tons, making total consumption of 53,617 tons in 2016 from 9,613 tons in 2006.

Generally when the demand and consumption are high, there is equally high risk of substandard rebars in the market whether imported or locally produced and the high need for quality assessment and control.

The overriding perception on the quality of reinforcing steel bars available in Rwanda deserve a serious attention as its judged based on the source, their qualities have been technically categorized based on the country of origin most times not even indicted on the rebars as it should be.

Knowledge on construction materials' engineering properties is of vital importance to construction industry stakeholders in the sense that their physical properties are expected to match the requirements of the design standards and outcomes. Sometimes, rebars though sold on local market, designed and used in civil engineering structures as high yield strength bars they actually meet the requirements of mild steel bars and consequences have been catastrophe (Singh, B, Kaushik. S.K, 2002). Opara (2007). Ejeh. S.P.I, Jibrin. M. U (2012) conducted a tensile strengths tests on reinforcing steel bars in the Nigerian construction industry and found out that, the characteristic strength for most of the locally produced steel reinforcing bar were low as compared to the 460N/mm<sup>2</sup> characteristic strength standard values specified in BS 4449, where 60% of the tested samples fell much below the would be high yield value, rather showing similarities of mild steel bars.

There is a serious concern that the steel used on sites are falling short of the design expectation because of lack of technical consciousness to test material before being used for control and compliance purposes on sites, Anthony Nkem Ede et al, 2015. Manufacturers of steel bars seem not to follow standard procedures right from inappropriate raw material feeds to production methods and consequently produce steel bars of different qualities, some of which are substandard and still being sold on local market to build complex buildings in untested and unknown status. According to UK CARES Part1 (2011) and Munyazikwiye (2013) the use of metal scraps in steel making is almost inevitable and therefore what is important is putting in place control measure to ensure quality scraps that results in quality rebars.

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Modern steel making process control requires accurate information regarding the quality of all feed stock materials, some used scraps have varying chemical percentage that results into substandard products.

In Rwanda, we have had so far few incidences of building collapse, however there has been quite a number of building collapses in our neighbouring countries where steel reinforcing bars are imported from and investigations conducted have shown a higher degree of deficiency in quality of steel reinforcing bars. This in itself causes suspicion in quality of steel reinforcing bars we are using in Rwanda hence need to be extra careful by taking all necessary precautions. According to Senfuka C, et al (2011) the main challenge faced by Ugandan steel industry is quality and quantity of appropriate steel scrap and consequently low quality scrap becomes unavoidable which produces poor quality steel. Munyazikwiye Bukaragire. B (2010) in his investigation on mechanical properties of reinforcing steel bars made from Scrap picked randomly from Kenya and Rwanda sites, found out that 69% of bars tested failed, the investigation further revealed that the number of contractors on sites have been using steel bars of low yield strength. According to him the possible causes could be inconsistency in chemical composition among others in addition to number of rolling mills operating in the country that are not certified as reported by Kenya Bureau of Standards, which are suspected of producing substandard rebars.

Mwasame G et al, 2012 reported series of collapsed buildings Nairobi and suburbs and investigations pinpointed poor construction materials among others. Rubaratuka.I. A, 2013, in his study on challenges of the quality of reinforced concrete buildings in Dar es Salaam, concluded that quality of designs, steel reinforcement bars and lack of quality control mechanisms was a big challenge. A study conducted by Opeyemi. J et al, (2013) confirmed that the predominantly used substandard reinforcing steel bars in the Nigerian construction sector has highly contributed to increasing incidences of structural building failures.

Therefore, in an attempt to investigate the quality of steel reinforcing bars available in Rwanda, a study was conducted on their major mechanical properties that influence quality of steel bars such as tensile strength, bendability, ductility, weldability, and chemical compositions together with external physical status. Findings from the study shall act as an aid in improving the Rwanda construction industry by guiding construction stakeholders on quality of steel bars used in the sector and further suggests quality control methods and various inspections that ensure quality of reinforcing steel bars.

## II. MATERIALS AND METHODS

### 2.1 Samples' Labeling

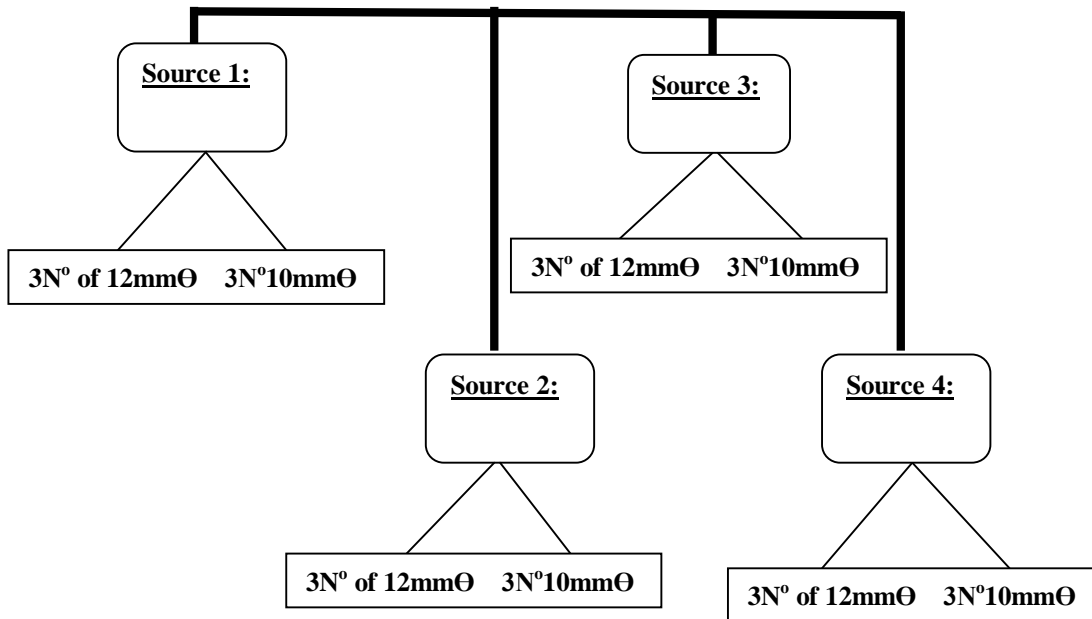
The Steel reinforcing bars used in this research were high tensile ribbed bars of grade 460 which are the ones predominantly being used in Rwanda, limited to use 12mm and 10 mm diameter steel bars, they are medium sizes easily suspected from foresight. Twenty four (24) steel reinforcing bars from four (4) sources were randomly picked from warehouses, the researcher decided to pick randomly from warehouses because it is the only appropriate place where the information regarding source of rebars could be obtained, construction site were tried but there were a lot of uncertainties on the origin of the rebars as there no clear marking on some of the bars, in addition to that, site men were hesitant to give the information which is not the case in warehouses, where the price depends on the source. The four sources were labeled as S<sub>1</sub>, S<sub>2</sub>, S<sub>3</sub>, S<sub>4</sub> as shown in the figure below.

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## 2.2 Approach

The investigation started with physical external verifications on the re-bars as being sold on the open market to assess their dimensional and marking compliance, then laboratory experimental test followed on their physical properties and chemical composition that influence their structural performance. The main performance characteristics required of steel reinforcing bars may be categorized as:

Tensile strength including yield strength and elongation, bend, fatigue, bond and weldability (chemical composition), according to UK CARES (2011). There are even more other tests such as, Impact and metallography test, energy absorbed, microstructure and grain size that are normally conducted to assess rebar status (Munyazikwiye 2013). However due to limited resources and equipment to perform all tests, our research focused on only tensile strength test, bend test, bond properties test and chemical composition tests.

## 2.3 Samples Preparation

### (a) Physical external verification

Length of steel reinforcing bars were measured using tape measure while diameter was measured using Vernier calipers and labeling was visually inspected

### (b) Physical Properties Test

#### 2.3.1 Tensile strength

Twenty four (24) steel samples each of 500mm from the four (4) sources were be prepared for tensile strength test where each source were represented by six (6) samples, three (3) of which are 12mm  $\phi$  and other three (3) are of 10mm  $\phi$ . Each sample was cut from different bar obtained from different bundle / heat.

After clear calibrating of the steel bar, the test specimens were placed one after the other into a tensile test Universal Testing Machine and subjected to tensile load until plastic deformation and complete necking were observed. The testing procedure followed conventional method stipulated in RS EAS 412-2: 2014 referenced to IS 15630-1 and BS 4447: 1997.

#### 2.3.2 Bending test

Eight (8) steel samples each of 500mm from the four (4) sources were be prepared for bending test where each source were represented by two (2) samples, one (1) of which is 12mm  $\phi$  and other one (1) is of 10mm  $\phi$ . The testing procedure followed conventional method stipulated in RS EAS 412-2: 2014 referenced to IS 15630-1 and BS 4447: 1997

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### 2.3.3 Bonding Test (commonly known as pullout test)

Sixteen (16) samples which was basically a concrete cube of 150mm x 150mm x 150mm with steel reinforcing bars of 12mm and 10mm diameters from different sources, one per each cube, embedded in concrete cube vertically protruding by 760mm to enable grip well in the machine clamps. The machine used was a UTM normally for tensile testing, samples were placed upside down, concrete block being on top while the protruding bar faces down to be held by machine clamps. Machine was started which moves lower plate up to clamp and hold well the rebar. After which the tensile force was applied pulling apart the rebar until the specimen failed by either being pulled out out of the concrete cube or breaking. The maximum force that pulls out or breaks the rebar was recorded as bond strength. At this point the machine automatically stops when no resistance is offered by specimen to tensile force being applied. Unconventional method was adopted due to absence of appropriate equipments to use conventional method stipulated BS 4447: 1997 annex D



UTM used for bonding test      two samples one pulled out and the other breaking

### © Chemical Tests

#### 2.3.4 Chemical composition test

Eight (8) steel samples each of 500mm from the four (4) sources were be prepared for chemical concentration test where each source were represented by two (2) samples, one (1) of which is 12mm  $\phi$  and other one (1) is of 10mm  $\phi$ . The chemical composition was determined by spectrometric methods which is the conventional method stipulated in RS EAS 412-2: 2014 referenced to IS 15630-1

## III. RESULTS AND DISCUSSIONS

The objective of this study was to assess the quality of steel bars available in Rwanda, disseminate the results to users and government, and then devise means of control based on experience cited from other developing countries similar to Rwanda. As stated in previous section, the study involved different methods of quality assessment and control through both visual and laboratory equipments to obtain necessary information that enable us reach a meaningful conclusion and recommendation thereafter. From the visual inspection, the assessment found out that all bars from all four sources do not conform to standards, while physical and chemical verifications confirmed legibility and non legibility of some of the bars.



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### 3.1 Results of visual inspection

No	Source	Item inspected	Observation
1	S <sub>1</sub>	Bar length Vs 12m	Length were in normal range of 11.94m
		Bar diameter Vs 12 and 10 mmØ	Diameters were in normal range of 12 and 10 mm Ø
		Bar Marking	Marked only country of origin other standards were not respected.
2	S <sub>2</sub>	Bar length 12m	Some bars had length in normal range of 11.92m, while others were abnormally short with 11.6m
		Bar diameter Vs 12 and 10 mmØ	Diameters were in normal range 12 and 10mm Ø
		Bar Marking	Marked only rolling mill other standards were not respected.
3	S <sub>3</sub>	Bar length 12m	Length were in normal range of 11.93m
		Bar diameter Vs 12 and 10 mmØ	Some bar diameters were abnormally smaller than their normal size 10.5 mm Ø and 8.5 mm Ø respectively.
		Bar Marking	No marks at all.
4	S <sub>4</sub>	Bar length 12m	Length were in normal range of 11.98m
		Bar diameter Vs 12 and 10 mmØ	Diameters were in normal range. 12 and 10 mm Ø
		Bar Marking	Marked only country of origin,

**According to BS 4449, 1997: Diameter deviation tolerance:** The deviation of any cross sectional dimension from its nominal size (other than those of ribs), shall not exceed 8 %

**Length deviation tolerance:** The permissible deviation from the nominal length shall be 0 to 100 mm. Other tolerances may be agreed at the time of enquiry and order.

There are some labels found on rebars which were not recognizable at all neither by sellers nor regulatory organs such RSB, this rises a lot of question whether regulators are in control.

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### 3. 2 Tensile test results

Source of sample	Bar size, mm	Weight (Kg)	Length (m)	Mass per meter run	Standard Mass/meter	Cross section area, mm <sup>2</sup>	Standard Cross section area (mm <sup>2</sup> )	Yield load, KN	Ultimate tensile load, KN	Yield stress, N/mm <sup>2</sup>	ultimate tensile stress, N/mm <sup>2</sup>	Rm/Reh	% Elongation
S1	10	0.32	0.5	0.63	0.616	80.25	78.5	37.6	43	468.5	560.1	1.20	18.4
	10	0.32	0.5	0.64	0.616	81.02	78.5	37.3	43.5	460.4	542.5	1.18	17.5
	10	0.32	0.5	0.64	0.616	81.27	78.5	37.9	43.3	466.9	552.3	1.18	17.7
	12	0.42	0.5	0.83	0.888	106.24	113	54.0	73.1	508.3	688.4	1.35	17.5
	12	0.42	0.5	0.83	0.888	106.24	113	58.0	66.9	545.9	591.8	1.08	17.8
	12	0.42	0.5	0.84	0.888	106.50	113	60.0	69.1	563.4	610.2	1.08	18.2
S2	10	0.30	0.5	0.60	0.616	76.43	78.5	29.8	43.6	390.0	543.2	1.39	17.4
	10	0.30	0.5	0.59	0.616	75.31	78.5	30.6	44.2	406.0	523.3	1.29	17.4
	10	0.33	0.5	0.65	0.616	82.80	78.5	35.7	45.2	439.3	516.1	1.17	17.4
	12	0.43	0.5	0.86	0.888	110.06	113	63.5	74.9	577.0	680.4	1.18	19.7
	12	0.43	0.5	0.86	0.888	109.81	113	60.9	67.9	555.0	681.1	1.23	20
	12	0.43	0.5	0.86	0.888	109.55	113	64.7	74.3	591.0	680.1	1.22	20
S3	10	0.24	0.5	0.48	0.616	60.64	78.5	20.5	34.9	338.2	444.1	1.31	23
	10	0.25	0.5	0.49	0.616	62.42	78.5	22.9	36.5	366.9	464.5	1.27	23
	10	0.24	0.5	0.48	0.616	61.15	78.5	21.6	36.1	352.9	460	1.30	23
	12	0.39	0.5	0.78	0.888	99.72	113	36.0	53.2	361.0	534	1.48	19.2
	12	0.36	0.5	0.72	0.888	106.00	113	42.0	55.7	396.0	492.3	1.24	18.5
	12	0.39	0.5	0.78	0.888	106.00	113	38.0	55.6	358.0	492.7	1.38	18.7
S4	10	0.30	0.5	0.60	0.616	76.61	78.5	42.5	50.3	555.0	651	1.17	25.4
	10	0.30	0.5	0.60	0.616	76.43	78.5	41.7	49.7	545.4	630.3	1.16	25
	10	0.31	0.5	0.62	0.616	78.47	78.5	47.0	53.1	598.9	675.3	1.13	24.9
	12	0.42	0.5	0.84	0.888	107.01	113	58.2	79.2	544.2	700.4	1.29	25
	12	0.42	0.5	0.84	0.888	107.01	113	59.7	79.4	557.8	701.8	1.26	25
	12	0.42	0.5	0.84	0.888	107.26	113	57.6	78.4	537.3	693.3	1.29	25

Met the requirements,
  Moderately lower than the requirements
  dangerously lower than the requirements

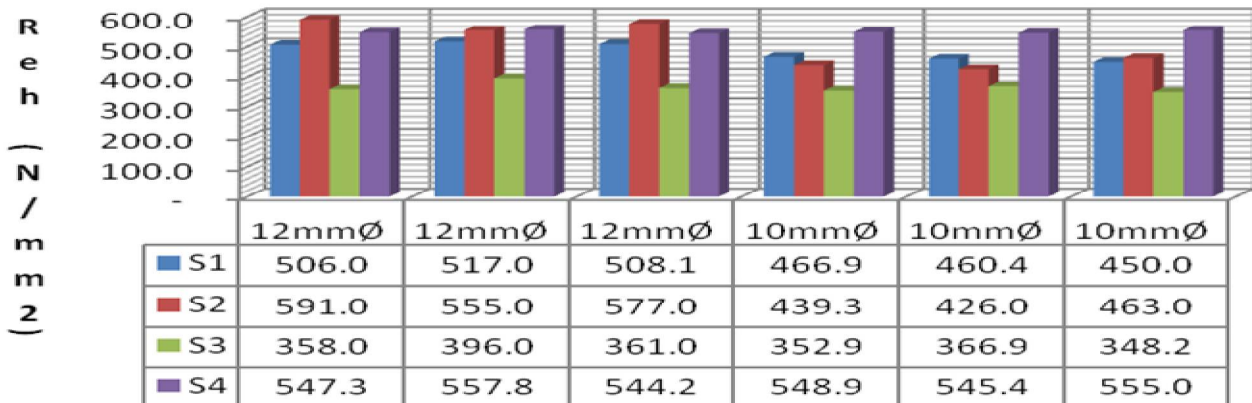
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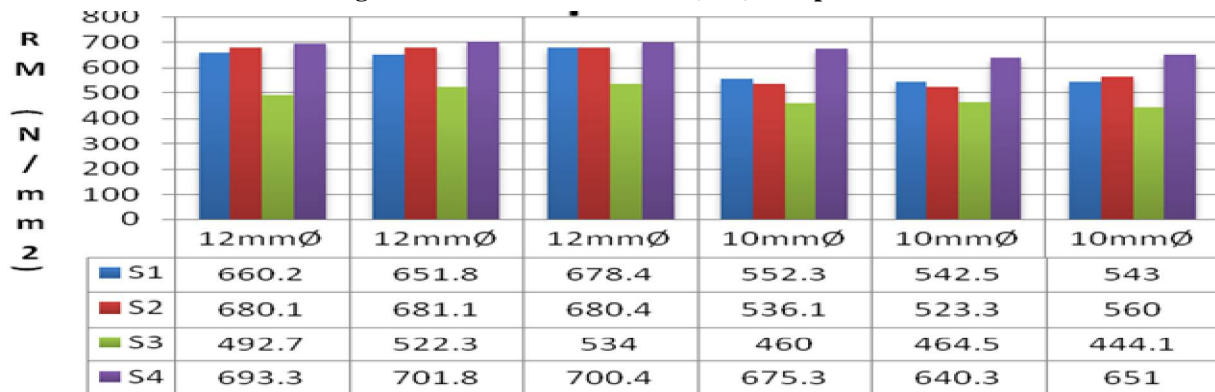
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**Fig 3.1 Yield stress (Reh) Comparison**



From the above table 3.1 and the graph on comparing the yield stress as a major property of rebars, it noticeable that S3 falls far below high yield steel bars requirements and so falls within mild steel bars limits. The size 12 mm and 10mm diameters bars are commonly used in floor slabs and if such rebar are used as high yield bars may eventually fail by flexural, incidentally most times they are used with out confirming their yield strength.

**Fig 3.2 Ultimate Tensile Stress (RM) Comparison**



The ultimate tensile stress being the point beyond which the material fails completely should be assessed in comparison to yield stress by analysing difference between the two values (RM-Reh), the ratio of yield stress to ultimate tensile stress (Reh/RM) and the ultimate tensile stress to yield stress (RM/Reh) ratio which is shown below, all of which indicates the extra stress required from yield point of a structure to total failure which inturn indicates the warning period before failure.



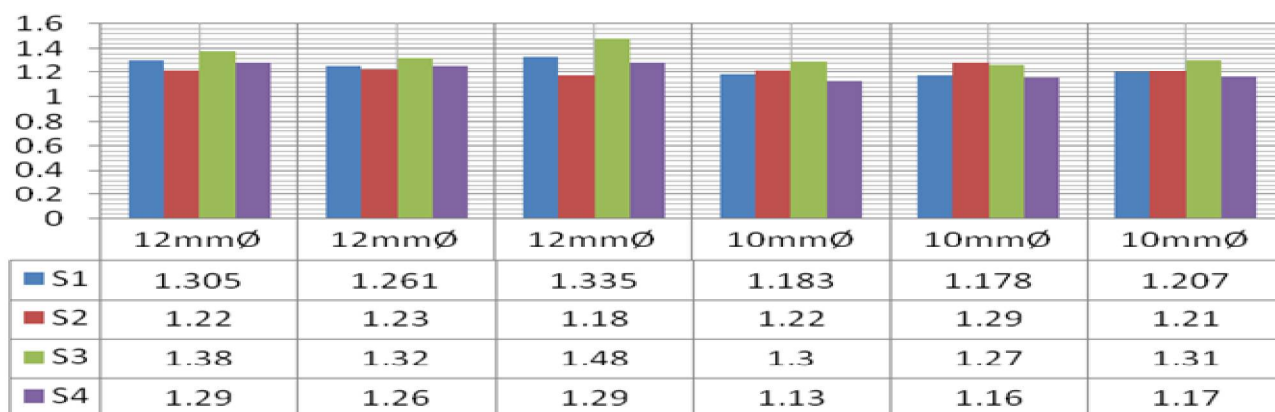
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**Fig 3.3 UTS to YS Ratio (RM/Reh)**



From the above graph and table of ultimate tensile stress to yield stress (RM/Reh) ratio, all samples met the requirements of BS 4447: 1997 and RS EAS 412-2: 2014 which sets the minimum value at 1.08 for high yield steel bars, definitely the higher the value the better is the sample. However as said above this value should not be appreciated in isolation to other primary factors such yield stress. As may be seen from above table and graph, the sample 3 (S3) performs very well but it becomes meaning less when compared to its yield stress which does not meet the requirements itself. Actually specifically on this sample further analysis may not be required if first requirement is not met.

**Table 3.3 Bending test average results**

S/No	Identification No	Bar Size	Former Diameter	Observation
1	S1	12 mm Ø	3d	No crack observed
		10 mm Ø	3d	No crack observed
2	S2	12 mm Ø	3d	No crack observed
		10 mm Ø	3d	No crack observed
3	S3	12 mm Ø	3d	No crack observed
		10 mm Ø	3d	No crack observed
4	S4	12 mm Ø	3d	No crack observed
		10 mm Ø	3d	No crack observed

According to RS EAS 412-2 (2014), the code stipulates that specimens must undergo rebend test and shall show no sign of fracture or irregular bending deformations. All samples tested didn't show any sign of fracture or irregular bending deformations and hence met the requirements of the code. The is true based on number of factors such as results of elongation, the ultimate tensile stress to yield stress ratio all of which portrays the ductility of a material and samples met the requirements.

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### 3.4 Bond/ Pull out test Bonding characteristics

The table shows averagely the bonding properties of samples with concrete, it should be noted that the variables here were only rebars source and size while concrete remained constant for all samples despite having casted for two days ( day 1 and day 2).

**Table 3.4 Bond/ Pull out test results**

SN	Specimens	Average crushing strength of the concrete cube	Maximum load at failure (KN)	Maximum strength at failure KN/mm <sup>2</sup>	Type of failure
1	S <sub>1</sub> C <sub>1</sub> (12mmØ) day1	33.98	51.5		Pulled out
	S <sub>1</sub> C <sub>3</sub> (12mmØ) day2	34.62	51.7		Pulled out
2	S <sub>2</sub> C <sub>1</sub> (12mmØ) day1	33.98	50.8		Pulled out
	S <sub>2</sub> C <sub>3</sub> (12mmØ) day2	34.62	51.1		Pulled out
3	S <sub>3</sub> C <sub>1</sub> (12mmØ) day1	33.98	50.4		Pulled out
	S <sub>3</sub> C <sub>3</sub> (12mmØ) day2	34.62	50.8		Pulled out
4	S <sub>4</sub> C <sub>1</sub> (12mmØ) day1	33.98	51.7		Pulled out
	S <sub>4</sub> C <sub>3</sub> (12mmØ) day2	34.62	51.9		Pulled out
5	S <sub>1</sub> C <sub>2</sub> (10mmØ) day1	33.98	50.5		Pulled out
	S <sub>1</sub> C <sub>4</sub> (10mmØ) day2	34.62	50.6		Pulled out
6	S <sub>2</sub> C <sub>2</sub> (10mmØ) day1	33.98	50.1		Pulled out
	S <sub>2</sub> C <sub>4</sub> (10mmØ) day2	34.62	50.4		Pulled out
7	S <sub>3</sub> C <sub>2</sub> (10mmØ) day1	33.98	49.8		Breaking
	S <sub>3</sub> C <sub>4</sub> (10mmØ) day2	34.62	49.7		Breaking
8	S <sub>4</sub> C <sub>2</sub> (10mmØ) day1	33.98	50.7		Pulled out
	S <sub>4</sub> C <sub>4</sub> (10mmØ) day2	34.62	50.9		Pulled out

As seen from the table, the samples were well pull out at different loads and tensile stresses apart from source 3(S3) size 10mmØ which is not surprising comparing to their ultimate tensile strength .

There is a good relation between the ultimate tensile strength results during tensile strength test and ultimate tensile strength results during pull out test at a breaking point which is 444.1 KN/mm<sup>2</sup> and 440KN/mm<sup>2</sup> respectively. The factors that need to be related to breaking of the bar may be the compressive strength of the concrete cube, the rib pattern of the rebars all which seem to comparatively constant or the same for all bars. The only reason behind the total bar breakage is the less yield strength compared to others.

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### 3.5 Chemical composition test results

The table below shows the average product analysis for the chemical composition of the steel samples selected.

**Table 3.5**

Element %	Source of the sample and bar size							
	S1		S2		S3		S4	
	12mm Ø	10 mm Ø	12mm Ø	10 mm Ø	12mm Ø	10 mm Ø	12mm Ø	10 mm Ø
C	0.140	0.239	0.189	0.178	0.157	0.146	0.159	0.122
Si	0.229	0.234	0.260	0.255	0.323	0.215	0.169	0.167
Mn	0.657	0.651	0.595	0.583	0.634	0.514	0.638	0.625
P	0.0299	0.0301	0.0441	0.0432	0.0406	0.0370	0.0269	0.0267
S	0.0182	0.0168	0.0346	0.0316	0.0287	0.0211	0.0138	0.0138
Cr	0.189	0.188	0.0819	0.0805	0.120	0.147	0.108	0.103
Mo	0.0041	0.0033	0.0074	0.0068	0.0084	0.0076	0.0072	0.0069
V	0.0027	0.0026	0.0014	0.0013	0.0020	0.0016	0.0071	0.0071
Fe	98.3	98.3	98.4	98.3	98.4	98.2	98.6	98.7
Cu	0.225	0.225	0.246	0.243	0.240	0.258	0.224	0.212
Ni	0.0628	0.0619	0.0786	0.0761	0.0843	0.103	0.0872	0.0863

#### Carbon equivalency: CE

S1: CE = 0.308;    S2: CE = 0.330;    S3: CE = 0.310;    S4: CE = 0.311

## IV. CONCLUSION AND RECOMMENDATIONS

### 4.1 CONCLUSION

From previous chapters drawn from literature review, material tests results and analysis made a number of conclusions can be made from them.

**1.** From visual verification and dimensional measurements, it was observed that most of the re-bars did not meet all requirements though to different extent. The worst being S3 which fell short of both diameters and labelling requirements.

**2.** Based on tensile test conducted and the analyses made the following conclusions were made:

(a) Steel reinforcing bars samples from different sources conducted, their characteristic strength values when compared to BS 4449: 1997: 14 samples of 24 met the requirements of tensile strength which is 460N/mm<sup>2</sup> minimum value. The failed 10 samples, 6 of them were S3 which were both 12mm and 10mm diameters. This means all samples of S3 failed to meet requirements of high yield steel bars with highest margins, only meeting requirements of mild steel bars.

(b) All of the steel reinforcing bar samples complied with the minimum ultimate tensile strength to yield strength ratio as specified by BS 4449: 1997. However, it should be noted that high value ratio renders no importance if the yield strength fails to meet requirements in the first place as is the case of S3

© The percentage elongation values for all samples were within acceptable code limits

**3.** For Bonding characteristics, apart from source 3(S3) size 10mmØ which failed by total breakage, all other samples were successfully pulled out before breaking. There seem to be a good relation between the ultimate tensile strength

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results during tensile strength test and ultimate tensile strength results during pull out test at a breaking point which is 444.1 KN/mm<sup>2</sup> and 440KN/mm<sup>2</sup> respectively.

4. Bending Properties: All samples tested didn't show any sign of fracture or irregular bending deformations and hence met the requirements stipulated in the standards in place.

5. The chemical concentration test results fell within limits of the requirements, though with visible big differences and direct consequences of brittleness and ductility differences.

6. Sometimes developers together with Engineers who should be their advisors prefer imported rebars, even at a higher cost with no characteristic strength consideration, from the above results S2 is locally made and seem to be performing well as compared to standard requirements. The issue of testing materials before use is of un known importance completely to both engineers and developers.

## 4.2 RECOMMENDATIONS

Based on the findings of this study, the following recommendations made:

1. From the research made and analysis of test results made, it seen that steel reinforcing bars that are not traceable exhibit poor strength results, it therefore recommended rebars without standard labelling be prohibited from both importation sold on local market.
2. Since recycling of metal scraps in steel making is inevitable, well defined system should be put in place for effective quality control of scraps before being used manufacturing of rebars
3. Engineers and developers should be careful while purchasing steel rebars, not to buy based on source but proper characterisation of rebars such chemeical composition and physical properties like yield stress, elongation and RM/Reh ratio which are very important properties for a sound and durable reinforced concrete structures. These important particulars will only be available on request of importation certificate and reaffirmed through rebars' testing.
4. It is recommended that all steel reinforcing bars be tested before being put into use to compare with design values otherwise design bears no justifiable meaning.
5. Regular inspections is inevitable for quality control and therefore regulators should inforce at all levels, at customs and inside the country at local markets to ensure right materials.
6. From literature review recycling of metal scraps in steel making is almost inevitable, therefore well defined system should be put in place for effective quality control of scraps before being used in milling of steel reinforcing bars.

## REFERENCES

1. Anthony Nkem Ede et la, 2015 Assessment of Quality of Steel Reinforcing Bars Used in Lagos, Nigeria; International Research Journal of Innovative Engineering  
Volume1, Issue 3 of March 2015
2. BRITISH STANDARD 4449:1997 (amended 2001) Specification for Carbon steel bars for the reinforcement of concrete. Engineering sector board, British Standards Board
3. Ejeh. S.P.I, Jibrin. M. U (2012) Tensile Tests on Reinforcing Steel Bars in the Nigerian Construction Industry, IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) ISSN: 2278-1684 Vol: 4, N<sup>o</sup>:2, Nov. - Dec. 2012, pp 06-12.
4. Government of Rwanda 2014, Housing Market Study in the City of Kigali. Rwanda Housing Authority.
5. -----, Steel Product Manufacturing in Rwanda.
6. -----, Steel Product Manufacturing in Rwanda.
7. Rwanda Development Board.

## International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: [www.ijirset.com](http://www.ijirset.com)

Vol. 7, Issue 6, June 2018

8. JIBRIN, + M. U. and EJEH, ++ S. P. (2013) A Comparative Assessment Of The Bend, Chemical And Tensile Properties Of Reinforcing Steel Bars In The Nigerian Construction Industry
9. *International Journal of Engineering Research & Technology (IJERT) Vol. 2 Issue 3, March - 2013 ISSN: 2278-0181*
10. Kankam C K , Asamoah M A( 2002) Strength and ductility characteristics of reinforcing steel bars milled from scrap metals. Material and Design 23, 2002, Pages 5132–5140, Elsevier Ltd
11. Munyazikwiye Bukaragire. B (2010) Investigation on Characterization and Variability of Mechanical Properties of Reinforcing Steel Bars made from Scrap. A thesis submitted in partial fulfilment for the Degree of Master of Science in Mechanical Engineering in the Jomo Kenyatta University of Agriculture and Technology
12. Mwasame.G, et al (2012) Safety and structural reliability of reinforced concrete buildings in Kenya. International Journal of Disaster Management and Risk Reduction, Vol. 4 No. 2, November 2012
13. Opara, P .N (2007). Building Failures and Collapses: A Case Study of Port Harcourt, Nigeria Journal of Technology and Education in Nigeria Vol. 12 (1) 2007: pp. 35-39
14. Opeyemi Joshua et la 2013, Assessment of the Quality Steel Reinforcement Bars Available in Nigerian Market, Architectural Engineering Conference 2011
15. RS EAS 412-2: 2012 , Steel for the reinforcement of concrete — Part 2: Ribbed bars, Rwanda Berua of Stanadards (2014)
16. *Rubaratuka.IA December – 2013, Challenges of the Quality of Reinforced Concrete Buildings In Dar es Salaam, International Journal of Engineering Research & Technology*
17. *Vol. 2 Issue 12, December - 2013*
18. Senfuka C, et al, The Concrete Reinforcing Value of Recycled Steel Bars in Uganda., IOSR Journal of Engineering (IOSRJEN) e-ISSN: 2250-3021, p-ISSN: 2278-8719 Vol. 3, Issue 1 (Jan. 2013), ||V2|| PP 15-19
19. Singh, B, Kaushik. S.K (2002) Influence of steel-making processes on the quality of reinforcement, The Indian Concrete Journal July 2002 . Elsevier Science Ltd
20. UK CARES Part 2, 2011, The CARES Guide to Reinforcing Steels; Part 3; Pembroke House, 21 Pembroke Road, Sevenoaks, Kent TN13 1XR