

## BEND AND ELONGATION CHARACTERISTICS OF REINFORCING STEEL BARS IN THE NIGERIAN CONSTRUCTION INDUSTRY

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### ABSTRACT

*Bend and elongation behaviour were investigated for reinforcing steel bars used in the Nigerian construction industry. This was done to ascertain their interrelationships and level of conformity with BS4449 standards. A total of fourteen (14) companies operating in Nigeria were visited and (19) nineteen samples collected randomly with each sample containing ten specimens which were used in the tests. Out of the nineteen (19) samples, thirteen (13) were locally produced, while six (6) were foreign. A total of 190 specimens were used for each of the two experiments implying a total of 380 specimens for all the tests. It was discovered that only one (1) sample out of the nineteen (19) samples examined failed to meet the requirements of BS4449:1997 in respect of the bend tests. In case of the elongation tests, five (5) out of the nineteen (19) samples did not record the minimum values of fourteen (14%) percent as prescribed by BS4449 (1997). The sample that failed the bend test which was designated as C<sub>16</sub>B recorded eight (8%). C<sub>10</sub>B and C<sub>8</sub>B are two (2) additional samples from the same company designated as C that gave out C<sub>16</sub>B and have passed both the bend and elongation tests, suggesting the need for constant quality checks in the production lines. Four bars designated as A<sub>10</sub>B, D<sub>8</sub>B\*, J<sub>8</sub>B\*, and K<sub>10</sub>B\*, despite satisfying the bend tests code requirements failed elongation tests by recording 13.90%, 1.67%, 2.67% and 10.07% respectively. The elongation values of 1.67%, 2.67% and 10.07% are considered not only very low, but dangerous for structural applications. Thus, the research is an indicator that the two tests though, seem to be related and cannot substitute one another in any ductility determination, caution must be taken in the arbitrary use of bars indiscriminately especially those whose sources and technical information are unknown. Thus, all reinforcing steel bars must be tested prior to use in site.*

**KEY WORDS:** Bend test, Elongation test, Reinforcing steel bars

### INTRODUCTION

Reinforcing steel bars play a key role as a construction material whose properties must be known to the users before being applied for design or construction purposes.

Steel reinforcing bars available in the Nigeria's Construction Industry are obtained from both local and foreign sources. The former comes mainly from both the indigenous major plants and the mini mills located in different parts of the country. Imported steel bars coming into the country are mainly from Russia and Ukraine. Others are those procured for specific uses by multinational companies for some specific projects.

Most construction companies in Nigeria procure all their reinforcing steel from the open local markets with-out any technical information that guides users on the appropriate use. Many reports on structural collapse have been associated with the use of substandard construction materials with reinforcing steel inclusive.

The need for a complete understanding of the bend and elongation properties of the reinforcing steel bars in the Nigerian Construction Industry can not be over emphasized. Bend and elongation tests are good indicators of ductility in reinforcing steel and their clear magnitude must be ascertained in order to predict the steel behaviour as a component of structural members. Out of the nineteen (19) samples from where specimens

were made, one (1) sample failed completely the bend test and five (5) samples failed out of the nineteen for the elongation. Many of them are foreign samples.

### SAMPLES PREPARATION AND EXPERIMENTS

#### General Survey

A general survey of all Steel rolling mills in the country was undertaken and samples from those found in production were taken for these tests.

From the survey, it was observed that the idea that led to the development of Iron and Steel Industry in Nigeria was born in 1958 by the Federal Government. That the steel rolling mills in the country can be classified in three phases or divisions as follows: (a) Ajaokuta Steel (b) Delta Steel Company with inland rolling mills at Katsina, Jos and Osogbo. Other group is (c) The private mini mills grouped together. While Ajaokuta is yet to be completed, Delta's concept is to process and pass billets as raw materials for Katsina, Jos and Osogbo rolling mills. Then the mini mills which are mainly foreign dominated are privately owned with many of them in operation before the establishment of the ones earlier stated above. For example, the first steel plant in Nigeria was in the group of mini plants and was established at Emene near Enugu in 1962 by the Eastern Nigerian Government. These were followed by two (2) similar plants which were established in Lagos in 1968 and 1970 respectively by private initiative.

### Samples Collection

The samples were collected from 14 different companies. Six of the companies are foreign and their actual names were not known but only the countries of origin were specified. Thus, there are nineteen samples from fourteen different companies including the foreign ones that were considered for the test.

The Sample diameters collected from the local sources depended on the available sizes as at the time of the research within the company. For samples from foreign sources, only diameters available in the Nigerian Construction Industry / market were collected.

### Samples' Labeling

All the fourteen companies from where the samples were collected were labeled in an alphabetical order as A, B, C ...N. The order of identification does not mean A is better than B , as the designations are only for identification purposes. For example:  $A_{12}B$  and  $A_{10}B$  imply company A, twelve millimeter diameter for bend test and company A, ten millimeter diameter for bend test respectively.  $A_{12}T$  and  $A_{10}T$  imply company A , twelve millimeter diameter for elongation test and company A , ten millimeter diameter for elongation test respectively, and so on. For each diameter, ten samples were used for each test in line with the BS standard procedure. The value presented in this paper is an average of ten (10) for each test (be in bend or elongation).

### Samples Preparation

#### Bend Tests

Ten samples were tested for each diameter as earlier stated with each specimen having of a length of 500 millimeters. Each

specimen was bent around a steel former whose diameter is  $(3\Theta + 3)$  millimetre in accordance with the BS4449:1997 provisions. Where  $\Theta$  is the bar diameter in millimeters and 3 represents a tolerance of 3mm as provided by the code to avoid the machine pressing the bar flat.

### Elongation Tests

Ten specimens were tested for each diameter as earlier stated. Each specimen has of a length of 500 millimeters. Each specimen diameter is measured in three places and the average is obtained as the diameter. Then each specimen was subjected to elongation test in accordance with the BS4449:1997 provisions, and after breaking, the elongation is calculated. The results of the bend tests as well as the elongation tests are presented in Tables 1 and 2.

### ANALYSES OF TEST RESULTS

The two test results are analysed and presented below to arrive at a conclusion. It is important to note that in bend tests, no cracks were allowed after bending through a former through  $180^\circ$ , while in elongation tests, the minimum required elongation is fourteen (14) percent.

#### Percentage Elongation

From table 2 , it can be observed that seven (7) samples from seven (7) companies failed to satisfy the elongation test. Three (3) companies (  $A_{10}T$  ,  $C_{16}T$  and  $D_8T$  ) are local companies who failed the elongation tests , while only one (1) - ( $L_{12}T$ ) from the foreign company passed the elongation test. The rest five (5) out of the six (6) foreign companies failed to satisfy the elongation tests.

**Table 1 : Bend Tests Results for the nineteen (19) samples.**

S/No	Mark	Bend Test
01	$A_{12}B$	No Crack
02	$A_{10}B$	No Crack
03	$B_{10}B$	No Crack
04	$B_8B$	No Crack
05	$C_{16}B$	Total Breakage
06	$C_{10}B$	No Crack
07	$C_8B$	No Crack
08	$D_8B$	No Crack
09	$E_{12}B$	No Crack
10	$E_{10}B$	No Crack
11	$F_{12}B$	No Crack
12	$G_{12}B$	No Crack
13	$H_{16}B$	No Crack
14	$I_{12}B$	No Crack
15	$J_8B$	No Crack
16	$K_{10}B$	No Crack
17	$L_{12}B$	No Crack
18	$M_{10}B$	No Crack
19	$N_{16}B$	No Crack

Table 2: Percentage Elongation results for the nineteen (19) samples.

S/No	Mark	Measured Diameter (mm)	Average Elongation (%)	Standard Deviation
01	A <sub>12</sub> T	11.88	16.50	0.92
02	A <sub>10</sub> T	9.65	13.90	1.00
03	B <sub>16</sub> T	9.56	19.60	1.25
04	B <sub>8</sub> T	7.44	23.82	1.13
05	C <sub>16</sub> T	15.82	8.33	0.00
06	C <sub>10</sub> T	9.55	19.93	1.38
07	C <sub>8</sub> T	7.46	21.17	1.12
08	D <sub>8</sub> T	7.23	1.67	0.00
09	E <sub>16</sub> T	24.56	19.83	0.53
10	E <sub>10</sub> T	19.57	24.27	0.97
11	F <sub>12</sub> T	11.4	19.07	2.15
12	G <sub>12</sub> T	11.48	14.83	1.23
13	H <sub>16</sub> T	15.52	14.53	1.75
14	I <sub>12</sub> T	11.40	14.50	1.13
15	J <sub>8</sub> T	6.50	2.67	0.86
16	K <sub>16</sub> T	9.36	10.07	1.38
17	L <sub>12</sub> T	11.82	14.93	1.59
18	M <sub>16</sub> T	9.23	11.77	0.86
19	N <sub>16</sub> T	15.60	13.90	0.79

The standard deviation is with respect to bar diameters from each source.

As earlier stated in 2.3, A<sub>10</sub>T is from same company as A<sub>12</sub>T. Thus, A<sub>10</sub>T failed while A<sub>12</sub>T passed the elongation tests. In company C, bars Samples designated as C<sub>16</sub>T failed, while C<sub>10</sub>T and C<sub>8</sub>T passed. The Samples designated as D<sub>8</sub>T

failed. All the foreign companies failed elongation except L<sub>12</sub>T. That is serial numbers 15 to 19 and also 8 are foreign companies and only L<sub>12</sub>T passed.

Table 3 : Percentage Elongation Values for the Nineteen compared with code specifications.

S/No	Mark	Percentage Elongation	Min. Provisions BS4449/1997	Remarks
1	A <sub>12</sub> T	16.50	14.00	Satisfactory
2	A <sub>10</sub> T	13.90	14.00	Not Satisfactory
3	B <sub>16</sub> T	19.60	14.00	Satisfactory
4	B <sub>8</sub> T	23.82	14.00	Satisfactory
5	C <sub>16</sub> T	8.33	14.00	Not Satisfactory
6	C <sub>10</sub> T	19.93	14.00	Satisfactory
7	C <sub>8</sub> T	21.17	14.00	Satisfactory
8	D <sub>8</sub> T*	1.67	14.00	Not Satisfactory
9	E <sub>16</sub> T	19.83	14.00	Satisfactory
10	E <sub>10</sub> T	24.27	14.00	Satisfactory
11	F <sub>12</sub> T	19.07	14.00	Satisfactory
12	G <sub>12</sub> T	14.83	14.00	Satisfactory
13	H <sub>16</sub> T	14.53	14.00	Satisfactory
14	I <sub>12</sub> T	14.50	14.00	Satisfactory
15	J <sub>8</sub> T*	2.67	14.00	Not Satisfactory
16	K <sub>16</sub> T*	10.07	14.00	Not Satisfactory
17	L <sub>12</sub> T*	14.93	14.00	Satisfactory
18	M <sub>16</sub> T*	11.77	14.00	Not Satisfactory
19	N <sub>16</sub> T*	13.90	14.00	Not Satisfactory

The value of standard deviation will determine the skilled people that are in the company producing the steel. Smaller values indicate high skilled personnel were employed. Values below or equal to five are an indicative of highly skilled personnel and above five indicates employment of low skilled men which lead to bad products, etc. The highest value of the standard deviation of 2.15 was obtained in sample F<sub>12</sub>T

(serial number 11) and the sample presented a very good average elongation values of 19.07. Minimum values of 0 were obtained in samples C<sub>16</sub>T (serial number 05) and D<sub>8</sub>T (serial number 08) that presented elongation values of 8.33 and 1.67 respectively which are all below the standards provided by BS4449:1997. This implies the production line and raw material would have to be thoroughly checked.

**Bend Test**

Eighteen out of the nineteen samples as shown in Table 1 have passed the bend test as neither micro cracks were observed, nor any form of unacceptable deformation. However, all the ten specimens constituting sample C<sub>16</sub>B as reflected in Table 1 have not complied with the BS4449:1997 requirement. It is worthy to note that C<sub>16</sub>B, C<sub>10</sub>B and C<sub>8</sub>B are from the same company and C<sub>16</sub>B failed the bend test completely.

From Table 1, only one (1) sample - C<sub>16</sub>B out of the nineteen (19) tested failed the bend test. If such reinforcement like C<sub>16</sub>B, which is company C with bar diameter 16 millimetres are used in structural elements, the element may fail

without warning. This situation may indicate high content of carbon with no elements for ductility in the production.

Table 3 summarizes the results of the bend and elongation tests. It can also be observed that eleven (11) out of the fourteen (14) locally produced bars passed the bend and elongation tests, while three (3) out of the six (6) foreign bars considered passed both the bend and elongation tests.

In the aggregate, fourteen (14) out of the nineteen samples considered for the experiment have passed the tests for elongation. This implies five (5) samples out of the nineteen (19) samples representing 26.3% have failed the elongation test and 5.26% for bend tests which is a source of concern.

**TABLE 3: TESTING OF BEND AND ELONGATION TEST PARAMETERS.**

S/No	Mark	Measured Diameter(mm)	Percentage Elongation (%)	Bend Test	Remarks
1	A <sub>12</sub> T	11.88	✓	✓	Satisfactory
2	A <sub>10</sub> T	9.65	✗	✓	Not Satisfactory
3	B <sub>10</sub> T	9.56	✓	✓	Satisfactory
4	B <sub>8</sub> T	7.44	✓	✓	Satisfactory
5	C <sub>16</sub> T	15.82	✗	✗	Not Satisfactory
6	C <sub>10</sub> T	9.55	✓	✓	Satisfactory
7	C <sub>8</sub> T	7.46	✓	✓	Satisfactory
8	D <sub>8</sub> T*	7.23	✗	✓	Not Satisfactory
9	E <sub>25</sub> T	24.56	✓	✓	Satisfactory
10	E <sub>20</sub> T	19.57	✓	✓	Satisfactory
11	F <sub>12</sub> T	11.40	✓	✓	Satisfactory
12	G <sub>12</sub> T	11.48	✓	✓	Satisfactory
13	H <sub>16</sub> T	15.52	✓	✓	Satisfactory
14	I <sub>12</sub> T	11.42	✓	✓	Satisfactory
15	J <sub>8</sub> T*	6.50	✓	✓	Satisfactory
16	K <sub>10</sub> T*	9.36	✗	✓	Not Satisfactory
17	L <sub>12</sub> T*	11.82	✓	✓	Satisfactory
18	M <sub>10</sub> T*	9.23	✓	✓	Satisfactory
19	N <sub>16</sub> T*	15.62	✗	✓	Not Satisfactory

Legend : ✓=> Satisfactory / Within Code Provision, ✗=> Unstisfactory / Outside Code Provision ; and \* indicates foreign Bars.

**CONCLUSION**

The elongation and bend tests conducted were analysed and based on the observations and, the following conclusions were made.

1. The percentage elongation values for most of the locally produced bar samples are within acceptable code limits.
2. The percentage elongation values for most of the foreign bar samples are below the minimum standard provisions.

3. Despite the evidence of brittleness in the foreign bars, only one out of the three samples from company C (C<sub>16</sub>B) failed the bend test.
4. It is evident that reinforcing bars can pass elongation tests and at the same time fail bend tests as evidenced in table 3.

## RECOMMENDATION

Both elongation and bend tests should be carried out to confirm brittleness or lack of ductility of reinforcing steel bars prior to use on site for construction.

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