International Journal of Civil and Structural Engineering Research ISSN 2348-7607 (Online)
Vol. 12, Issue 2, pp: (123-127), Month: October 2024 - March 2025, Available at: www.researchpublish.com

INVESTIGATION OF THE TENSILE STRENGTHS AND DUCTILITY OF REINFORCING STEEL USED IN COLLAPSED BUILDING PROJECTS IN SOUTH EAST NIGERIA

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DOI: https://doi.org/10.5281/zenodo.14857112

Published Date: 12-February-2025

Abstract: **This research work assessed the tensile strength and ductility of reinforcing steel bars used in the construction of collapsed building projects in South East, Nigeria. The method adopted in the work was laboratory experimentation and testing of the tensile strength and ductility of the reinforcing steel bars. The results obtained revealed that fifteen percent (15%) of the reinforcing steel bars used in the collapsed buildings under study, were of good quality another fifteen percent (15%) were of satisfactory quality, while seventy percent (70%) were poor quality reinforcing steel bars. On the other hand, fifty five percent (55%) of the reinforcing steel were ductile, while forty five percent (45%) of them, were brittle in nature. Thus a substantial quantity of reinforcing steel bars available in building material market in South East, Nigeria, are both weak and brittle in nature. This implies that there is a high probability that any steel acquired and deployed for construction of buildings, may be sub-standard. It is therefore, recommended that all reinforcing steel bars must be tested to determine their quality and hence their suitability for building construction**

Keywords: **Tensile strength, Ductility, Reinforcing steel, Concrete and Collapsed Building Structures.**

1. INTRODUCTION

Concrete is widely used in the construction of various structures, such as buildings, bridges and dams. According to Zongjin (2011), concrete is the most widely used structural material. Although, it has substantial strength in compression, it is very weak in tension due to its brittle nature. Due to this weakness in tension concrete is unable to resist direction tension which often results into cracking of the concrete. Thus, concrete structures and their elements are usually reinforced with steel bars, particularly, in their tension zone. In other words, the deficiency of concrete is overcome by introducing reinforcement in form of steel bars to produce a composite material known as reinforced concrete (Maleka, Garba and Adamu, 2014), which depends on concrete's strength in compression and steel's strength in tension (Kopas, Saga, Baniari, Vaske and Handrik, 2017). The versality of concrete, is greatly increased with the addition of steel reinforcement, which compensates for the tensile weakness of concrete (Zongjin, 2011). Consequently, both concrete and steel provide complementary support to each other, by compensating for the weakness in the properties of the other materials (Arya, 2009; Vlack, 1982 and Marrel, 1977), thereby making concrete a universal construction material (Ede, Egunjiobi, Bamigboye and Ogundeji, 2015). These building materials, namely concrete and steel, bear the loads imposed on structures, thereby contributing to the stability of such structures.

The use of sub-standard reinforcing steel bars with low and inferior quality, compromise the strength and ductility of buildings constructed with them. Sub-standard reinforcing, may be weak in tensile strength and/or brittle in nature. The use of such sub-standard reinforcing steel, results into sub-standard buildings that are susceptible to collapse. One of the most frequently adduced causes of building collapse in Nigeria, is the use of sub-standard reinforcing steel bars, whose structural properties, do not conform to actual design specifications (Ede et al, 2015). Ajufor, Gumau and Inusa (2014), stated that most contractors in Nigeria, prefer to use sub-standard steel reinforcement. Other investigators such as Adeleke, Ajagbe and Arasi, 2015; and Kolawole and Akanni (2012) found that low quality reinforcing steel bars, were among the causes of building collapses in Nigeria. For this reason, Chendo and Obi (2015) stressed the need for reinforcing steel bars to undergo tensile tests, so as to determine their tensile strengths. And, Oyedele stated that building materials, ought to be tested before and during construction as a quality control measure and after construction for integrity.

In their own study, Bamigboye, Olaniyi, Olukanni, Ede and Akinwumi (2017) carried out a comparative analysis of the quality of steel reinforcements produced locally in Nigeria and imported ones. They found that locally made steel bars deviated significantly from standard specification than imported ones. They identified the causes of building collapse to be sub-standard steel bars produced by corrupt local steel manufacturers, who do not conform to standard specifications. Consequently, they recommended that regulatory agencies, should ensure strict compliance with standard specifications and penalization of defaulters so as to discourage the corrupt practice of producing or using sub-standard building materials.

Adeleke and Odusote (2013) performed mechanical analysis of reinforcing steel bars used in the Nigerian construction industry. Their finding showed that the reinforcing steel bars investigated, have low ductility. They attributed the collapse of buildings to low quality reinforcing steel bars available in Nigeria. They recommended that continuous random tests of building material, should be conducted in order to ensure compliance of building materials with standards.

In their own work, Ede et al (2015) assessed the quality of steel reinforcing bars used in Lagos State. The results of the samples of reinforcing steel tested in a laboratory showed that an average of the samples tested, met the specification of BS8110 code. But, Kolawole and Akanni (2012) carried out chemical analysis of reinforcing steel bars. Their findings revealed significant deviation from standard specifications. They blamed the low quality of reinforcing steel and corruption of stakeholders for the collapse of buildings. Consequently, they stressed the need to ensure that quality steel bars, are used and sanctions prescribed for corrupt production practices.

However, the investigation of Hansson ,Poursaee and Jaffer (2012), concentrated on corrosion of reinforcing bars in concrete on corrosion of reinforcing bars in concrete. Their review showed that Portland cement concrete provides excellent protection for embedded steel in the absence of chloride contamination or carbonation by acting as a physical barrier and by chemically passivating the steel surface.

From the foregoing, there is evidence to show that sub-standard reinforcing steel bars, were among the major causes of building collapse in Nigeria and so they ought to be investigated particularly in South East, Nigeria. And, this research work presents the results of the laboratory experimentation and testing of the tensile strength and ductility of reinforcing steel bars that were used in collapsed buildings in South East, Nigeria.

2. METHODOLOGY

Tensile strengths and ductility of materials are always determined by subjecting the materials in question to tensile tests. Thus, the method employed in this work is laboratory experimentation and testing of reinforcing steel bars. The tensile tests, were performed on forty samples of 10mm, 12mm, 16mm and 20mm reinforcing steel bars collected from five purposively selected collapsed building sites in South Eastern region of Nigeria. Five test specimen were cut out from each sample of reinforcing steel bar, giving a total of two hundred specimen that were prepared, tested in tension and analyzed. The tests were carried out in a universal testing machine with load capacity, 40 Tons, in accordance with the specifications of BS4449 (1997).

After the tensile test, the yield strength, and the percentage elongation E, where calculated using Equations (1) and (2) respectively.

$$\text{Yield stress, } \sigma = \frac{\text{yield force}}{\text{Original cross section}} \quad (1)$$

$$\text{Percentage elongation, } E = \frac{\text{final length} - \text{original length x100}}{\text{Original length}} \quad (2)$$

3. RESULTS

The Results of the tensile tests performed on the forty reinforcing steel bars obtained from five purposively selected collapsed building sites in South east, Nigeria, were analyzed by Onwuka and used to determine the qualities of the reinforcing steel bars based on a method of quality classification adapted from Ede (2015). In the method a reinforcing steel bar is classified as having good quality, if its yield stress, Ꝺ, is greater or equal to 460N/mm^2 (i.e Ꝺ ≥ 460N/mm^2); satisfactory if it falls between 410N/mm^2 and 460N/mm^2 (i.e 410N/mm^2 ≤ Ꝺ ≤ 460N/mm^2) and poor quality if it is less 410N/mm^2 (i.e 410N/mm^2). And for the ductility of the reinforcing steel bars, it is said to be ductile, if the percentage elongation, E- value is greater or equal (≥) 14% and brittle, if its value is less than (<) 14%.

Table 1: Qualities of Reinforcing Steel Bars Collected from Various Collapsed Building Sites in South East, Nigeria.

Site	Location	Size of Steel	Characteristics of steel			
			Yield stress (N/mm^2)	Quality of Steel	% Elongation	Nature of Steel
1	Abia	10	477.71	Good	26.7	Ductile
		12	363.31	Poor	28.51	Ductile
		16	316.59	Poor	28.88	Ductile
		20	285.94	Poor	8.71	Brittle
	Anambra	10	573.00	Good	12.7	Brittle
		12	410.41	Satisfactory	25.75	Ductile
		16	330.24	Poor	11.94	Brittle
		20	285.94	Poor	30.85	Ductile
	Ebonyi	10	445.86	Satisfactory	9.09	Brittle
		12	353.21	Poor	5.25	Brittle
		16	336.92	Poor	29.12	Ductile
		20	293.97	Poor	7.00	Brittle
	Imo	10	477.71	Good	26.70	Ductile
		12	363.31	Poor	28.51	Ductile
		16	316.59	Poor	28.88	Ductile
		20	285.94	Poor	8.71	Brittle
	Enugu	10	458.60	Satisfactory	29.00	Ductile
		12	272.48	Poor	1017	Brittle
		16	347.79	Poor	24.50	Ductile
		20	300.73	Poor	7.50	Brittle

Source: Field Survey, 2024

A close examination of the Table 1, indicates that all the reinforcing steel bars (representing 75%) collected from collapsed building site 7 in Imo state, were poor quality steel, except for 10mm reinforcement (representing 25%), which is of good quality. But, the 10mm, 12mm and 16mm reinforcing steel bars, were ductile, while the 20mm reinforcing steel bars, was brittle in nature.

And, the results and analyses of reinforcing steel bars collected from collapsed building site 10 in Enugu state, revealed that the 12mm, 16mm and 20mm reinforcing steel bars (representing 75%), were of poor quality, while the 10mm reinforcing steel bar (representing 25%), has satisfactory quality. However, the 10mm and 16mm (representing 50%), were both ductile, while 12mm and 20mm (representing 50%), were both brittle.

4. DISCUSSION

The results of the survey by Onwuka (2024), showed that inferior reinforcing steel bars, were ranked fourth (4th) quality problem of building material, that led to building collapses in South East, Nigeria. This finding is in good agreement with the discovery of Bamigboye et. al.(2017), who found that building materials like reinforcing steel bars, cement, sand, granite, sandcrete blocks and concrete, play huge roles in either collapse or stability of buildings. However, Hamma-adama and Kouider, (2017) listed reinforcing steel bars as the major building material that caused building collapse.

From another test conducted by Odusote and Adeleke (2012) on rebars collected from collapsed building sites in Lagos, it was discovered that the brittleness of the reinforcing bars, caused by the presence of deleterious materials, may be responsible for the collapsed of buildings in Nigeria. Many dubious contractors and developers, who like cutting corners, use these inferior steels bars for construction of buildings in Nigeria.

Consequently, in depth and extensive tensile tests, were performed on 10mm, 12mm, 16mm, and 20mm reinforcing steel bars, collected from the five collapsed building sites in South East, Nigeria. Ten test specimens, were collected from each reinforcing steel bar size in each state. In all, two hundred (200) specimens were tested, analyzed and presented in Table 1. Using a steel classification method adapted from Ede et al. (2015), a reinforcing steel bar is said to be of good quality, if the yield stress, ɓ, is greater or equal to 460N/mm^2 (ɓ $\geq$ 460 N/mm^2), satisfactory quality, if it falls between 410 N/mm^2 and 460 N/mm^2 (i.e. 410 $\leq$ ɓ $\leq$ 460N/mm^2) and poor quality if it less than 410N/mm^2. Table 1. shows the qualities of the various reinforcing steel bars used in the construction of some collapsed buildings in South Eastern States of Nigeria.

And for elongation of reinforcing steel bars, each bar is classified as ductile, if its percentage elongation value, is greater than or equal to 14% (ie ≥ 14%), and brittle, if its value is less than 14% (i.e < 14%)

From the Table 1, it is evident that all the 12mm, 16mm and 20mm reinforcing steel bars (representing 75%), collected from collapsed building site 1 in Abia State, were poor quality steel, while the 10mm (representing 25%) reinforcing steel bar, was of good quality. However, the 10mm reinforcing steel bar as well as the 12mm and 16mm reinforcing steel bars, were ductile, while the 20mm reinforcing steel bar, was brittle in nature.

For the steel reinforcing bars obtained from the collapsed building site 6 in Anambra State, the 10mm and 12mm reinforcing steel bars, were of good quality and satisfactory quality respectively, while the 16mm and 20mm reinforcing steel bar, were of poor quality. This represents 50% of the entire reinforcement from collapsed building site 6. However, the 10mm and 16mm reinforcing steel bars, were brittle, while both 12mm and 20mm reinforcing steel bars were ductile in nature. Except for 10mm reinforcing steel bar (representing 25%), which is of satisfactory quality, all other reinforcing steel bars (representing 75%), collected from the collapsed building site in Ebonyi state, have poor quality. Concerning ductility, only the 16mm reinforcing steel bar (representing 25%) was ductile, while the other three sizes of reinforcing bars (representing 75%), were brittle in nature.

In summary, it could be stated that seventy percent (70%) of the reinforcing steel bars used in the construction of the purposively selected and studied collapsed buildings in South East, Nigeria had characteristic yield strengths lower than 410N/mm^2, while forty five percent (45%) were not ductile (% E<14%). Thus, substantial quantity reinforcing steel bars are both weak and brittle in nature. Ajufor, Gumau and Inusa (2014), stated that most contractors prefer to use these sub-standard steel reinforcement. These sub-standard reinforcing steel bars, are both produced in the country and imported from other countries. They are most likely to be one of the major causes of building collapses in South Eastern region of Nigeria. This finding agrees with the assertion of Ede, Olofinnade and Joshua (2014); and Joshua, Olusola, Ayegba and Yusuf (2013), that non-conformance of structural properties (e.g tensile strength and ductility) of building materials (e.g steel) used in construction of buildings, is one of the most frequently adduced causes of building collapse in Nigeria. Adewole, Ajagba and Arasi (2015); and Kolawole and Akanni (2012) found that low quality reinforcing steel bar, was among the causes of building collapse. In collaboration, Ede et al (2015) stated that lack of ductility of reinforcing steel bars usually lead to sudden collapse of buildings without warning. To reverse the ugly trend, quality steel bars with a minimum characteristics yield strength of 460N/mm^2 as specified by BS8110 (1997), and adequate ductility with percentage elongation equal or greater than 14%, should always be used in the construction of structures.

5. CONCLUSION

Substantial quantities of the reinforcing steel bars (about 70%) available in the Nigeria building material markets within the south Eastern region are sub-standard. And the use of these sub-standard reinforcing steel bars is one of the major causes of building collapses in South East Nigeria for the construction of safe and stable buildings in Nigeria, strong and ductile reinforcing steel bars with minimum strength of 460N/mm^2, must be used in the construction of buildings. The use of any reinforcing steel bars with tensile strengths σ_y that are less than 460N/mm^2, portends a great danger to the society as buildings constructed with such inferior steel are doomed to collapse. To ensure the safety and stability of building structures, it is recommended that reinforcing steel bars, should be subjected to tensile strength and ductility tests, before being deployed for use in building construction.

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