# FLEXURAL STRENGTH EVALUATION OF CONCRETE BEAMS REINFORCED WITH DIFFERENT REBAR TYPES IN NIGERIA.

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## ABSTRACT

The assessment of size variation of local and imported steel rebars coupled with the experimental study of mechanical properties of steel rebars and the flexural strength test of concrete beams and slabs reinforced with rebars will contribute immensely to the body of knowledge by assessing the limitation of the materials thereby safeguarding the huge public and private investments as well as ensuring safely of lives and properties. The flexural stiffnesses of imported bars for 12 mm and 16 mm were 22.3 kN/mm and 49.9 kN/mm respectively, while the local and TMT imported bars were 11.5% and 7.5% lower. In conclusion, though the imported bars marginally satisfied the ASTM and BS standards in strength except durability, while local bars did not meet the two requirements. Hence, the development of National Building Codes that reflect the actual material characteristics is imperative to avert premature failure.

**Keywords:** Flexural strength, steel rebars, concrete beams, Nigeria.

**No: of Tables: 01** **No: of Figures: 03** **No: of References: 14**

## INTRODUCTION

Structural integrity of reinforced concrete structures is hinged on the reliability of the characteristic strength and ductility parameters of ribbed reinforcing bars in the Nigeria bar market with a view to determining the extent to which they conform to the requirements of various National Standards for Standardization and Characterization (Ede 2010; Erhard 2006; Kayali and Singh 2002). Hence, the degree of compliance or discordance with the design specifications in terms of geometric sizing and tensile strength parameters is a good measure to determine whether or not they contribute to the incidence of building failures in the country (Bellis 2011; Hashemi 2006). Setting a benchmark for the applicability of building material especially the steel reinforcement, investigation on the short-term and long-term behaviour of locally manufactured reinforcement bars are very imperative to safeguard the integrity of existing and new structure (Basu et al. 2004; Kankam and Adom-Asamoh 2002). To eradicate frequent collapse of building that result into unexpected loss of lives and investment as a result of catastrophic structural failure, thorough evaluation of material properties cannot be underemphasized (Kaushik and Singh 2002; Logan 2000). Investigations have shown that building components tend to fail at different rates depending on quality of materials, designs and construction method, environmental conditions and the use of the building. However, substandard materials and design errors were identified as to major causes of component or element failures (Kosmatka et al. 2003; Phillips 1998). The specific causes of failure of building components, aside substandard materials and design errors, revolve round the construction method and the component materials (Maghsoudi and Akbarzadeh 2006, ASTM 2013). The assessment of geometric/size variation of local and imported steel rebars coupled with the experimental study of mechanical properties of steel rebars and the flexural strength test of concrete beams and slabs reinforced with rebars will contribute immensely to the body of knowledge by assessing the limitation of the materials thereby safeguarding the huge public and private investments as well as ensuring safely of lives and properties. In conclusion, though the imported bars marginally satisfied the ASTM and BS standards in strength except durability, while local bars did not meet the two requirements. Hence, the development of National Building Codes that reflect the actual material characteristics is imperative to avert premature failure.

### Methods

The determination of flexural strength which is also called modulus of rupture is essential to estimate the load at which the concrete members may crack. The size of the beam specimen is 150 mm × 150 mm × 750 mm long. A total of eighteen RC beams were studied for flexural behaviour – nine of which were reinforced with 12 mm and the other nine with 16 mm nominal bar sizes. For each case, three beams were reinforced with imported, TMT and local steel rebars to comparatively determine the ultimate load-carrying capacities and assess the flexural rigidities of the beams.

## 3.0 Results and Discussions

### 3.1 Flexural Strength Test Results

The determination of flexural strength which is also called modulus of rupture were conducted in accordance with BS 1881-118 (1983) and the experimental setup is as presented in Figure 1

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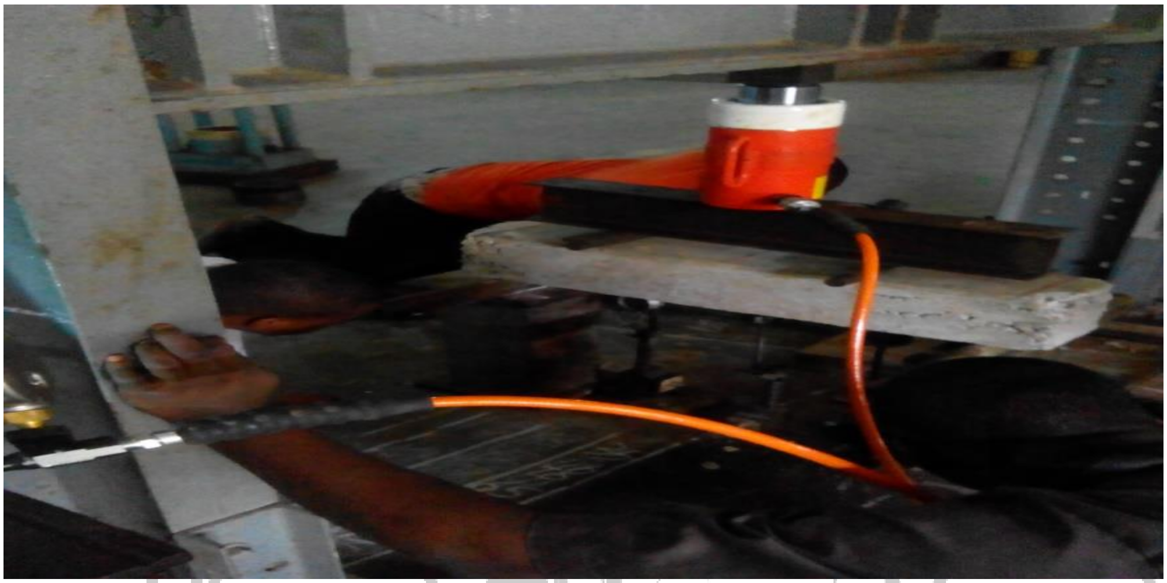

Figure 1. Flexural strength setup for beam under third-point loading

From Figure 1, modulus of rupture is essential to estimate the load at which the concrete members may crack. The size of the beam specimen is 150 mm × 150 mm × 750 mm long. A total of eighteen RC beams were studied for flexural behaviour – nine of which were reinforced with 12 mm and the other nine with 16 mm nominal bar sizes. For each case, three beams were reinforced with imported, TMT and local steel rebars to comparatively determine the ultimate load-carrying capacities and assess the flexural rigidities of the beams. The concrete beams were produced from ordinary Portland cement (OPC),fine aggregate from natural river sand and coarse aggregate from crushed granite of nominal maximum size of about 17 mm. The 28th day compressive strength of concrete gave an average value of 20 N/mm$^2$. The flexural tests were conducted in accordance with BS 1881-118 (1983) and the experimental setup is as presented in Figure 1. The lateral displacement (vertical deflection) was measured using well calibrated dial gauges mounted underside at the third-points and mid-span.

### 3.2 Analysis of Section for Flexural Strength

The flexural strength of any beam specimen of symmetrical section was calculated as

$$f_{cr} = \frac{M_u}{Z} = \frac{6M_u}{bh^2} \quad (1)$$

where the elastic modulus of the section,

$$Z = \frac{bh^2}{6} \quad (2)$$

For a simply supported beam with third point loading, that is $\frac{P}{2}$ applied at the one-third and two-third points of the span.

$$M_u = \frac{PL}{6} \quad (3)$$

$$f_{cr} = \frac{PL}{bh^2} \quad (4)$$

where: $f_{cr}$ is the modulus of rupture (flexural strength); P is the failure load at collapse; $M_U$ means the ultimate moment resulting from the ultimate load; b, h are width and overall depth of the beam section; while L means the distance between knife edges on which the sample is supported and Z is the section modulus.

**Failures modes**

The primary failure modes during flexural strength test are displayed in Table 1.

Table 1. Flexural stress and failure properties of the Lagos steel bars.

| Steel samples | Flexural stress (N/mm$^2$) | | Pull out failure (%) | |
|---|---|---|---|---|
| | Y12 | Y16 | Yield loads | Ultimate load |
| Yaba steel | 11.1 | 15.6 | 45.66 | 65.53 |
| Obalende steel | 11.0 | 15.5 | 45.65 | 65.52 |
| Sura steel | 11.0 | 15.5 | 45.65 | 65.52 |
| Agege steel | 11.1 | 15.6 | 45.66 | 65.53 |
| Ogba steel | 11.2 | 15.7 | 45.67 | 65.54 |

From Table 1, four primary failure modes are common during the flexural strength test. These include tension failure – when the tension reinforcement has yielded before the concrete fails, compression failure - when the tension reinforcement remains unyielded even when the concrete has failed completely by crushing, shear failure – when the concrete fails literally as if no shear reinforcement is provided, and balanced failure - when concrete fails almost simultaneously as the tension reinforcement begins to yield, but all the steel bars fall within pull out failure.

## 3.4 Beam stiffness

The stiffness of beams during flexural strength test are displayed in Figures 2 and 3.

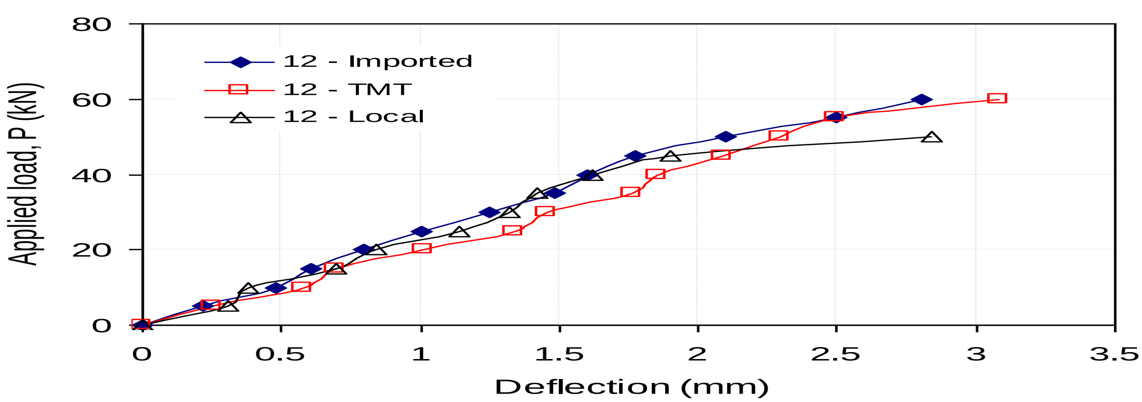


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Figure 2. Flexural strength assessment of square concrete beams reinforced with different bar types of sizes for 12 mm.

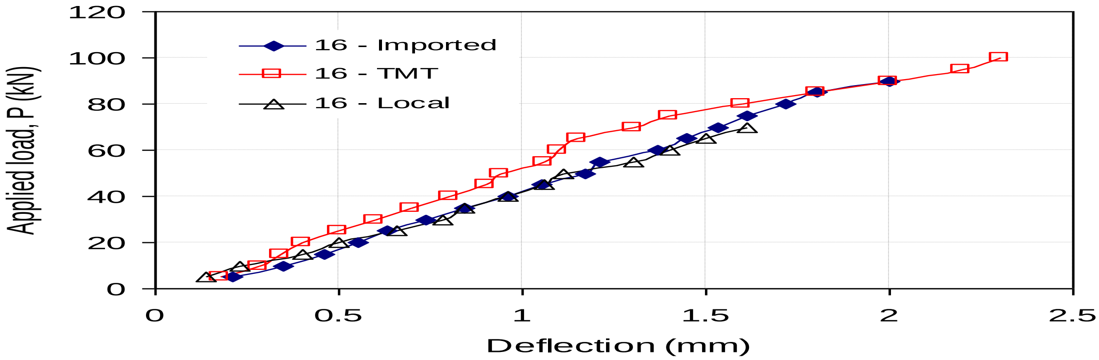


Figure 3. Flexural strength assessment of square concrete beams reinforced with different bar types of sizes for 16 mm.

From Figure 2 & 3, expectedly, the stiffness of the beams reinforced with 16 mm bar size, regardless the steel types, was higher than the 12 mm bar size. The stiffness measured as the slope of the load-deflection curve revealed that beams reinforced with 16 mm bar size were 77%, 140% and 86% higher than those reinforced with 12 mm for the imported, TMT, local respectively. For the 12 mm bar RC beams, the stiffness of the imported was the highest, while TMT and local bars were 14% and 6% lesser. However, the imported and local were comparable for the 16 mm bars, while the TMT was 17% higher. Due to the relatively small span of the beam, the failure modes experienced during testing were essentially compression and shear. Shear, in the sense that, it attained the maximum value at the support. Also, since the span was small and the loading pattern was such that the first and last one-third of the span had the same shear force of one-half the applied load. The compression failure was also evident because the beams completely failed by crushing without yielding of the reinforcing bars. The modulus of rupture or flexural stress measured at the extreme bottom fibre of the RC beams reinforced with imported, TMT and local bars were 13.3 $N/mm^2$, 13.3 $N/mm^2$ and 11.1 $N/mm^2$ for the 12 mm bar size and 20 $N/mm^2$, 22.2 $N/mm^2$ and 15.6 $N/mm^2$ for the 16 mm bar size.

## Conclusion

This paper reveals that the stiffness measured as the slope of the load-deflection curve with beams reinforced with 16 mm bar size were 77%, 140% and 86% are higher than those reinforced with 12 mm for the imported, TMT, local respectively. For the 12 mm bar RC beams, the stiffness of the imported was the highest, while TMT and local bars were 14% and 6% lesser. However, the imported and local were comparable for the 16 mm bars, while the TMT was 17% higher. The modulus of rupture or flexural stress measured at the extreme bottom fibre of the RC beams reinforced with imported, TMT and local bars were 13.3 N/mm$^2$, 13.3 N/mm$^2$ and 11.1 N/mm$^2$ for the 12 mm bar size and 20 N/mm$^2$, 22.2 N/mm$^2$ and 15.6 N/mm$^2$ for the 16 mm bar size. The flexural stiffness's of imported bars for 12 mm and 16 mm were 22.3 kN/mm and 49.9 kN/mm respectively, while the local and TMT imported bars were 11.5% and 7.5% lower. In conclusion, though the imported bars marginally satisfied the ASTM and BS standards in strength except durability, while local bars did not meet the two requirements.

**REFERENCES**

**Anthony Nkem Ede**. (2010), Building Collapse in Nigeria, International Journal for Civil and Environmental Vol. 10 No. 0632.

ASTM A706/A706M, Standard Specification for Low-Alloy Steel Deformed and Plain Bars for Concrete Reinforcement (2013).

**Basu, P. C., Shylamoni P. and Roshan A. D.** (2004) Characterisation of steel reinforcement for RC structures: An overview and related issues. Indian Concrete Journal. 78(1): 19-30.

**Bellis M.** (2011).The History of Concrete and Cement and Concrete Research, 15(6):21-30.

**Chahrour, A. and Soudki, K.**, (2005). Flexural response of reinforce concrete beams strengthened with end –anchored partially bonded carbon fiber-reinforced polymer strips ,Journal of Composites for Construction. **9**(2):170-177.

**Erhard G**. (2006) Designing with Plastics. African Journal of Science and Technology (AJST). 7(3):73-78.

**Hashemi, S.H.** (2006). Analytical and experimental study of HSC members strengthened with CFRP. PhD Thesis, Kerman University, Kerman, Iran.

**Kankam, C. K. and Adom-Asamoah, M.** (2002) Strength and ductility characteristics of reinforcing steel bars milled from scrap metals. *Materials and Design*. **23**: 537–545.

**Kaushik, S.K. and Singh, B**. (2002) Influence of steel-making processes on the quality of reinforcement, *The Indian Concrete Journal*, 76(7): 407-412.

**Kayali O. and Zhu B**. (2005). Chloride induced reinforcement corrosion in lightweight aggregate High-strength fly ash concrete. *Construction and Building Materials*. 19,327-336

**Kosmatka, S. H., Kerkhoff, B. and Panarese, W. C.** (2003) Design and Control of Concrete Mixtures, 14th Edition. Portland Cement Association, Skokie, Illinois, USA.

**Logan, M. B.** (2000) Concrete Strength Study. http://www.oas.ucok.edu/ojas/99/papers/logan..html

**Maghsoudi,A. A. and Akbarzadeh, H.** (2006). Flexural ductility of HSC members. Structural Engineering and Mechanics. 24(2):195-213.

**Philips, E. O.** (1998). Steel for General Structural Purposes"paper presented at the National Seminar on Structural Codes of Practice by the Nigerian Society of Engineers (Structural Engineering Division): August.