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MECHANICAL AND MORPHOLOGICAL CHARACTERISTICS OF BOTH TREATED AND UNTREATED SUGARCANE BAGASSE FOR CONCRETE PRODUCTION

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Abstract: The study investigates the effects of incorporating treated and untreated sugarcane bagasse on the properties of normal concrete. Sugarcane bagasse, a by–product of the sugar industry, is explored as a potentially sustainable and cost–effective material in concrete production. The study involves alkaline treatment of bagasse with sodium hydroxide (NaOH) to enhance its properties. Workability, compressive strength, and flexural strength tests were carried out to determine the performances of the untreated and treated sugarcane bagasse concrete samples containing 0%, 0.5%, 1.0%, and 1.5% of bagasse by weight of cement. The mix ratio of 1:1½:3 and water–cement ratio of 0.45 were employed at curing days of 7, 14, and 28 days for the compressive strength and 28, 56, and 90 days for the flexural strength. The test results revealed that the incorporation of sugarcane bagasse in concrete reduces the compressive and flexural strength of normal concrete to 30% for treated and 35% for untreated when compared with the control sample. Furthermore, sugarcane bagasse concrete's compressive strength and flexural strength decline with an increase in the weight of Sugarcane bagasse in the mix. Concrete containing 0.5% treated sugarcane bagasse gave the highest compressive and flexural strength compared to the control specimen. The results indicated that sugarcane bagasse is a good filler in concrete and can be employed for use in lightweight concrete.
Keywords: Compressive strength, Concrete, Flexural strength, Scanning electron microscopy, Sugarcane bagasse

1. INTRODUCTION

Concrete is a fundamental material in the construction industry, prized for its versatility, durability, and relative cost–effectiveness. A major ingredient in the production of concrete is cement and its production involves high energy consumption and significant CO_2 emissions, prompting the search for sustainable alternatives (Abiodun *et al.,* 2023).

Sugarcane bagasse is the fibrous residue remaining after sugarcane stalks are crushed to extract their juice. With an annual production of millions of tons worldwide, it represents a significant waste management challenge (Farooq and Jamil, 2020). It is a byproduct of the sugar industry, with millions of tons produced annually worldwide, particularly in countries like Brazil, India, and Thailand (Cordeiro *et al.,* 2009). Traditionally, bagasse has been used as a fuel for cogeneration in sugar mills or as a raw material for the paper and pulp industry (Onwuka and Ayodele, 2020). However, these uses do not fully exploit the potential of bagasse, especially given the vast quantities produced (Basheer and Ali, 2016). Sugarcane Bagasse is an agricultural byproduct of sugarcane processing, rich in cellulose, hemicelluloses, and lignin (Balogun and Adeniyi, 2020).

Previous research highlights bagasse's potential to improve concrete properties due to its lignocellulosic composition. However, untreated bagasse often weakens concrete due to impurities and irregular morphology. Treatment methods such as chemical processing can improve its performance by removing lignin, hemicellulose, and other extractives (Rezende *et al.,* 2011). Kurama and Topcu (2004) investigated the thermal treatment of sugarcane bagasse fibers (SCBF), It showed a reduction in water absorption by 35% compared to untreated fibers and the compressive strength of concrete containing treated SCBF increased by 20%, demonstrating enhanced fiber–matrix bonding due to thermal treatment. Parveen and Rana (2013) compared the mechanical properties of concrete with treated and untreated sugarcane bagasse fibers (SCBF). Compressive strength increased from 21 N/mm^2 (untreated) to 26N/mm^2 (treated) and flexural strength rose from 4.3 N/mm^2 (untreated) to 5.5 N/mm^2 (treated). Thomas *et al.* (2008) focused on the flexural strength of lightweight concrete reinforced with treated sugarcane bagasse fibers (SCBF). The

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flexural strength of concrete reinforced with treated SCBF reached 6.2 N/mm^2 compared to 4.8 N/mm^2 for concrete with untreated fibers, indicating a 29% improvement in strength due to the treatment.

Disposing of sugarcane bagasse poses environmental concerns. Utilizing it in concrete as an alternative material can promote sustainability. This study has shown that the incorporation of sugarcane bagasse, whether treated or untreated has the potential to enhance the mechanical properties of concrete and reduce environmental impact; contributing to waste management and resource optimization.

2. MATERIALS AND METHODS

Materials

- Cement: Ordinary Portland Cement (OPC): Ordinary Portland cement from Lafarge whose production was according to BS12:1996.
- Fine Aggregates: Ogun River sand (natural sand) was used, with particle sizes ranging from 0.075 mm to 1.8 mm. The fine aggregate was clean and free from clay. The physical properties of the fine aggregate like aggregate size, grading, and surface texture were carried out according to BS 882:1992.
- Coarse Aggregates: Crushed granite ranging from 20mm down to 12.5mm aggregate sizes were used as specified by BS882:1992.
- Sugarcane Bagasse: As shown in Figure 1, the Sugarcane Bagasse collection sites were "Idi–Oro" and "Abbatoir" sites in Lagos State, Nigeria. The average length of sugarcane bagasse fibers used in this study was 5 mm.

Figure 1. Sugarcane bagasse dumpsite

Methodology

Chemical Treatment of Sugarcane Bagasse

The Sugarcane Bagasse was collected, soaked inside Sodium Hydroxide for 3 days, and sun–dried for 7 days in other to remove the moisture and other trace components from it. The concentration of sodium hydroxide used was 3% (w/v); 3 grams of NaOH per 100 milliliters of water.

High–performance liquid chromatography (HPLC) on Treated and Untreated Sugarcane Bagasse

HPLC is an analytical technique used to identify the components in a mixture and separate mixtures of similar compounds. This was used to analyse the composition of both the untreated and treated sugarcane bagasse used in the study. Samples for the test were milled and then mixed with chemical reagents. Each sugarcane bagasse sample was distributed between mobile and stationary phases. The specific inter–molecular interactions between the molecules of the samples and the packing material define their time 'on–column'. A UV detector recognizes the analytes after leaving the column and the signals are converted and recorded by a data management system (computer software) and then shown in a chromatogram. The test was carried out at the All School Laboratory, Ota, Ogun State, Nigeria.

Experimental Program

Sugarcane bagasse, both treated and untreated was added to concrete mixes at 0.0%, 0.5%, 1.0%, 1.5% of the weight of cement separately. The constituents were measured based on the mix ratio of 1:1½:3 and water–cement ratio of 0.45. Workability (Slump Test) which evaluated the consistency and workability of the concrete mix was carried out in accordance with BS 12395–2 (2009) as shown in Figure 2. The concrete was then tested for compressive strength at 7 days, 14 days and 28 days

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using 150 x 150 x 150 mm moulds in accordance with BS 12390–3 (2019) as shown in Figure 3. For Flexural strength test, beams of size 150 x 150 x 750 mm was used and tested at 28 days, 56 days and 90 days in accordance with BS 12390–5 (2019) as shown in Figure 4.

Figure 2. Workability test Figure 3. Compressive strenght Figure 4. Flexural strengh setup

— Scanning Electron Microscopy of Treated and Untreated sugarcane Bagasse Concrete

Scanning electron microscopy test (SEM) was also carried out to examine the morphology of the selected samples of treated and untreated sugarcane Bagasse Concrete. This investigation was carried out at All school labs, in Ota, Ogun State. By using a concentrated electron beam to scan a sample's surface, a scanning electron microscope (SEM) creates images of the material. The sample's atoms and electrons interact to produce a variety of signals that reveal details about the sample's composition and surface topography. An image is created by combining the position of the electron beam and the strength of the detected signal after it is scanned in a raster scan pattern. A secondary electron detector detects secondary electrons released by atoms stimulated by the electron beam in the most popular SEM mode.

3. RESULTS AND DISCUSSION

Chemical composition of untreated and treated bagasse using alkaline Pretreatment

The chemical composition of untreated and treated bagasse subjected to alkaline pretreatment (NaOH) is presented in Table 1. Percentages of cellulose, hemicellulose, lignin and other trace compounds were calculated on a dry weight basis.

Table 1. Chemical composition of untreated and treated sugarcane bagasse

Bagasse Composition (%)	Untreated	Treated
Cellulose	35.2	84.7
Hemicellulose	24.5	3.3
Lignin	21.0	9.5
Trace Compound	19.3	2.5

Values for cellulose included glucose, cellobiose and hydroxymethylfurfural amounts quantified by High–performance liquid chromatography (HPLC). Hemicellulose comprised xylose, arabinose, furfural, glucuronic and acetic acids, while the total lignin amount was calculated by adding up the concentrations of soluble and insoluble lignins (Garcia and Remirez, 2020). Untreated bagasse has 35.2% cellulose and similar amounts of hemicellulose (24.5%) and lignin (21.0%), as shown in Table 1. The cellulose amount increased continuously after alkaline pretreatment, ranging from an initial 35.2% content to 84.7 % under pretreatments using NaOH (3% w/v). Most of the hemicellulose fraction was removed using NaOH, as shown by its percentage decrease from 24.5% to 3.3%. Finally, the lignin relative percentage in the sample decreased progressively with pretreatments using NaOH concentration. This result was similar to what was reported by Fan *et al.* (2012).

Workability (Slump) test

As presented in Figure 5, the slump value decreases as the percentage of untreated sugarcane bagasse increases. This indicates that adding untreated bagasse fibers reduces the workability of the concrete. The control mix (0%) had the highest slump value of 50 mm, while the mix with 1.5% bagasse had the lowest slump value of 35 mm. In the treated bagasse concrete, the slump values were slightly higher than those of the untreated samples. This suggests that the treatment process improves the workability of the concrete. The highest slump value was 50 mm (0%), and the lowest was 38 mm (1.5%). Both treated and untreated sugarcane bagasse fibers reduce the slump as their percentage increases, with untreated fibers having a more significant effect on reducing workability while treated bagasse fibers result in higher slump values indicating better workability.

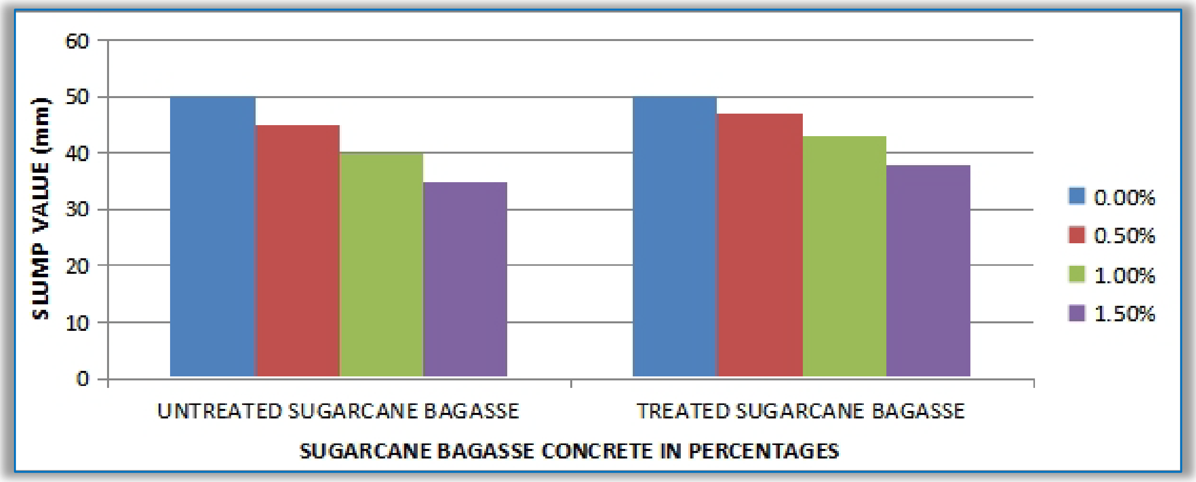

Figure 5. Effect of Treated and Untreated Sugarcane Bagasse on Workability of Concrete

Compressive Strength of Sugarcane Bagasse Concrete

Figure 6 shows that the compressive strength of concrete at 7, 14 and 28days curing days. Control sample containing 0% sugarcane bagasse at 7, 14 and 28 days obtained 19.58 N/mm^2, 22.74 N/mm^2 and 25.65 N/mm^2 respectively.

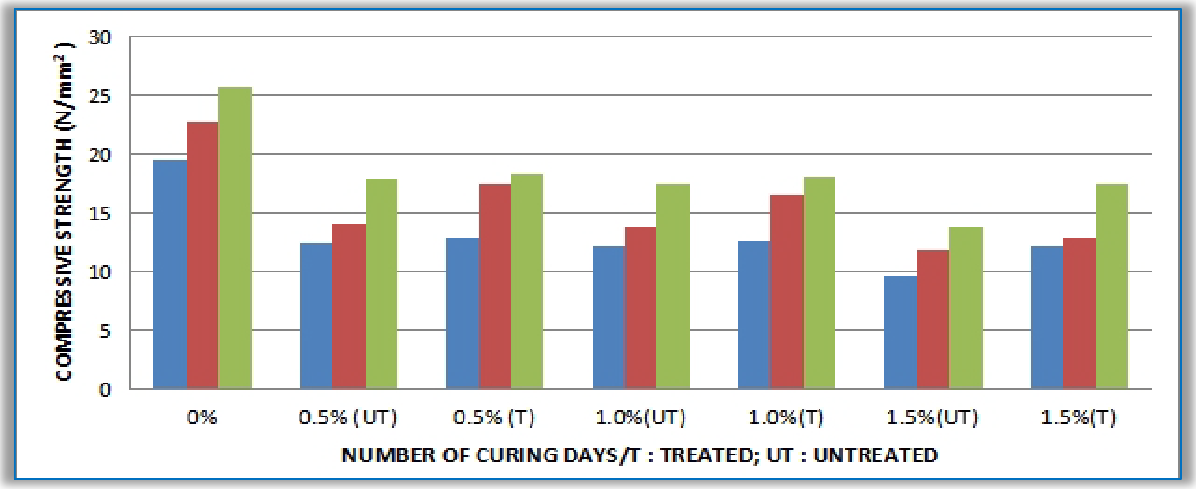

Figure 6. Effect of Treated and Untreated Sugarcane Bagasse on Compressive Strength of Concrete

At 1.5% untreated sugarcane bagasse concrete for 7, 14 and 28 days of curing, compressive strength obtained 9.70 N/mm^2, 11.81 N/mm^2 and 13.85 N/mm^2 respectively while for treated sugarcane bagasse concrete at the same percentage and curing days, the compressive strength obtained 12.19 N/mm^2, 12.96 N/mm^2 and 17.41 N/mm^2 respectively. The result shows that; there was a decline in strength with an increase in the percentages of sugarcane bagasse; the lower the percentage of Sugarcane bagasse (either treated or untreated) into concrete, the higher the compressive strength. 0.5% Sugarcane bagasse concrete obtained higher result, followed by 1.0%, while 1.5% Sugarcane bagasse obtained the lowest strength. Also, treated sugarcane bagasse concrete obtained a higher result compared to untreated sugarcane bagasse concrete. This might occur due to a better compatibility of treated sugarcane bagasse with the concrete matrix, leading to better bonding, more consistent hydration, and fewer weak points in the concrete, all of which contribute to higher overall strength compared to concrete made with untreated bagasse. Furthermore, treated sugarcane might have a lower water absorption capacity which may reduce the porosity of the bagasse or coat it with substances that make it less hydrophilic compared to untreated bagasse. The results obtained were similar to Abdel–Halim and Ibrahim (2016) as 0.5% of sugarcane bagasse obtained the highest value of compressive strength of 6.50 N/mm^2. Meanwhile, the value of compressive strength for samples containing 1.0% and 1.5% recorded slightly decline value compared to sample control and 0.5 % which were 4.31 N/mm^2 and 1.54 N/mm^2 after curing for 7 days.

Flexural Strength of Sugarcane Bagasse Concrete Beams

Figure 7 below shows that the flexural strength of concrete at 28, 56 and 90days curing days. Control sample containing 0% sugarcane bagasse at 28, 56 and 90 days obtained 14.44 N/mm^2, 16.30 N/mm^2 and 17.40 N/mm^2 respectively.

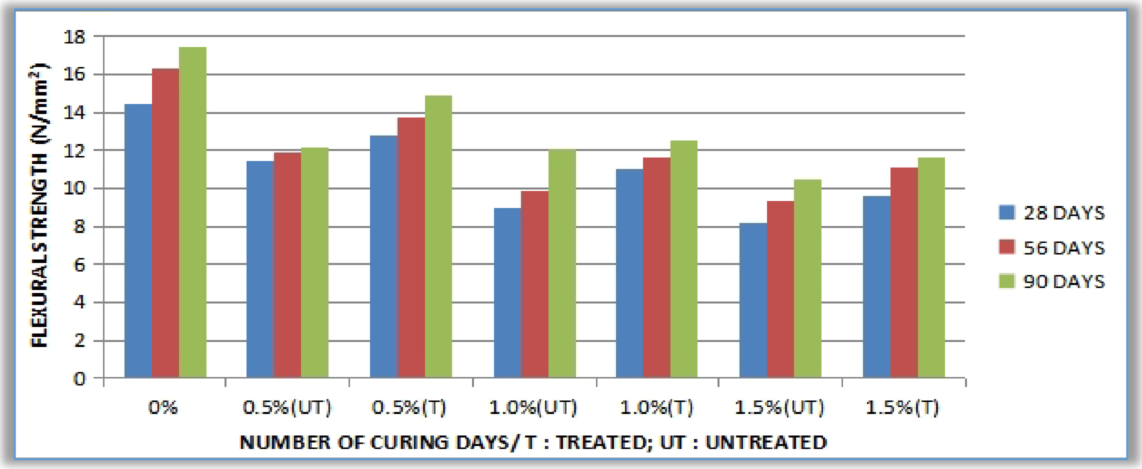

Figure 7. Effect of Treated and Untreated Sugarcane Bagasse on Flexural Strength of Concrete

At 1.5% untreated sugarcane bagasse concrete for 28, 56 and 90 days of curing, compressive strength obtained 8.22 N/mm^2, 9.33 N/mm^2 and 10.44 N/mm^2 respectively. While for treated sugarcane bagasse concrete at the same percentage and curing days, the compressive strength obtained 9.56 N/mm^2, 11.11 N/mm^2 and 11.60 N/mm^2 respectively. The result showed a decline in strength with an increase in the percentages of sugarcane bagasse; the lower the percentage of Sugarcane bagasse (either treated or untreated) into concrete, the higher the compressive and flexural strength. Treated sugarcane bagasse concrete obtained a higher result compared to untreated sugarcane bagasse concrete. This might occur due to a better compatibility of treated sugarcane bagasse with the concrete matrix, leading to better bonding, more consistent hydration, and fewer weak points in the concrete (Abbas and Mustapha, 2021), all of which contribute to higher overall strength compared to concrete made with untreated bagasse. Furthermore, treated sugarcane might have a lower water absorption capacity which may reduce the porosity of the bagasse or coat it with substances that make it less hydrophilic compared to untreated bagasse. The result obtained in this study was similar to the report of Jain and Soni (2021).

Scanning Electron Microscopy (SEM) Analysis of both Treated and untreated Sugarcane and Sugarcane Bagasse.

The SEM of the untreated and treated sugarcane bagasse (fibre) is presented in Figure 8.The presence of dirt, and other foreign elements in untreated sugarcane bagasse frequently has an inhibiting influence on the hydrating temperatures of Portland cement as reported by Bilba *et al.* (2003). SEM micrographs shows that the NaOH pretreatment removed the unwanted compounds. Remains on the surface and in the pores of the untreated sugarcane bagasse fibers can be seen in Figure 8a. These residues are absent from the treated sugarcane bagasse fibers in Figure 8b. For the untreated and treated sugarcane bagasse concrete cured for 28 days, the SEM is presented in Figure 9. For the untreated sugarcane bagasse concrete, the overall microstructure reveals a rough and porous surface.

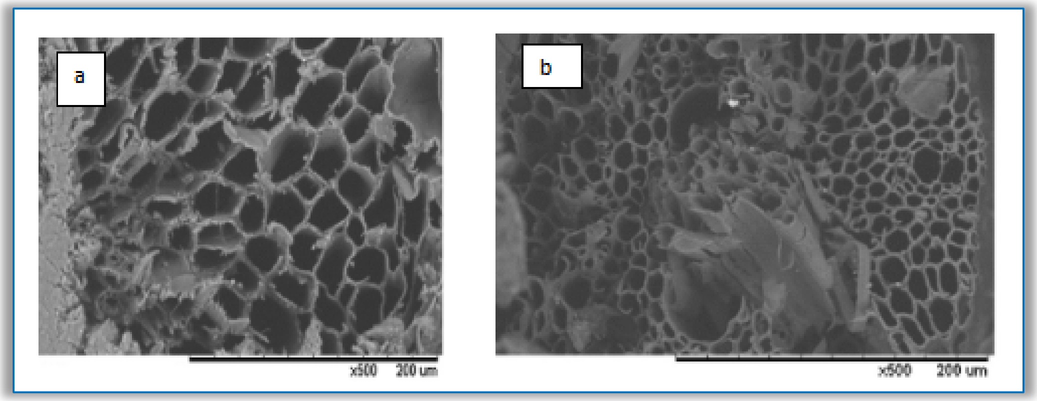

Figure 8. SEM of sugarcane bagasse (a) Untreated fibers (b) Treated fibers

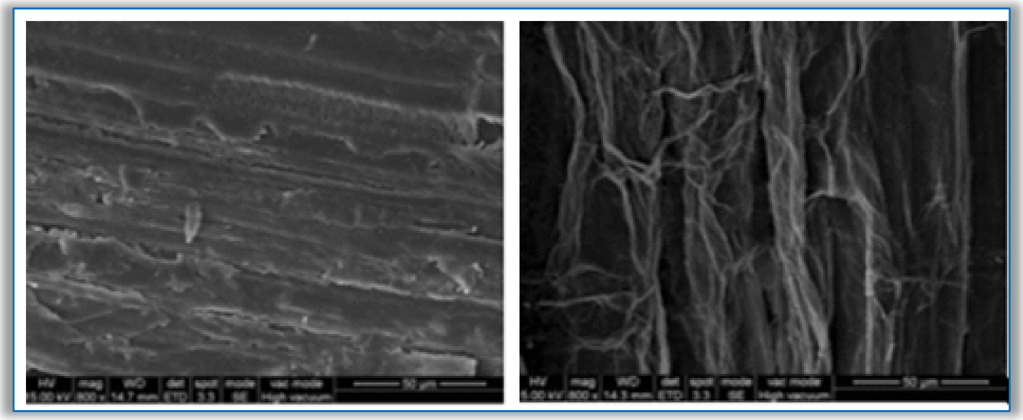

Figure 9. SEM of sugarcane bagasse concrete (a) Untreated concrete (b) Treated concrete

The surface shows visible irregularities, likely due to the presence of non–cellulosic materials like hemicellulose and lignin. The fiber–matrix interface appears weak contributing to poor bonding between the fibers and the surrounding matrix. However, for the treated sugarcane bagasse concrete, the overall structure appears more compact and uniform. The concrete shows improved bonding, with fewer voids between the fibers and the matrix. The removal of non–cellulosic materials (lignin, hemicellulose) enhances the adhesion between the fibers and the surrounding matrix. The results of the SEM for both the fibers (untreated and treated) and the sugarcane bagasse concrete (untreated and treated) samples agreed with the report of Rodrigues *et al*. (2010) and Patel and Desai (2016).

4. CONCLUSION

From the results of the study on comparative study between Treated and untreated Sugarcane Bagasse on the strength of normal concrete, the following conclusions were made:

- Slump test results indicated that the addition of treated sugarcane bagasse at 0%, 0.5%, 1.0%, 1.5% of the weight of cement obtained 50mm, 47mm, 43mm, 38mm which improved the workability of concrete compared to un–treated sugarcane bagasse which obtained 45mm, 40mm, 35mm respectively.
- The compressive and flexural strength of sugarcane bagasse concrete declines with an increase in the volume of Sugarcane bagasse. Incorporation of Sugarcane bagasse reduces the compressive strength of normal concrete to 30% (19.58–12.86 N/mm^2 at 7 days and 25.65–18.75 N/mm^{2}at 28 days for 0–0.5% treated sugarcane bagasse) and 35% (19.58– 12.50 N/mm^{2}at 7 days and 25.65–17.85 N/mm^{2}at 28 days for 0–0.5% untreated Sugarcane bagasse when compared with the Control Specimen at 7 days and 28 days of curing.
- Incorporation of Sugarcane bagasse reduced the flexural strength of normal concrete to 30% (14.44 N/mm^2 – 12.73 N/mm^2 at 28 days and 17.40–14.92 N/mm^2 at 90 days for 0% – 0.5% treated sugarcane bagasse) and 35% (14.44–11.41 N/mm^2 at 28 days and 17.40 –12.17 N/mm^2

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at 90 days for 0–0.5% untreated Sugarcane bagasse when compared with the Control Specimen at 28 and 90 days of curing.

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