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Eco-concrete: Utilizing Cotton Textile Waste Strips and Broken Bottles as Partial Replacement of Fine Aggregates and Coarse Aggregates in Concrete Production

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Abstract - This study utilized cotton textile waste strips and broken glass as partial replacement for fine aggregates and coarse aggregates for development of eco-concretes. Through mixing, casting, and curing, three mixtures of eco-concretes and commercially produced concretes were produced. Areal density, bulk density, density, and compressive strength were tested for the three mixtures and the control group. Based on the findings, all mixtures showed successful results in compressive strength test with Mixture 3 achieving the highest average compressive strength (2.1 MPa). Among the mixtures, F- test of Independent Means showed no significant difference in the mean compressive strength among concrete mixes containing varying proportions of cotton waste textile strips and broken glass, and commercially produced concrete. This implied that the concrete with cotton textile waste strips and broken bottles can be a good substitute for commercial concrete and can also enhance more strength to the concrete made. To help improve compressive strength, use different drying days of curing days for concrete production

Keywords - eco-concrete, areal density, bulk density, compressive strength.

INTRODUCTION

There is a rapid issue pertaining to the consumption of textiles and the amount of waste derived from it. Currently, the trend in fast fashion is rising and it stimulates people to buy more apparel and dispose of it in a shorter timeframe. As a result, there is a huge demand in clothing and leads a high-volume of waste textile disposal. In landfills, textiles can take years to decompose or burned. This results to release of toxic greenhouse gases which accelerates climate change and environmental degradation. If this trend persists, it could inflict irreversible harm on nature and the planet.

In many countries, the problem of textile waste is growing vastly. Each year, around 100 billion pieces are produced, and approximately 92 million tonnes end up in landfills (Igini, 2024). In China, the largest textile producer and consumer, where above 26 million tonnes of clothes are thrown away annually (Associated Press, 2024). In the United States, around 11.3 million tonnes of textile waste, which is a total of 85% of all textiles, are sent to landfills on an annual basis. Over 37 kilograms per person per year and around 2,150 garments of clothing discarded every second across the country (Igini, 2024b). In addition, India, around 7.8 million tonnes (7,793 kilotons), or 8.5% of the world's textile waste, is accumulated annually. Of this, 41% is either downcycled (19%), burned (5%), or ends up in a landfill (17%) (Fashion for Good, n.d.). These concerning figures emphasize the demand need for sustainable solutions, improved recycling systems, and mindful consumer behavior.

In the Philippines, textile waste from manufacturing and post-production processes continues to accumulate, causing both environmental degradation and resource depletion. Over 267,111 tons of textile waste are disposed of in landfills annually (Business World, 2024). A leading local clothing brand generates about 16 tons of textile waste each year (Realino, 2025). Examining the local market, around 29% of Filipinos have thrown away their clothes after a single use, while the consumption of new clothing has significantly increased (Scale 360 PH, 2023). This demonstrates that even medium-scale businesses significantly contribute to the problem. Due to the lack of an efficient recovery and recycling system, much of this waste remains unused, piling up in landfills and informal dumpsites.

In Davao City, discarded textiles are a growing problem faced by all Dabawenyos, exacerbated by a culture of fast fashion and consumption, limited enforcement of waste segregation, and a landfill that is operating at full capacity. Currently, the city's government currently collects 700 to 800 tons of unsegregated trash per day (Alama, 2025). Furthermore, in Zamboanga City, each resident generates an average of 0.45 kilograms of textile waste daily. A waste audit by the Office of the City Environmental and Natural Resources (OCENR) indicates that approximately forty-two percent of this waste is biodegradable, including textiles, yard waste, and food scraps (Local Sustainable Plan Team, 2021). This increasing volume of textile waste poses significant environmental and waste management challenges.

Broken bottles have become a growing concern in many communities worldwide due to it can easily shattered into sharp fragments that persists in the environment for centuries due to glass is non-biodegradable nature and it takes thousands of years to decomposing and have been dumped into landfill sites. About 130 million tons of glass are produced around the world every year, and around five million tons of glass are used in the UK annually (Business Waste, 2025).

While numerous studies have investigated the use of individual waste materials, such as cotton textile waste strips and broken glass, in sustainable construction. However, limited study has examined their combined application in producing of eco-friendly concrete. This study aims to fill this significant gap by combining both cotton textile waste and broken bottles as composite materials in production of eco-concrete. This study seeks to determine the most effective proportion of cotton textile waste and broken bottles in concrete mix and assess whether this combination can not only reduce waste from landfills but also produce a stronger, more durable, and thermally efficient construction material, contributing to environmental sustainability.

Statement of the Problem

This study aimed to investigate the compressive strength of cotton textile waste strips and broken bottles as partial replacement material for concrete production. Specifically, this research wanted to determine the following;

- What is the areal density of cotton textile waste strips (g/cm2)?
- What is the density of broken bottles (g/mL)?
- What is the bulk density of the materials used in concrete mixture, specifically:

Cement (kg/m³);
Fine Aggregate (kg/m³);
Coarse Aggregate (kg/m³); and

What is the compressive strength of the concrete, considering the following concentrations:

- Cement (10.7%), Sand (29.8%), Gravel (59.5%), Cotton Waste Textile
- Strips (0%), and Broken Bottles (0%);
- Cement (10.7%), Sand (28.8%), Gravel (49.5%), Cotton Waste Textile
- Strips (1.0%), and Broken Bottles (10%);
- Cement (10.7%), Sand (27.3%), Gravel (39.5%), Cotton Waste Textile Strips (2.5%), and Broken Bottles (20%); and
- Cement (10.7%), Sand (27.1%), Gravel (29.5%), Cotton Waste Textile

Strips (2.7%), and Broken Bottles (30%)?

Is there a significant difference in the mean compressive strength among concrete mixes containing varying proportions of cotton waste textile strips and broken glass, and commercially produced concrete?

Research Hypothesis

This study will be tested at 0.05 level of significance.
There is no significant difference in the mean compressive strength among concrete mixes containing varying proportions of cotton waste textile strips and broken glass, and commercially produced concrete.

Significance of the Study

This study investigated the potential of utilizing textile waste, specifically cotton textile waste and broken bottles, as partial replacement materials in the production of eco-concrete. This study aligned with Sustainable Development Goals 11: Sustainable Cities and Communities and Sustainable Development

Goals 12: Responsible Consumption and Production, as it promoted waste reduction, material reuse, and encourages sustainable innovation in construction. By repurposing textile waste that would otherwise have ended up in landfills or incinerators, the study contributed to the development of circular economy solutions that reduced environmental impact. The study is important to the following:

Environment Management Bureau. This study can benefit Environment Management Bureau by it presents a sustainable approach to managing two major waste streams, cotton waste textiles and broken bottle aggregates. The study may serve as a foundation for creating technical guidelines or policy recommendations that encourage the use of alternative, low-impact materials in infrastructure development.

Government and Policy Makers. This study can benefit Government and Policy Makers by providing a practical and research-based solution to pressing environmental concerns: post-consumer textile. Policy makers can use the findings to craft or update legislation that encourages waste diversion, material reuse, and green building practices.

Consumers. This study can benefit consumers by promoting awareness and participation in sustainable practices by demonstrating how everyday waste, such as old clothes and broken glass, can be repurposed into useful construction materials. Additionally, the development of affordable, eco-friendly concrete made from waste may eventually lead to lower-cost and greener housing option, benefiting communities in need of sustainable infrastructure.

Future Researcher. This study can benefit Future Researchers by exploring the combination of cotton waste textile and broken glass in eco-concrete production, a topic with minimal prior investigation, it opens up new possibilities for further experimentation and refinement. Future researchers can build upon this study by testing different binder types, adjusting material ratios, or exploring other agricultural and textile waste combinations.

Scope and Delimitation of the Study

This research focused on the development of an eco-concrete made from a combination of cotton textile waste strips and broken bottle aggregates. It aimed to investigate the production and determine the optimal concentration of cotton waste strips and broken bottles needed to enhance the strength of concrete. The researcher seeks to evaluate the potential of these materials as an eco-friendly alternative to conventional concrete.

This study is limited to laboratory testing and does not involve real- application, such as the construction of actual buildings. Factors such as large- scale production, long-term durability under real construction conditions, and the performance of concrete in varying climate environments will not be covered in this study. Therefore, further studies will be necessary to assess the full environmental impact of this eco-concrete, including their long-term durability, potential chemical emissions, and decomposition rate under real-world construction and weathering conditions.

Definition of the Terms

The following terms were operationally defined:

Eco-concrete: It is a sustainable alternative to conventional concrete that uses recycled and industrial by-products instead of or in addition to traditional **Portland cement.**

Cotton Textile Waste Strips. It serves as the material use to address this issue by being repurposed in the creation of eco-concrete.

Broken Bottle. A type of glass that has been shattered and is no longer useful in its original form. However, it can be repurposed as material for creating eco-concrete.

Weighing Scale. An equipment used to measure the weight or mass of the material.

Analytical Balance. A laboratory equipment used to measure the mass of small objects with high precisions because it is enclosed in a glass case to prevent air currents, dust, and temperature fluctuations.

Graduated Cylinder. A laboratory equipment used to obtain the density of broken bottles.

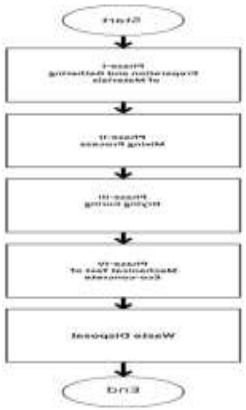
Straight Edge. An equipment used to level the surface of the concrete after it has been placed in the mold.

Mold. An equipment used to shape and hold the fresh concrete mixture until it hardens.

Tamping Rods. An equipment used to compact material inside molds.

Method

This section presents the methods used in this study, which consists of four (4) phases: Phase I – Gathering and Preparation of Materials; Phase II – Mixing Process; Phase III – Drying and Curing; Phase IV: Mechanical Test of Eco-friendly Concrete. All experimental procedures were conducted at Carlos P. Garcia Senior High School, while the mechanical testing was conducted at Terms Concrete and Materials Testing Laboratory Inc.



High School, while the mechanical testing was conducted at Terms Concrete and Materials Testing Laboratory Inc.

Research Design

An experimental-quantitative research methodology was used in this study to collect data and information. According to Knight (2010) as cited in Sirisilla (2023), researchers can more easily and effectively carry out their research aims when they use an experimental research design. An appropriate experimental design acts as a roadmap for the research techniques, giving readers a better understanding of the data collection process and, as a result, allowing an exact description of the findings. Specifically, this study utilized the true experimental design approach to identifying the optimal concentration of cotton textile waste strips and broken bottle aggregates as partial replacement materials needed to enhance the strength of concrete. This research aims to encourage and promote the recycling of waste, as well as reducing waste. Additionally, the research study highlights the potential for alternative, low-cost building materials that support sustainable practices.

Phase I. Gathering and Preparing of Materials

In this study, a total of 12 concrete specimens were developed. The materials were Portland pozzolanic cement, cotton textile waste, broken bottles, water, fine Aggregates (sand), and coarse aggregate (gravel). These concrete specimens were divided into four groups. Table 1 presents the percentage composition of each concrete specimen. The cotton waste textile was manually cut into strips of approximately equal lengths, measuring 2cm x 5cm. The cotton waste textile strips and broken bottles were washed to eliminate or remove impurities.

Table 1. Percentage Composition of Concrete Mix

Mixture ID	Control	Mixture 1	Mixture 2	Mixture 3
Cement	10.7 %	10.7%	10.7%	10.7%
Coarse Aggregate (Gravel)	59.5 %	49.5%	39.5%	29.5%
Fine Aggregate (Sand)	29.8 %	28.8%	27.3%	27.1%
Cotton Textile Waste	0.0%	1.0%	2.5%	2.7%
Broken Bottle	0.0%	10.0%	20.0%	30.0%
Total	100%	100%	100%	100%

Phase II. Mixing Process

This study adapted the procedures that were utilized based on the study of Oan and Alrefaei (2022) entitled “Using Glass Wastes as Partial Replacement of Coarse Aggregates in Concrete.” These were the following procedures:

Measured in grams (g) each material used in the development of the concretes with different concentrations. The Table 2 shown below presents the composition of concrete mix in grams (g).

Table 2. Composition of Concrete Mix in Grams (g)

Mixture ID	Control (g)	Mixture 1 (g)	Mixture 2 (g)	Mixture 3 (g)
Cement	1070	1070	1070	1070
Coarse Aggregates (gravel)	5970.0	5373.0	4776.0	4179.0
Fine Aggregates (Sand)	2990.0	2960.1	2915.2	2909.3
Cotton Textile Waste	0	29.9	74.8	80.7
Broken Bottle	0	597.0	1194.0	1791.0
Total	10030	10030	10030	10030

- Conducted five trials to obtain the areal density of each cotton textile waste strip. The area of each cotton textile waste strip was measured.
- Conducted five trials to obtain the density of each sample of broken bottles. The mass in grams (g) of each sample of broken bottle was measured. Then, the volume of each sample of broken bottle was measured through water displacement method.
- Conducted five trials for each material to obtain the bulk density of cement, coarse aggregate (gravel), fine aggregate (sand), and broken bottles. The researcher began by taking an empty cube mold with dimensions of 15 cm x 15 cm x 15 cm and measure its weight. The cube mold was the filled about one-third full with thoroughly mixed material and compacted with 25 strokes using the rounded end of tamping rod. The second layer of the material, using similar quantity, was added and again given 25 strokes. The material shall be filled to overflowing and gave 25 strokes, the surplus quantity is stuck off using the straight edge. The cube mold was measured filled with compacted material. Finally, the filled mold was then weight, and the weight of the empty mold was

- then subtracted from this value to determine the bulk density of the compacted material.
- Thoroughly mixed the cement, fine aggregate (sand), coarse aggregate (gravel), cotton textile waste strips, and broken bottles for one (1) minute. A total of 1 kg of water was added to the mixture. The addition of water was done by batch, that is, add first ¼ of the water. Then another ¼ of the water until all water was added. Finally, materials should be mixed thoroughly for one minute. The prepared concrete mixture was poured into the mold. This process was done three (3) times for each group – control group, mixture 1, mixture 2, and mixture 3.

Phase III. Drying and Curing Process

Figure 1. Prepared Concrete Cubes with Different Mix Proportions

After 24 hours of casting, cubes were placed in water for 1 minute at a controlled temperature around 20°C to eliminate excess water from the mortar, a more elaborate dewatering process designed to improve material consistency.

For curing, the specimens were cured in municipal water for a period of 7 days. This standard curing period helps the concrete reach its target compressive strength of 30 MPa. Proper curing ensures adequate hydration of the cement, which is essential for strength development and durability.

Phase IV. Mechanical Testing of Eco-concrete

In this study, the compressive strength of the prepared concrete samples were tested at the Terms Concrete and Materials Testing Laboratory Inc.

Waste Disposal

All damaged materials, debris and dust were placed in a sealed container with proper label. The researcher sent the waste materials to the Material Recovery Facility of Barangay 28-C, Davao City. While useful materials were recycled.

Data Analysis

The following statistical tests were used to analyze the data. Average. This statistical test was used to determine the average areal density, bulk density, and compressive strength. In terms of compressive strength, this identified the overall performance of each mixture.

F-test of Independent Means. This statistical tool was utilized to determine the significant difference in compressive strength between the eco- concretes and commercially produced concrete.

Results

This section presents the findings based on the data gathered such as areal density determination, bulk density determination, and the compressive strength test conducted on study about development of eco-concretes where cotton textile waste strips was utilized as partial replacement of fine aggregates and broken bottles as partial replacement of coarse aggregates. The presentation is organized into four sections: 1) areal density of cotton textile waste strips; 2) bulk density of materials used; 3) compressive strength of concrete specimens; and 4) F-test of Independent Means.

Areal Density

Areal density is a measure of a quantity per unit of area. Table 3 shows the areal density of cotton textile waste strips.

Table 3. Areal Density of Cotton Textile Waste Strips

						Areal Density (g/cm^2)
Material						
	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Average
Waste Cotton Textile Strips	0.024	0.027	0.027	0.026	0.028	0.026

The average areal density of cotton textile waste strips is 0.026 g/cm2.

Density

Density is the measurement of how much mass is contained in a given volume, calculated by dividing an object's mass by its volume. Table 4 presents the density of broken bottles.

Table 4. Density of Broken Bottles

Material	Density (g/mL)					
	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Average
Broken Bottles	2.57	2.42	2.63	2.58	2.54	2.55

The average density of broken bottles is 2.55 g/mL.

Bulk Density

Bulk density is the mass of a material divided by its total volume, which includes the volume of the solids and the pore spaces between them. Table 5 presents the bulk density of concrete materials.

Table 5. Bulk Density of Concrete Materials

	Bulk Density (kg/m^3)					
Material	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Average
Cement	1280	1292	1250	1304	1310	1287
Fine Aggregate (sand)	1244	1292	1280	1274	1339	1286
Coarse Aggregate (gravel)	1630	1641	1600	1606	1624	1620

The average bulk density of cement is 1287 kg/m^3. Meanwhile, the average bulk density of fine aggregate (sand) is 1286 kg/m^3. On the other hand, the average bulk density of coarse aggregate (gravel) is 1620 kg/m^3.

These results indicates that the bulk densities of cement, fine aggregate (sand), and coarse aggregate (gravel) fall within the standard range for concrete materials, confirming their sustainability for concrete production.

Compressive Strength of Concrete

The compressive strength of concrete is a measure of its ability to withstand a crushing load, typically reported in megapascals (MPa). Table 6 presents the compressive strength of concrete specimens.

Table 6. Compressive Strength of Concrete Specimens

Sample Identification		Weight (kg)	Compressive Strength (Mpa)	Average (Mpa)
	Replicate 1	*8.2*	*2.2*	
Control	*Replicate 2*	*8.0*	*1.6*	1.8
	Replicate 3	*8.1*	*1.7*	
	Replicate 1	*8.3*	*2.0*	
Mixture 1	*Replicate 2*	*8.2*	*1.9*	1.8
	Replicate 3	*8.2*	*1.6*	
	Replicate 1	*8.1*	*1.9*	
Mixture 2	*Replicate 2*	*8.3*	*1.7*	1.7
	Replicate 3	*8.3*	*1.5*	
	Replicate 1	*7.9*	*1.2*	
	Replicate 2	*8.1*	*2.0*	
Mixture 3				2.1
	Replicate 3	*8.1*	*2.0*	

Table 6 shows the mean strength of eco-concretes of different mix percentage composition when tested with compressive strength in megapascal (MPa). For control, the commercial concrete in Replicate – 1, Replicate – 2, Replicate – 3 have average compressive strength of 2.2 MPa, 1.6 MPa, and 1.7 MPa respectively. For mixture 1, the average compressive strength of eco- concrete in Replicate – 1, Replicate – 2, and Replicate – 3 are 2.0 MPa, 1.9 MPa, and 1.6 MPa respectively. For Mixture 2, the average compressive strength of eco-concrete in Replicate – 1, Replicate – 2, and Replicate 3 are 1.9 MPa, 1.7 MPa, and 1.5 MPa respectively. For mixture 3, the average compressive strength of eco-concrete in Replicate – 1, Replicate – 2, and Replicated – 3 are 1.2 MPa, 2.0 MPa, and 3.0 MPa respectively. Among the mixtures, Mixture 3 has the highest average compressive strength which is 2.1 MPa. This indicates that Mixture 3 achieved the best overall performance among all the mixtures of eco-concretes. On the other hand, Mixture 2 has the weakest performance among all the mixtures according to its mean compressive strength of 1.7Mpa.

F-test of Independent Means

F-test of independent means is utilized to determine the significant difference in compressive strength between the eco-concretes and commercially produced concrete.

Table 7. Result of F-test of Independent Means

Concrete	Mpa Df	Sum Sq	Mean Sq	F-value	Decision on H_0
Eco-concrete	3	0.20917	0.069722	0.2789	0.8392
Commercial Concrete	8	2.00000	0.250000		

Level of Significance: 0.05

Table 7 presents the concrete with cotton textile waste strips and broken bottles which has a mean square of 0.069722 while the commercial concrete has a mean square of 0.25000. Therefore, the researcher failed to reject Ho (F(3.8) = 0.8392, $p > 0.05$). The researcher has insufficient evidence to conclude that at least two of average compressive strengths are significantly different. This also means that the incorporation of varying proportions of cotton textile waste strips and broken bottles as partial replacement of fine aggregate and coarse aggregate do not significantly affect the compressive strength of concrete.

It implies that the concrete with cotton textile waste strips and broken bottles can be a good substitute for commercial concrete and can also enhance more strength to the concrete made.

Discussion

The performance of eco-concretes which consist of cotton textile waste strips and broken bottles as particle replacement of fine aggregates and coarse aggregates and its findings in this study reveal valuable insights. It was found that while differences in measured compressive strength through comparative evaluation of eco-concretes and commercially produced concretes, these differences in measured compressive strength were found statistically insignificant based on the F-test of Independent Means' result at the 0.05 level of significance.

The average areal density of cotton textile waste strips is 0.026 g/cm2. Furthermore, among the five trials, the highest areal density is 0.028 and the lowest areal density is 0.024. This indicates that the cotton textile waste strips have a relatively uniform thickness and mass distribution, ensuring consistency and reliability when used as a partial replacement of fine aggregates. This result is supported by the study of Khelidj (2022) which states that the areal density of different textile ranges from 117 to 1145 g/cm2.

The average density of broken bottles is 2.55 g/mL. Furthermore, among the five trials, the highest density 2.63 g/mL and the lowest density is 2.42 g/mL. This finding is supported by Tyagher and Utsev (2011), states that specific gravity of the bottles was 2.55 g/mL.

The average bulk density of cement is 1287 kg/m³. Meanwhile, the average bulk density of fine aggregate (sand) is 1286 kg/m³. On the other hand, the average bulk density of coarse aggregate (gravel) is 1620 kg/m³. This finding is supported by Civil Engineering (n.d.), states that the approximate bulk density of aggregate that is commonly used in normal-weight concrete is between 1200-1750 kg/m3.

Among the mixtures, Mixture 3 has the highest average compressive strength which is 2.1 MPa. This indicates that Mixture 3 achieved the best overall performance among all the mixtures of eco-concretes. On the other hand, Mixture 2 has the weakest performance among all the mixtures according to its mean compressive strength of

1.7MPa. This finding is supported by Valenzuela-Leyva (2025), the optimization of concrete with waste mixtures represents a significant advancement toward more sustainable construction practices that maintain or exceed conventional performance standards.

The incorporation of varying proportions of cotton textile waste strips and broken bottles as partial replacement of fine aggregate and coarse aggregate do not significantly affect the compressive strength of concrete as shown in the result of F-test of independent means (p > 0.05). This agrees with the study conducted by Sasi et. al. (2024 that textiles obtained from recycled textile waste can be used to reinforce concrete.

II. CONCLUSIONS AND RECOMMENDATIONS

This section presents the conclusions that were drawn out the findings of the study. This section further offers recommendations as to how the findings of this study can improve practice.

Conclusions

Based on the findings of the study, the following conclusions are drawn by the researcher:

- The average of the areal density of cotton textile waste strips is 0.026 g/cm2.
- The value of five trials are close to each other, which indicates that the samples have consistent thickness and mass distribution.
- The average of the density of broken bottles is 2.55 g/mL. The value of five trials are close to each other, which indicates that the samples have the same mass distribution.
- The average of bulk density of each material, including cement, fine aggregate (sand), and coarse aggregate (gravel). For cement, the average of bulk density has 1287 kg/m3. For fine aggregate (sand), the average of bulk density has 1286 kg/m3. For coarse aggregate (gravel) the average of bulk density has 1620 kg/m3. The results are acceptable since the average are within the range of bulk density.
- Mixture 3 (2.7% CWTS and 30% Broken Bottles) has the highest mean compressive strength of 2.07 MPa, indicating that it achieved the best overall performance among all the concrete mixtures. On the other hand, Mixture 2
- (2.5% CWTS and 20% Broken Bottles) has the weakest performance among all the mxitures according to its mean compressive strenght of 1.7 MPa.
- We fail to reject $H0$ (F (3,8) = 0.8392, $p > 0.05$). We have insufficient evidence to conclude that atleast two of the mean compressive strengths are significantly different. This also means that the incorporation of varying proportions of cotton waste textile strips and broken glass as partial replacement of fine aggregate and coarse aggregate do not significantly affect the compressive strength of concrete.

Recommendations

Based on the conclusions presented, the following recommendations are

given:

- Explore other consumer wastes that can be incorporates to concrete to improve the compressive strength of the material.
- Apply different ratios of cotton waste textile and broken bottles to concrete production.
- Use different drying days of curing days for concrete production.

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