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Assessment of Concrete Compressive Strength by Adding Fiberglass and Shredded Plastic

Aves, Federico A Jr.
Department of Civil Engineering, Surigao del Norte State University, Surigao City, Philippines
faves@ssct.edu.ph

Abstract: *Wall panels are flat and rectangular in shape and are precast construction materials used as exterior and interior walls in fast-paced constructions because of their time and labor efficiency. This research determined the desired concrete mix of cement, sand fiberglass, and shredded plastic for a lightweight wall panel that conforms to the required strength and physical properties. Quantities of sand, fiberglass and shredded plastic were varied in six designed concrete mixtures. Control mixture 1 and mixture 2 were both classed as normal-weight concrete; however, mixtures 3, 4, 5, and 6 were designated as lightweight concrete. Mix Design 3 was chosen as the best mix design, with a density of 15.79 kN/m3 and the best compression, splitting tensile, and flexure results of 15.446 MPa, 2.304 MPa, and 3.424 MPa, respectively. The density of the wall panel using mixture C was determined to be 1610.113 kg/m^{3}and the compressive strength between 15.446 and 13.204 MPa passed the standard requirement and was way better than the conventional wall using hollow concrete blocks.*

Keywords: Fiber Reinforced Concrete, Fiberglass**,** Shredded Plastic, Wall Panel

I. INTRODUCTION

Concrete, renowned for its strength and resilience, stands as the second most utilized construction material worldwide, with a staggering consumption of 30 billion tonnes annually. To enhance or modify its properties, numerous materials have been incorporated into concrete over the years. Recently, researchers and the concrete industry have directed their focus towards adding fibers like steel, glass, polymeric materials, carbon, cellulose, plastics, and nylon to fresh concrete. This deliberate addition aims to improve specific characteristics such as compressive strength, toughness, flexural strength, flexural toughness, and abrasion resistance [1][2][3].

Fiberglass-reinforced concrete (FRC) is known for its high tensile strength, and it utilizes fiberglass as a tensile reinforcement in FRC plain concrete composite members. This combination offers the potential for substantial cost savings in materials and construction [4][5][6]. By incorporating fibers into concrete, its strength and toughness can be enhanced. However, the direction, length, and tensile strength of the fibers play a crucial role in determining the concrete's overall strength and toughness. The critical length of a fiber is the minimum length required for it to maintain stress or strain equal to its strength. When using fibers that are too short or too long beyond their critical length, their strength and ability to withstand stress or tension may be compromised [7][8][9].

The inclusion of shredded plastic in concrete can enhance its workability and make it easier to handle and place during construction. The use of shredded plastic can help reduce the occurrence of shrinkage cracks in concrete, leading to improved durability and longevity. The addition of shredded plastic fibers can enhance the flexural strength of concrete, making it more resistant to bending and cracking under loads. Conrete containing shredded plastic exhibits improved impact resistance, making it suitable for applications where impact loads are a concern [10,11,12,13]. Shredded plastic in concrete can lead to reduced water absorption, which helps in improving the concrete's resistance to moisture-related issues. Utilizing shredded plastic waste as a concrete additive contributes to the recycling and sustainable use of plastic materials, reducing environmental pollution. Incorporating shredded plastic waste in concrete can be cost-effective, as it provides an alternative to traditional concrete additives while recycling waste materials [20,21, 22].

Fibers offer notable improvements in both the structural integrity and performance characteristics of concrete wall panels when compared to conventional concrete panels [14]. Successful applications of fibers have been observed in precast elements, contributing to the development of fiber-reinforced concrete. In addition to reducing costs and production times associated with fiber-reinforced concrete, combining fibers with a self-compacting concrete matrix leads to the creation of self-compacting fiber-reinforced concrete. This innovative approach allows for the casting of structural elements with intricate geometries and thin components [15]. Comparing them to conventional reinforced panels, glass fiber reinforced concrete panels (GFRP) demonstrate a substantial increase in load-carrying capacity and improved flexural behavior [16][17][18][19].

This study focuses on evaluating the physical and mechanical characteristics of shredded plastic concrete reinforced with glass fiber. The investigation involved six different design mixes comprising cement, sand, fiberglass, and shredded plastic. Moreover, the research aims to determine an optimal design mix ratio to create a lightweight wall panel that meets the required standard criteria.

II. MATERIALS AND METHODS

2.1. Materials

The following materials used in this research were as follows:

2.1.1. Cement: Ordinary Portland Cement (OPC) with a specific gravity was acquired from a local construction supply store. The OPC adheres to the specifications of Type IP Portland cement as outlined in the ASTM C150-05 (2005) standard (Specification for Portland Cement).

2.1.2. Fine Aggregates: Fine aggregates were sourced from a local supplier and obtained from a quarry within the Philippines.

2.1.3. Water: Potable water sourced from water supply outlets was utilized for concrete mixing. The water used in concrete mixing was required to be clean and free from any substances that might adversely affect the cement hydration process and the quality of the concrete or its reinforcements.

2.1.4. Shredded Plastic: Shredded plastic with a bulk density of 1.06 kg/m3 was employed.

2.1.5: Glass Fiber: Glass fiber, composed of extremely fine glass fibers, was used. It possesses mechanical properties comparable to polymers and carbon fiber. To enhance the tensile strength of concrete, 1-inch-long alkali-resistant glass fibers were utilized as reinforcement in the study.

2.2 Methods

The following methods were adopted in this research were as follows:

2.2.1 Mixture proportion: For hollow blocks, the cement-aggregate ratio was typically 1:4 by volume. In the shredded plastic mix, sand to shredded plastic ratios of M1:100:0 (control mix), M2:90:10, M3:80:20, M4:70:30, M5:60:40, and M6:50:50 were used, with respectively. A constant percentage of fiber was used for the whole mixture.

Table 1: Mix Design of Cement, Sand, Fiber Glass and EPS

Mix Design	Glass Fiber (m^3)	Cement (m^3)	Sand (m^3)	Shreeded Plastic (m^3)	W/C (%)
Mix 1	0.0029	0.25	0.82	0	44
Mix 2	0.0029	0.25	0.74	0.09	44
Mix 3	0.0029	0.25	0.66	0.17	44
Mix 4	0.0029	0.25	0.58	0.25	44
Mix 5	0.0029	0.25	0.50	0.33	44
Mix 6	0.0029	0.25	0.42	0.41	44

2.2.2. Preparation of Precast Concrete: The precast concrete specimens were fabricated using wooden molds. The concrete mix was carefully poured into the molds, and to avoid water evaporation, the casted specimens were covered with wet burlap. Subsequently, the wall panel specimens were cured for a minimum of seven days before being removed from the formworks for further processing of the wall panel elements. The precast concrete wall panel had dimensions of 300mm x 300mm x 100mm.

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2.3 Laboratory tests

2.3.1 Specific Gravity and Water Absorption of Fine Aggregates: The specific gravity and water absorption test for ordinary sand were conducted following ASTM C 128-79, which is the standard criterion for determining fine aggregates' specific gravity and absorption.

2.3.2 Specific Gravity of Cement: The specific gravity test for cement in both control and design concrete mixtures adhered to ASTM C150, the standard specification for Portland cement. The quantity of cement was measured using its specific gravity.

2.3.3 Sieve Analysis: The sieve analysis of fine and coarse aggregates was carried out using the standard test method ASTM C136. Fine aggregates with particles passing through a 2.36 mm sieve were used in the concrete mix.

2.3.4 Unit Weight of Aggregates: The unit weight of aggregates in both compacted and loose states was determined in accordance with ASTM C29-78, the standard method of test for bulk density (unit weight) and voids in aggregates.

2.3.5 Mixing Procedure: ASTM C305-82 specified the proper mixing procedure for achieving uniformity in cement, water, and aggregates. The homogeneity and blending of these ingredients significantly impacted the strength of the sample. The mixture was stirred for 2 to 5 minutes to achieve the desired solidity and workability.

2.3.6 Curing: The curing process followed ASTM C140-91, which involved storing the test specimen at room temperature for 20 to 48 hours before removal. After removal, the specimens were placed in a curing tank at room temperature for curing periods of 7, 14, and 28 days, respectively.

2.3.7 Compressive Strength Test: The average compressive strength of concrete specimens was determined under normal curing periods of 7 days, 14 days, and 28 days, using the standard test method ASTM C39-86.

2.3.8 Compressive Strength Test of Wall Panel: This test method, as per ASTM C39-86, covered the determination of compressive strength of wall panel specimens. It was applicable to concrete with a unit weight exceeding 50 lb/ft3 (800 kg/m3).

2.3.9 Flexural Strength Test: The flexural strength of the specimen was tested according to ASTM C293, the standard test method for flexural strength of concrete using a simple beam with center-point loading.

2.3.10 Split Tensile Test: The split tensile strength of the specimen was determined following the ASTM C496 method. This test measured the splitting tensile strength of cylindrical concrete test specimens, such as molded cylinders and drilled cores.

IV. RESULTS AND DISCUSSION

TABLE 1: PHYSICAL PROPERTIES OF MATERIALS

Material	Physical Property
Specific Gravity of Fine Aggregates	2.48
Specific Gravity of Cement	3.5
Bulk Density of Shredded Plastic	1.06 kg/m^3
Bulk Density of Fine Aggregates	1459.65 kg/m^3
Percent Absorption of Fine Aggregates	3.02%

The physical properties of concrete materials, including cement, sand, and shredded plastic, were thoroughly tested, and the overall average of these materials is presented in Table 1. The bulk density of fine aggregates met the standard criteria for lightweight material.

TABLE 2: QUANTITIES AND PROPERTIES OF MATERIALS

Design Mix	Fiber Length (in)	Fiber Quantity (%)	Shredded Plastic (%)	Average Density after 28 days (kg/m^3)
1	1	0.29	0	2007.450
2	1	0.29	10	1723.046
3	1	0.29	20	1610.113
4	1	0.29	30	1570.430
5	1	0.29	40	1460.261
6	1	0.29	50	1436.223

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Table 2 displays the densities of specimens from various mixed patterns. The results indicate that mix designs 2, 3, 4, 5, and 6 achieved the target density of 1440 to 1840 kg/m3 after 28 days, as indicated in the table's average density column. The recorded densities of 1723.046 kg/m3, 1610.113 kg/m3, 1570.430 kg/m3, 1460.261 kg/m3, and 1436.223 kg/m3 fall within the 1440 to 1840 kg/m3 range, classifying them as lightweight concrete. Furthermore, Table 2 reveals that the densities of specimens without shredded plastic were higher compared to the densities of mixes 2, 3, 4, 5, and 6 containing shredded plastic. This is attributed to the reduced density of shredded plastics when mixed with fiberglass.

TABLE 3: COMPRESSIVE STRENGTH OF SPECIMENS (FC'), MPA

Mix Design	Curing Period		
	7 days	14 days	28 days
1	15.173	21.352	26.963
2	14.826	15.013	16.635
3	13.204	14.327	15.446
4	13.286	13.336	14.421
5	10.562	10.142	11.532
6	9.023	9.224	10.345

Table 3 presents the results of the compressive strength test on the concrete specimens. The findings reveal that as the specimens aged, their compressive strength increased. Among all the mixtures consisting of fibers, varying amounts of sand, and different percentages of shredded plastic, the control mix with glass fiber, varying amounts of sand, and no shredded plastic content exhibited the highest compressive strength. Figure 1 illustrates that after 28 days, the specimens with zero (0) percent shredded plastic displayed the highest compressive strength among the mixtures containing shredded plastic. However, when more than or equal to 10% shredded plastic was added, the strength decreased, as observed in the 0.29 percent fiber amount. Increasing the amount of shredded plastic in the mix resulted in lighter concrete but also led to a reduction in strength.

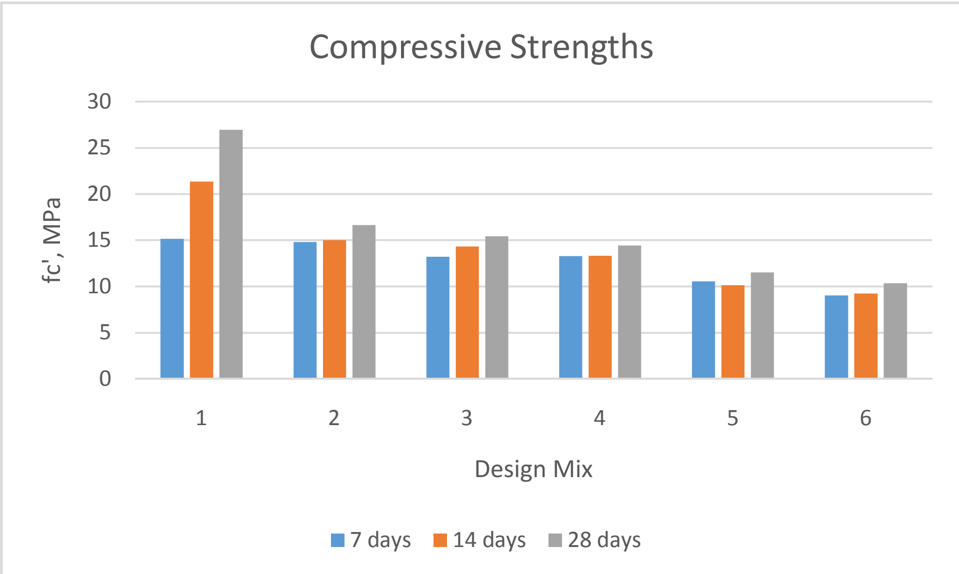

Figure 1. Compressive Strength of Specimens (fc'), MPa

The tensile strength results of the specimens are displayed in table 4. A noticeable increase in tensile strength can be observed as the curing period progresses, for each presented mixture design at 7, 14, and 28 days. Furthermore, it was observed that after 14 and 28 days of curing, the tensile strength of concrete specimens in mix design 2, 3, and 4, which contained varying amounts of sand, shredded plastic, and glass fiber, exhibited significant improvement and achieved the desired strength of 2 MPa or greater. These mix designs also fell within the density range of 1440 kg/m3 to 1840 kg/m3, as compared to mix designs 5 and 6, which had lower densities as presented in Table 2. Figure 2 also depicts the variations in strengths as shredded plastic is added to the mix along with controlled fiberglass, providing further insight into the relationship between strength and shredded plastic content. The results of the splitting tensile test of cylindrical

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specimens cured at 28 days with six varied mix designs are shown in figure 2. It was discovered that the amount of shredded plastic used impacts the split tensile strength of concrete. The strength of the mixture decreased as the number of shredded plastic in it increased.

TABLE 4: TENSILE STRENGTH OF SPECIMENS, MPA

Mix Design	Curing Period		
	7 days	14 days	28 days
1	2.786	2.960	3.299
2	2.120	2.367	2.512
3	1.821	2.147	2.304
4	1.702	2.035	2.176
5	1.486	1.613	1.812
6	1.136	1.487	1.593

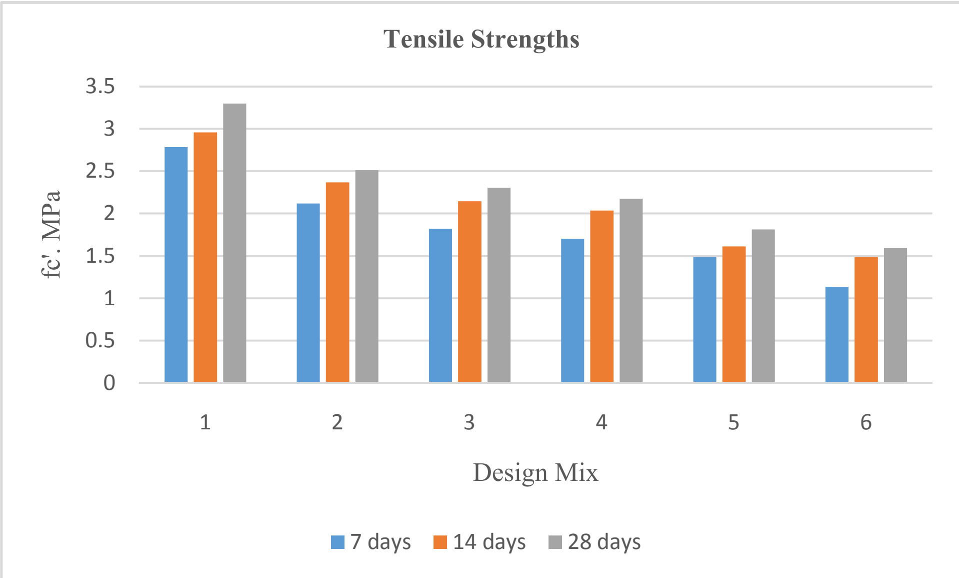

Figure 2. Tensile Strength of Specimens

TABLE 5: FLEXURAL STRENGTH OF SPECIMENS, MPA

Mix Design	Curing Period		
	7 days	14 days	28 days
1	3.545	3.706	5.526
2	2.906	3.332	4.184
3	2.731	2.905	3.424
4	2.317	2.625	2.968
5	1.649	1.949	2.873
6	1.474	1.733	2.434

Table 5 above presents the flexural strengths of the concrete samples. Among mix designs 2, 3, 4, 5, and 6, the control mix 1 without shredded plastic displayed the highest flexural strength at 7, 14, and 28 days. Notably, each mix design exhibited an increase in flexural strength as the curing age progressed. The figure illustrates a clear trend where mix designs with higher sand content and lower amounts of shredded plastic resulted in higher flexural strengths. This demonstrates that the proportion of sand and shredded plastic in the mix significantly influences the flexural strength of the concrete.

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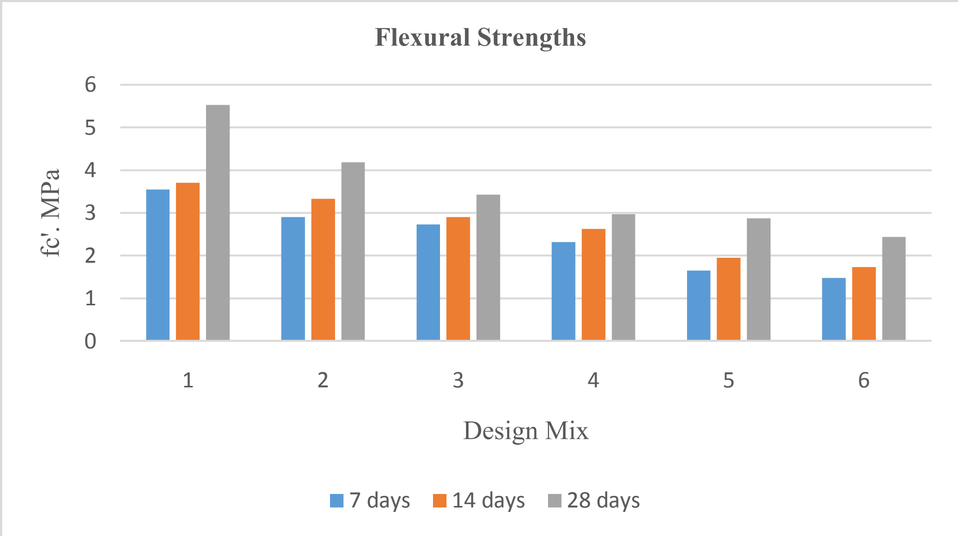

Figure 3. Flexural Strength of Specimens

Figure 3 illustrates that after 28 days of curing, the specimens with 0% shredded plastic and 0.29 percent glass fiber exhibited the highest flexural strength among the mixtures incorporating fibers. On the other hand, the lowest flexural strength values were observed in each mix design with a constant fiber amount of 0.29 percent, an increase in the percentage of shredded plastic, and a decrease in the amount of sand. The graph clearly indicates that mix design 3 was the most optimal and preferred choice for wall panels, as it achieved the highest flexural strength. Generally, the flexural strength of the specimens was higher in mixtures with a lower percentage of shredded plastic and a higher amount of sand. This highlights the importance of carefully controlling the proportions of shredded plastic and sand in achieving the desired flexural strength in the concrete specimens.

TABLE 6: PHYSICAL AND MECHANICAL PROPERTIES OF WALL PANEL

Bulk dessity of the wall panel	1610.113 kg/m^3
Average compressive strength of the wall panel	15.446 MPa

Table 6 presents the physical and mechanical properties of the wall panel. The results demonstrate that the desired bulk density of the wall panel, falling within the range of lightweight concrete (1440 kg/m^3 to 1840 kg/m^3), was achieved with a value of 1610.113 kg/m^3. The average compressive strength of the wall panel at a curing age of 7 days was measured at 13.204 MPa, while the desired strength of 15.446 MPa was achieved at a curing age of 28 days.

V. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion

- The density of the concrete samples, resulting from various mix designs, ranged from 1436.223 kg/m3 to 2007.450 kg/m3. This variance in density is attributed to the differing amounts of sand and shredded plastic used in each mix.
- The flexural strengths of the concrete samples varied between 2.434 MPa and 5.526 MPa, while the compressive values ranged from 10.345 MPa to 26.963 MPa. Additionally, the splitting tensile strengths ranged from 1.593 MPa to 3.299 MPa. Notably, as the proportion of shredded plastic in the mixture increased, the mechanical characteristics of the concrete showed a decline.
- Both control mixture 1 and mixture 2 were classified as normal-weight concrete, while Mixtures 3, 4, 5, and 6 were designated as lightweight concrete. Among these, Mix Design C was identified as the most favorable choice, displaying a density of 1610.113 kg/m3 along with the best compression, splitting tensile, and flexural results, measuring 15.446 MPa, 2.304 MPa, and 3.424 MPa, respectively.
- The density of the wall panel was determined to be 15.79 kN/m3, confirming its status as a lightweight wall panel, successfully passing the test. Moreover, the wall panel's compressive strength ranged from 15.446 MPa to 10.345 MPa, surpassing the normal compressive strength of hollow concrete blocks, which is 3.2 MPa.

5.2 Recommendation

For the future development and betterment of this study, the researcher recommends the following:

- Determine the physical strength of the concrete mixture by varying the amount of replacement of glass fiber.
- Determine the necessary concrete mix design with fiberglass that meets the lightweight concrete criterion while keeping the wall system's cost minimum.
- Based on the results of the tests, the precast concrete design can be employed as a wall system instead of traditional concrete hollow blocks to lighten the weight of concrete constructions.

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