

Reuse of Crushed Glass and Aluminum Filings Wastes as Partial Replacement of Sand in Concrete Mixture

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Abstract : The development in inhabited areas lead to accumulate solid wastes which is considered an essential trouble in the world. The modern studies affecting the used materials that have less environmental effect. The aim of this study is to develop an effective and environmentally disposal method of Crushed Glass Waste (CGW), and Aluminum Filings Waste (AFW) that collected from different locations to reduce the disposal problem of these Wastes and examined their performance properties in concrete mixtures. Different percentages (10, 15, 20 and 30 %) of CGW and AFW are used as a partial replacement by sand's weight, and checking their effect on the mechanical properties of concrete. Mixing, casting, and curing at (7, 28, and 56) days are applied subsequently. The fresh and hardened properties of concrete are performed such as (slump, oven dry density, compressive strength, flexural strength, splitting tensile strength, and water absorption). The obtained results of CGW and AFW are showed that, the possibly utilized CGW up to 30% without any adverse effect on concrete, while the utilization of AFW make the concrete lightweight.

Keywords : Crushed Glass, Aluminum Filings, slump, oven dry density, compressive strength, flexural strength, splitting tensile strength, water absorption.

Introduction

In the densely populated areas the waste accumulation is a problem in the worldwide. Due to the technology development along with a current lifestyle has directed to a growth in the solid waste amount and type that being generated. The non-decaying waste materials cause a waste disposal crisis, therefore; contributing to the environmental problems. Most of these wastes are left as landfill material, stockpiles, and illegally dumped in areas [1]. The quantity of solid wastes leads to create environmental issues which utilizing them in the apartment of creating construction materials, ordinary predictable materials, normal raw resources, conserved energy, and costly. The reused method is considered as a significant waste disposal technology, which appear as a practical selection to balance the environmental influence connected with the construction industry [2]. Many researchers are used solid waste in construction materials as [3] who studying the different mechanical properties of concrete that including crushed glass waste as sand replacement with different percentages (10%, 15%, and 20%) by weight at 3, 7, 14, and 28 days. The (flexural and compressive) strengths were above the control mixture by 10.99% and 4.23% respectively, at 28 days. The slumps test was reduced with glass waste content increased. At 3 and 7 days of curing ages, the compressive strength was increased along with the presence of glass waste, whereas at 14 days of curing age decreased. At 28 days of curing age, 20% of glass waste was presented a highest compressive strength. At all ages, the flexural strength was

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increased along with increasing glass waste. Whereas, the authors of [4] studied the increase in compressive strength when 10% and 20% of sand partially replaced in concrete by the waste glass (4.75–0.15 mm) particle size.

The outcomes of [5] presented that the compressive strength was increased when replacing 10%, 20%, and 30% glass waste (1.18–0 mm) particle size by sand's weight. However, the findings of [6] stated the compressive strength at 7 and 28 days was reduced when replacing (25%, 50%, 75% and 100%) glass waste by sand's weight in concrete blocks with an un-sieved particle sizes (<2.36 mm and < 1.18 mm). In contrast, compressive strength was increased when glass waste with a particle size (<0.6 mm). At 28 days, the compressive strength was reduced by 10.55% and 16.75% with the replacement of 25% and 100% glass waste (<2.36 mm) particle size by sand's weight, while the increasing by 5.1% and 34.31% when using (<0.6 mm) particle size. Whilst, Based on [7] who demonstrated the compressive strength of concrete, with partially replacing 5%, 10%, and 20% waste glass (<4 mm) particle size by weight of sand, was reduced around 10.94%, 17.19%, and 14.06%, respectively.

The achievements of who Conducted on the possibility of partially replacing aluminum filings by weight of sand in a cement mortar. Different percentages of aluminum filings were used in the lightweight mortar production. The results were showed that the use of this type of aggregate reduces compressive strength of cement mortar cubes, tested at ambient temperature, compared with the reference mix which had natural sand. The results also were shown that replacing the sand with aluminum filings were decreased the rate of reduction in compressive strength when the samples tested immediately after heated at 55°C in an oven. The thermal conductivity test results were positive, where there was a decrease in thermal conductivity when increasing the aluminum waste content.

Experimental Procedure

The specimens included (cubes and cylinders) with dimensions (150×150×150 and 150×300) mm respectively. The utilization materials include Portland limestone cement (PLC), water, sand, and aggregate, also the different type of waste that used as a partial replacement by sand's weight.

Materials

All materials characteristics are tested according to the **standard specifications of (IQS) and/or of (ASTM)**.

Aggregate

In this research, the fine aggregate (Sand) that used for mixes, is a natural washed sand from (**Al-Ekhaidhir**) quarry which is a local source in Iraq with zone III (0.15 - 4.75) mm according to [9] have fineness modulus 2.6, specific gravity 2.65, and water absorption 0.74%. While coarse aggregate (gravel) that used for mixes, is crushed gravel from (**Al-Nebai**) region which is a local source in Iraq with a maximum size of 19 mm.

Water

For all the mixes, the Portable water has been used which taken from the water supply network system (tap water).

Cement

The Portland Limestone Cement (PLC) manufactured in Iraq with a commercial name (**KARSTA**) has been used in this study. The physical properties of cement shown in Table (1).

Table (1) : Physical Cement Properties

Physical Properties	Result	Limits of IQS No.5/1984
Fineness (Blaine method), (m^2/kg)	364	No specified
Setting time (Vice apparatus)		
a. Initial setting time, (min)	177	$\geq 45\text{min}$
b. Final setting, (hrs.).	3:377	$\leq 10\text{hrs}$
Compressive strength is not less than (mN/m^2)		
For 2 days	21.8	≥ 20
For 28 days	52.1	≥ 42.5
Soundness (expansion) mm	0.34	≤ 10

Table (2) Grading of Crushed Glass Waste*

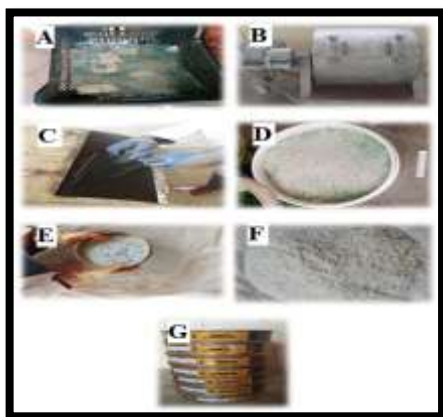
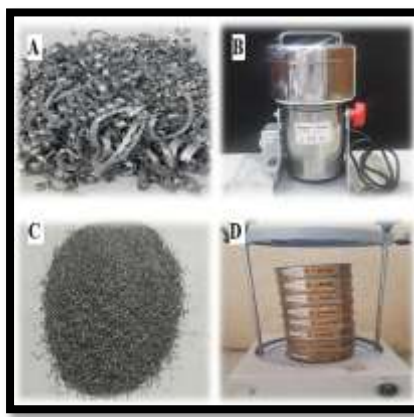
Sieve Size (mm)	Cumulative Passing%	Limit of IQS No.45/1984, Zone II
4.75	100	90-100
2.36	97.5	75-100
1.18	60.2	55-90
0.6	47	35-59
0.3	14.1	8-30
0.15	3.6	0-10

The testing results are prepared in constructions materials laboratory at civil Engineering Department / Babylon University.

Crushed Glass Waste (CGW)

The glasses waste that used in this study are collected from some local industrial workshops and landfill ground in Babylon city, then washed with water to dispose of unwanted impurities. It has been crushed by ball milling machine known as (loss Angeles crusher).to be used as a fine aggregate in concrete,

Plate (1) illustrates the preparation of (CGW). The grading of CGW is listed in Table (2).


Plate (1): The Preparation of CGW

Plate (2): The Preparation of AFW

Aluminum Filings Waste (AFW)

The aluminum filings waste has been obtained from some local workshop. Aluminum crushed machine (Kitchen grinder) has been used to cut aluminum filings into small pieces to get the required size of Aluminum filings, then it is collected from the grinder machine and stored in order to be ready for use when casting the specimens. Plate (2) shows that the preparation of WAF. The grading of AFW is recorded in Table (3). The Energy Dispersive X-ray Fluorescence technology (ED-XRF) has been performed to determine the chemical composition of PLC, CGW and AFW which is carried out in Iraqi German Laboratory at Faculty of Science / Department of Earth Sciences/ University of Baghdad and presented in Table (4).

Table (3): Gradation of Aluminum waste*

Sieve Size (mm)	Cumulative Passing%	Limits of IQS No.45/1984, zone 2
4.75	100	90-100
2.36	100	75-100
1.18	75.2	55-90
0.6	42.5	35-59
0.3	8	8-30
0.15	3.2	0-10

The testing results are prepared in constructions materials laboratory at Civil Engineering Department / Babylon University.

Table (4): Chemical Composition of Materials

Compound composition	Abbreviation	(CGW) %	(AFW) %	(PLC) %
Silica dioxide	SiO ₂	80.06	3.54	21.1
Calcium oxide	CaO	13.75	1.7	64.78
Alumina	Al ₂ O ₃	0.83	92.01	4.78
Iron oxide	Fe ₂ O ₃	0.97	0.63	3.19
Magnesia	MgO	3.14	1.55	1.76
Potassium oxide	K ₂ O	0.16	0.03	-
Sulfate	SO ₃	0.26	0.47	2.45
chlorine	Cl	0.06	0.04	-
Phosphorus	P ₂ O ₅	0.77	0.03	-

Mix procedure

A mixer of (0.09m³) capacity is used to mixing the concrete, as shown in Plate (3) according to [10].


Plate (3) Mixing Machine

Testing

At the age of (7, 28, and 56) days the concrete specimens of the compressive strength test were performed in this research according to the [11], while splitting tensile strength test according to [12], flexural tensile strength test according to [13] and water absorption test according to [14], slump test according to the [15], and oven Dry density test according to [16].

Reference Mixtures and Work mixtures

The values of the reference design mixture (without any partial replacement of waste) that is used in this study, content: (420 $\frac{kg}{m^3}$) cement, (705 $\frac{kg}{m^3}$) sand, (1024 $\frac{kg}{m^3}$) gravel, and the water to cement ratio (w/c) is (0.47), to produce a normal concrete with (1:1.8:2.4) as explained in (cement: sand: gravel) that has the

desirable properties in the fresh and hardened state, which is achieved the requirements. It is represented as (Re). The tests' results of the reference mixture are recorded in Table(5). Table (6) illustrates the symbols of mixes work.

Table (5): Reference Mixture Tests' Results

Test Name	Value		
Slump Test (cm)	10		
Test Name	Value at		
	7 days	28 days	56 days
Oven Dry Density (kg/m^3)	-	2416.12	-
Compressive strength (Mpa)	29.07	41.99	48.38
Splitting tensile strength (Mpa)	2.55	3.2	3.4
Water Absorption (%)		3.9%	
Flexural Strength (Mpa)	4.14	5.83	6.07

Table (6) Symbols of the Work Mixes

Type of waste	Mixture Symbol	Waste Percentage	Partially replacing by
crushed Glass	CGW_1	10%	Sand
	CGW_2	15%	
	CGW_3	20%	
	CGW_4	30%	
Aluminum Filings	AFW_1	10%	Sand
	AFW_2	15%	
	AFW_3	20%	
	AFW_4	30%	

Result and Discussion

Slump Test

The results displayed that Slump test of CGW and AFW concrete mixtures with different percentages (10, 15, 20 and 30)% decreased with increasing waste content (%) compared to the reference mixture the reduction of a slump is (18%,24%,29%, and 35%) for (CGW_1 , CGW_2 , CGW_3 , and CGW_4) respectively and (9%, 18%, 27%, and 33%) for (AFW_1 , AFW_2 , AFW_3 , and AFW_4) respectively . As a result of the particle size of the wastes that have an angular shape, the workability decreases as mentioned by [17]. The decreasing ratio (%) in a slump (%) is increased with increasing waste content (%),as shown in Figure (2).

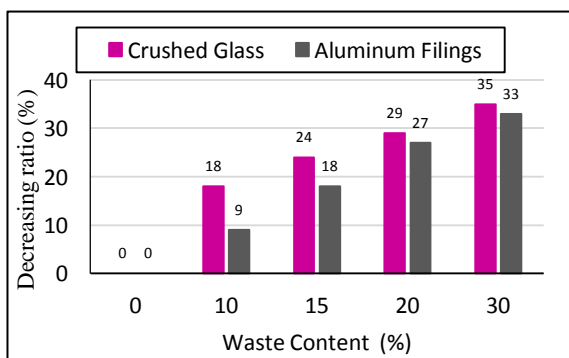


Fig.(1) Over view of Casting Specimen

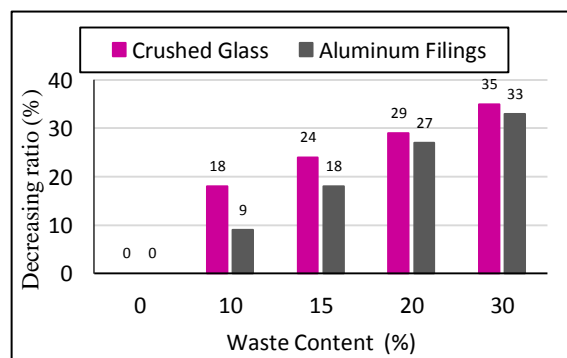
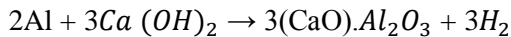


Figure (2): Decreasing Ratio in Slump (%) Verse Waste Content (%).

Oven Dry Density

The obtained results showed that the oven dry density of CGW and AFW concrete mixtures decrease in oven density by increasing waste content (%). This decreases in oven dry density of the specimens has reached to (2.8%, 3.1%, 3.29%, and 3.82%) for mixtures containing (10%, 15%, 20% and 30%) of CGW compared to Re, and to (21.64%, 22.77%, 23.4%, and 24.72%) for mixes containing (10%, 15%, 20% and 30%) of AFW respectively compared to Re. The decreases in the oven dry density of CGW concrete mixture possibly attributed to the variances in density between wastes and natural fine aggregate (sand) [18]. While the decrease in oven dry density of AFW concrete mixture is due to the soft grains of aluminum filings that have the ability to react chemically with $Ca(OH)_2$ resulted from the hydration of the silicates. Such reaction leads to the forming of hydrogen bubbles throughout the mixture as illustrated by [19].



The Specimens swelling are observed after a short period of mixing and casting which indicates that this interaction occurs and the gas is liberated in Figure (3). Figure (4) illustrates that the decreasing ratio in oven dry density (%) of WGP, WPA, and WSSI concrete mixture at (28) days is increased with increasing wastes content (%) compared to Re which lead to made concrete lightweight (LWC).

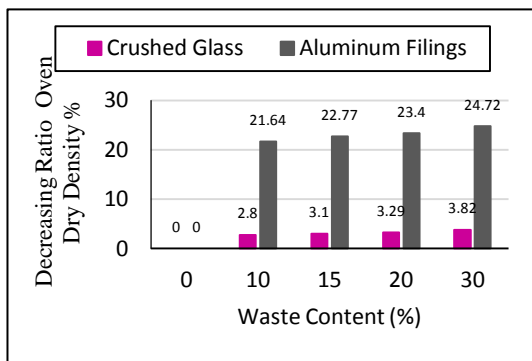


Figure (3): Swelling of Specimens after Short Period of Mixing and Casting

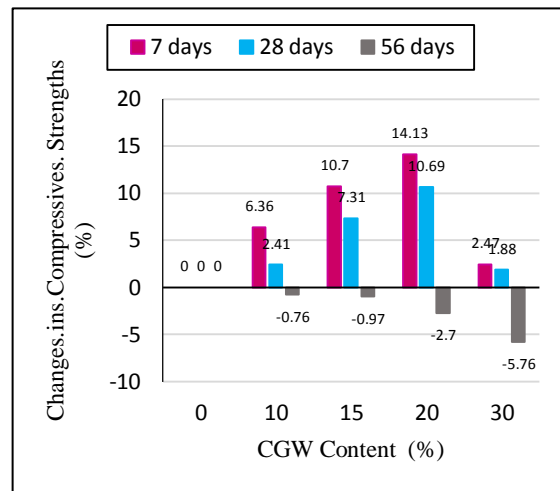


Figure (4): Decreasing Ratio in Oven Dry Density (%) Verse Waste Content (%)

Compressive strength

- The results of compressive strength for CGW and AFW increases proportionally with curing process, due to the hydration products with time still continuous until getting the full strength of concrete as mentioned by [20] which leads to reducing the voids and porosity.
- The highest change in compressive strength is (14.13%) above the reference mixture with 20% crushed glass waste at 7 curing age. The results showed that CGW possibly used effectively as a replacement of fine aggregate (up to 30%) without significant change in strength, but the optimum result has been obtained when 20% of CGW is partially replaced by sand's weight. This result is due to the fact that the CGW contains a high amount of silica which leads to increase the reaction of hydration concrete in early ages as illustrated by [3]. The changes in compressive strength of CGW concrete mixtures compared to Re at 7, 28, and 56 days of cubes are shown in Figure (5).
- Replace sand with 10%, 15%, 20%, and 30% of aluminum filings is increased the decreasing ratio of reduction in compressive strength. These results are back to the fact that the waste materials strength is less than the natural aggregate due to the pores capillary and holes that are produced by the reaction between aluminum filings and $Ca(OH)_2$, which lead to make the concrete lightweight, afterwards compressive strength is extremely decreased but it still on structural concrete according to [16]. The changes in compressive strength of AFW concrete mixtures compared to Re at 7, 28, and 56 days of cubes are shown in Figure (6).

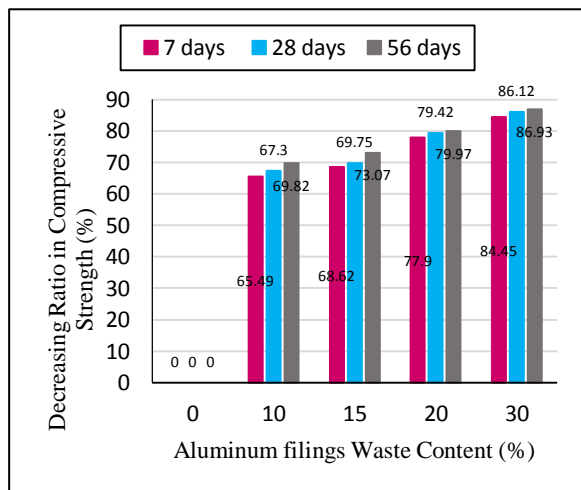


Figure (5): Change in Compressive Strength (%) Verse CGW Content (%).

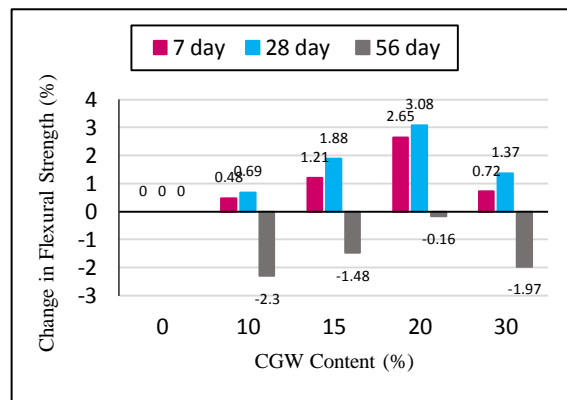


Figure (6): Decreasing in Compressive Strength (%) Verse AFW Content (%).

Flexural strength

- The results of flexural strength for CGW and AFW increases consistently with curing process because the hydration process still continuous until getting the full strength of concrete as point out [20] which leads to reducing the voids and porosity.
- The optimum result has been obtained 3.08% above the reference mixture when partially replacing 20% of CGW by weight of sand, the reason behind that is the hydration progress of the mixture and this results are due to difference in particle size between sand and crushed glass waste, which enabled it to perform as a filler material in concrete specimens. The effect of using CGW in concrete with (100×100×400mm) prisms at curing age (7, 28, and 56 days) on the flexural strength tests are shown in Figure (7) compared to Re.
- From the testing results, The decreasing ratio (%) in flexural strength is increased with increasing AFWs content (%) compared to the reference mixture at all curing ages. The reason behind these results is that, the presence of holes in the chemical structure of specimens as a result of the reaction between aluminum filings and the concrete mixture components. The highest decreasing ratio has been recorded in flexural strength is 73.97% when partially replacing 30% aluminum filings waste by sand at 56 days, while the lowest is 55.79% when partially replacing 10% aluminum filings waste by sand at 7 days. The effect of using AFW in concrete with (100×100×400mm) prisms at curing age (7, 28, and 56 days) on the flexural strength tests are shown in Figure (8) compared to Re.

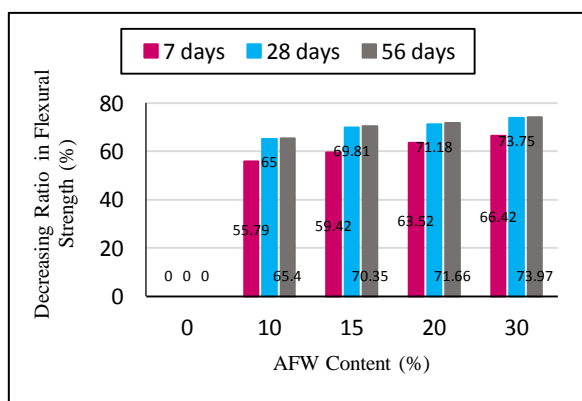


Figure (7): Change in Flexural Strength (%) Verse CGW Content (%).

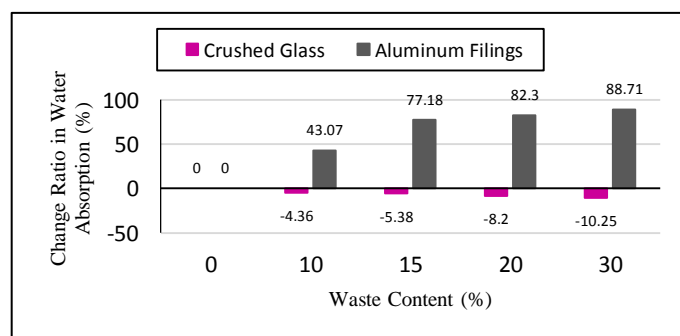


Figure (8): Decreasing Ratio in Flexural Strength (%) Verse AFW content (%).

Water Absorption

The water absorption test is considered as a standard measure of the concrete quality and durability once exposed to adverse environments. The change ratio in water absorption (%) compared to Re for CGW and AFW concrete mixtures at 28 days age is displayed in Figure (9).

- The water absorption (%) gradually decreased by (4.36, 5.38, 8.2 and 10.25) % for (CGW₁, CGW₂, CGW₃, and CGW₄) respectively with increasing CGW content (%) at 28 days. This result is attributed to the fact that glass considered as an impermeable material which is proved by [21].
- The water absorption (%) is significantly increased by (43.07, 77.18, 82.3, and 88.71)% when increasing AFW content (%) at 28 days. The reason behind that the concrete has many holes and pores capillary due to the reaction between AFW and the concrete components to a comparison between two waste materials.

Splitting Tensile Strength

- The results of splitting tensile strength for CGW and AFW increases consistently with curing process because the hydration process still continuous until getting the full strength of concrete as point out [20] which leads to reducing the voids and porosity.
- The optimum result has been recorded is 5.88% at 7 days above the reference mixture when partially replacing 20% of CGW by weight of sand, which means partially replacing 20% by sand lead to achieve higher splitting tensile strength compared to Re at 7, 28 and 56 days. This result is due to the fact that the replaced waste is fine particle than the sand, which enabled it to perform as a filler material in concrete specimens. Figure (10) illustrates the change in splitting tensile strength for CGW concrete mixture using (150×300)mm specimens cured for (7, 28, and 56) days compared to Re.
- The decreasing ratio (%) in splitting tensile strength AFW content compared to Re at all curing ages. As a result of the reaction between aluminum filings and the concrete mixture components, holes and pores capillary in the chemical structure of specimens are formed which lead to significantly decrease in splitting tensile strength. The highest recorded decreasing ratio (%) is 62.35% when partially replacing 30% aluminum filings by sand at 56 days, while the lowest is 47.84% when partially replacing 10% of aluminum filings by sand at 7 days. Figure (11) illustrates the change in splitting tensile strength for AFW.

The Cost Analysis

The analysis cost demonstrations that production cost of CGW and AFW concrete mixtures is decreased by 1.26%, 1.89% 2.53%, and 3.79% compared to Re with replacing 10%, 15%, 20% and 30% respectively.

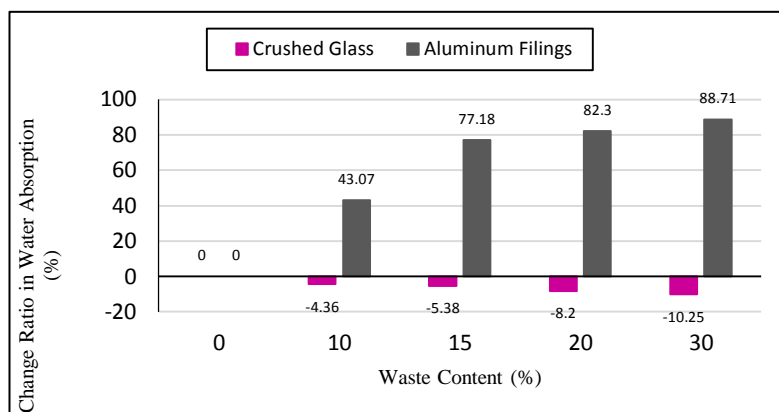


Figure (9): Change Ratio in Water Absorption (%)Verse Waste Content (%) at 28 days.

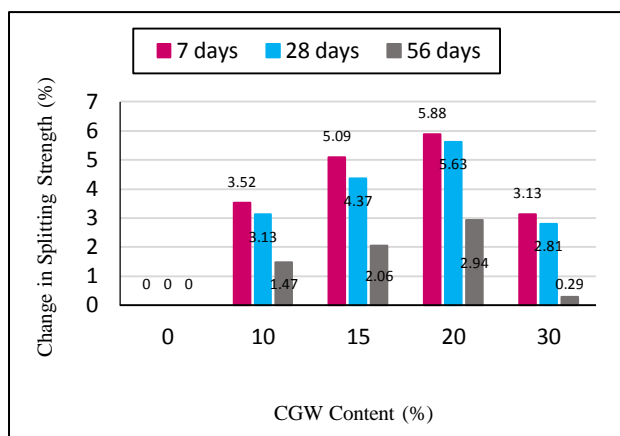


Figure (10): Changing Ratio in Splitting Tensile Strength (%) Verse CGW Content (%).

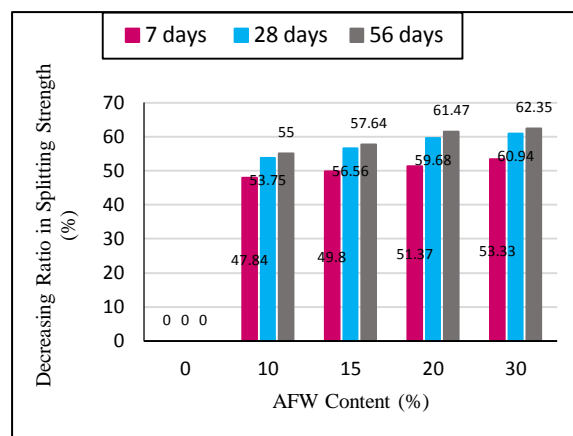


Figure (11): Decreasing Ratio in Splitting Tensile Strength (%) Verse AFW Content (%).

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