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GREEN CONCRETE ROAD DESIGN USING FURNACE SLAG AND FLY ASH

RAFEAA M. ALHDEDY and ABDULBASIT ABDULAZIZ MUHMOOD
Northern Technical University-Iraq

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ABSTRACT:

Green concrete is important in low energy & resource consumption, no environmental pollution & sustainable development. Green cement concrete is produced by using recycled waste materials such as activated fly ash, slag, and the results were assessed against reference concrete. This pavement approach uses slabs of reinforced concrete or cement concrete to create stiff pavement that is more stable. Promoting the usage of concrete made from optimized fly ash pavement can end the asphalt pavement's monopoly over heavy-duty highways and significantly reduce the amount of industrial wastes, including fly ash and blast furnace slag, In changed concretes cement had been, replaced by the weight of (FA) three test groups were constituted is the replacement of percentages as: 0% (fa-00), 20% (fa-20) and 30% (fa-30). Moreover, the findings were paired with concrete's performance on roads to examine the mechanism underlying the very durable fly ash pavement concrete's design. The experiments were carried out after (3, 7, 28, 90, 180, and 365) days of curing. Cement is replaced by from different weast, both blast furnace slag and fly ash. It has been established that, if the identical working performance goals are met, optimized fly ash concrete pavement may be utilized in place of asphalt pavement. The percentages of slag substitution by cement are (30%, 40% and 50%) by weight. Mechanical, physical, and environmental properties have been evaluate. The main mechanical properties—compressive and flexural strength were analyses; density and porosity tests were reported and analyses; and an environmental leachate study was conducted.

KEYWORD: Green concrete, flexural strength, slag, fly ash, concrete pavement

1. INTRODUCTION

Production of green concrete for the future will require the adoption of cleaner technologies. The main points to be considered are: reduction of CO2 emissions in the environment, reduction in energy consumption or fuel derived from form the cement manufacturing process is reduction the substances that can endanger health and the environment such as the use of several types of chemicals in concrete mixture [6]. Additionally, most research only conduct experimental experiments to determine the ideal fly ash concrete mix ratio and design, failing to understand how the pore structure of the concrete pavement affects its longevity and capacity to act as a road surface[30][31]. Slag and fly ash are frequently used as mineral admixtures to make concrete that is ecologically friendly. The additions of fly ash and slag provide a number of benefits for the performance of concrete, including better early-age workability, late-age strength, and durability against chloride ingress. However, the addition of fly ash and slag reduces the carbonation resistance of concrete. For the material design of the fly ash and slag is blended concrete in an atmospheric environment, carbonation resistance should be carefully checked [5]. Green concrete capable of sustainable development is characterization by industrial waste application to reduce natural resource consumption, energy and environmental pollution. Fly ash (pulverized ash) is commonly used as a partial cement replacement. Although adding fly ash to concrete has several benefits, it also significantly reduces early strength because fly ash hydrates rather slowly. There are adequate supplies of sustained binders, like as slags, alkaline activated fly ash, or mixtures of these, to take the role of cement. have been shown to develop a higher compressive strength than a similarly composed concrete based on a Portland cement binder and gravel, sand as aggregates.is the increase in work ability of concrete are gives additional benefit to concrete be obtained by the use of these two materials together, and to quantify that benefits. If the experiment is successful, employing the two byproducts in big numbers might be possible, decreasing the need for chemical admixtures. [14] Use of fly ash in the concrete in the right proportions enhances the performance of the material. Fly ash can theoretically replace all Portland cement, however at replacement levels exceeding 80%, 60%, 50%, 40%, 30%, 20%, 10%, we require a chemical activator. The classifications are Class C and Class F. Some Class C fly ash with high calcium content is self-binding; while those without such a high concentration of alumina and silicon have, pozzolanic agents that help them bond. [11]. Due to its rarity and expensive cost, river sand usage must be reduced, and research should be conducted to find an alternative material that has similar features. This would promote sustainability and stop the depletion of river sand, which will cause environmental issues including the loss of estuaries, the drying up of the groundwater supply, soil erosion in riverbeds, and other related issues [23, 24]. Figure 1 depicts fly ash, a high-performance green concrete.

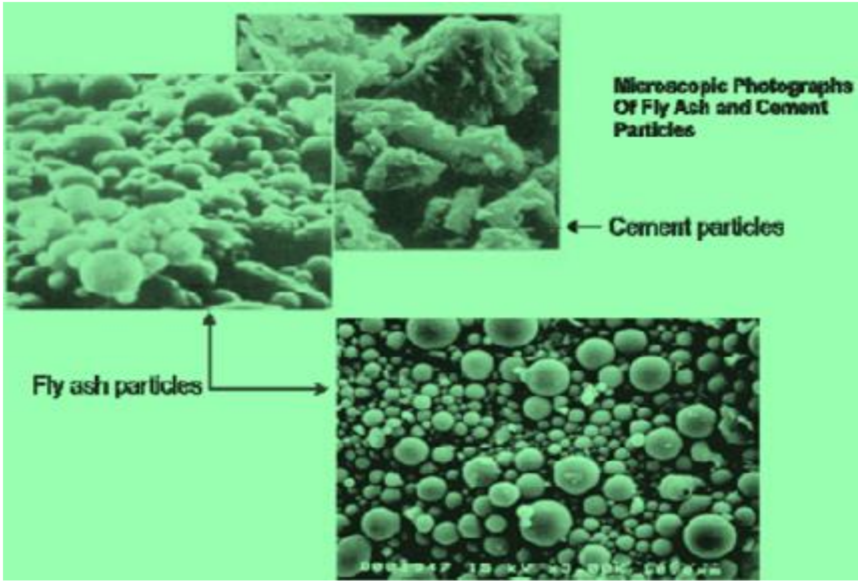

Fig.(1):- Fly Ash a High Performance Green Concrete [24, 25]

It is an excellent cementitious material. Slag is made by crushing molten iron slag, a byproduct of producing iron and steel, in water or steam to create a granular, glassy product, which is then dried and powdered into a fine powder. Similar to fly ash, even (GGBFS) creates less heat of hydration (GGBFS) is also in charge of enhancing the mechanical characteristics and durability of concrete. [1]. The results of the experimental investigation carried out to find the: effect of the (G B S) inclusion on the fresh concrete property, work ability; optimum dose of (GGBFS) as partial replacement of (OPC) in concrete, in respect of the mechanical properties of the hardened concrete (compressive, flexural and split tensile strengths) are presented [3]. Striving for minimal trash and more environmentally conscious pavement design.

2. Literature Review

In todays, the modern world there has been enormous development in the field of “Concrete Technology”. The usage of concrete has increased significantly as a result of this growth in modern living. Cement and aggregate (sand, gravel) make up the majority of concrete, and when combined in the right proportion with water, the resulting substance is known as "concrete." The excessive use of concrete has had an environmental effect both on the use of resources and on pollution. The idea of "Green Concrete" came into being to resolve these consequences. Green concrete is the concrete that replaces one or more of its components with a resource saving material, which ultimately reduces the impact on the environment in terms of both, the use of resources and the joint effects on pollution.

3. Literature Review for green concrete use the slag

The effect of partial replacement of cement with (GGBS) on the strength development of concrete is negatively impacted in this research and healing environments during summer and winter are established. SHAHAB SAMAD defined three levels of cement substitution [1]. , the percentage (30%, 40% and 50%) have been selected. The usage of (GGBS) concrete is restricted because its early-age strength is lower than that of (PC) concrete. Concrete can obtain high early-age strength by containing (GGBS) up to (50%) of it [2] ,A study was conducted to determine the effects of concrete made with high volumes of fly ash (HVFA) and slag [3]. To determine the ideal replacement level of (GGBS), eight concrete mixes including (0, 10, 20, 30, 40, 45, 50, & 55%) of the (GGBS) (weight basis) as cement (OPC) replacement were created [4]. utilized, cement replaces slag at a proportion of 30%, 40%, and 50% (by weight). [5], the aim of this study is to assess the possibility of can applying iron waste in different percentages (6%, 12%, 18%, 24%, and 30%).

3.1 Properties of Fresh green Concrete use slag:-

Concretes made of slag-mixed cement have excellent flow characteristics especially where vibration is used. For a given slump, concrete made with slag cement is easier to place and compact and it is therefore possible to use concrete with a lower slump to exploit this advantage. , and will thereby reduce the water/binder ratio to improve the strength and durability of the concrete. The slump flow of the slag employed in this study rises as the GGBS percentage increases; a 75mm slump is used in the concrete mix design. [10]. Additionally, other studies employed the slag, finding that as GGBS content increased (0 to 55%), the slump increased from 105 mm to 125 mm. [3]. The percentage of slag utilized by the researcher indicates that the slump is increasing. [9]. The findings indicate that as iron waste grew, the slump progressively and marginally lessened. This indicates that concrete has good durability and is workable within a reasonable range. The slump test for all mixing ratios is shown in Figure 2.[4].

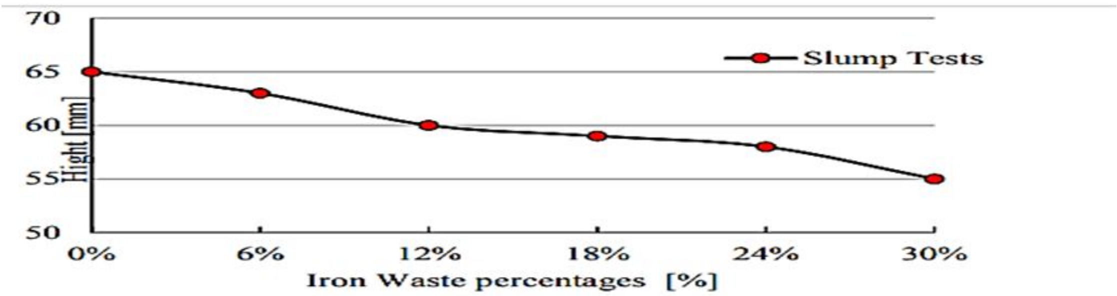

Fig.(2):- depicts the slump test for all mixing ratios[4]

3.2 Properties of Hardened Concrete that use Slag:

Different combinations' compressive strength, split tensile strength, and flexural strength (modulus of rupture) were assessed**.**

3.2.1 Compressive strength:-

Mane researchers used slag produced from construction waste by replacement of Cement with content at curing age of 28 days. (35%,45%) of total cement content at curing age of 28 days. From results researchers concluded that: and use (w/c 0.50) the optimum strength of concrete Mix (30.19N/mm²) having 35%GGBS and strength of concrete Mix (33.16 N/mm²) having 45% GGBS [10]. The specified strength of GGBS concrete at 28 days is greater than PC, which represents the ideal level of cement replaced by GGBS for the specific batch of GGBS used in this research. The researchers used slag produced from construction waste by replacement of Cement with content at curing age of 28 days and use (w/c 0.35) (70PC/30GGBS) is (72.0 MPa), (50PC/50GGBS) is (68.0 MPa, and (100PC-Control) is (77.0 MP [1]. At all ages, the compressive strengths were strengthened by the addition of GGBS. Even at a 55% replacement level, strength increases, but the 40% replacement level (Optimum) with (w/c 0.4) yields the greatest strength gains. Figure 3 Shows that [3].

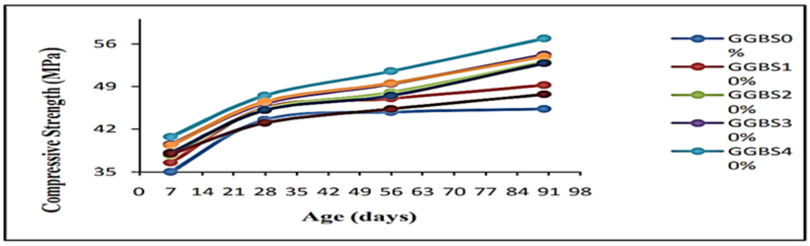

Fig.(3):- GGBS concrete's compressive strength varies with age at various replacement amounts [3]

Also discovered are additional researchers who used slag (GGBFS). Ball milling crushed blast furnace slag into fine powder . Concrete with 30%, 40% or 50% cement replaced with processed slag use (w/c 0.5) and Figure(4) are shows the compressive strength over time and how the GGBF slag effectiveness concrete properties, from(1)day to (90) days of testing[4]

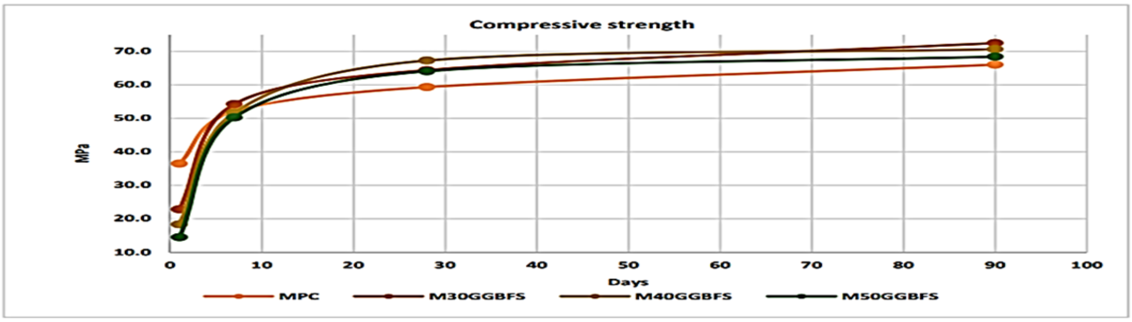

Fig.(4):- Compressive strength GGBFS [4]

used Slag were made with M30 grade of concrete for (w/c 0.45) Compressive strength of Conventional concrete(37.54 N/mm2)and Compressive strength of concrete for Replacement of cement by stainless steel slag with content at curing age 28 days. (25%) is (36.35 N/mm2), 50%) is (33.29 N/mm2), (75%) is (26.42 N/mm2), (100%) is (18.92 N/mm2) [12].

3.2.2. Split Tensile strength.

The researchers used slag produced, casted three cylinders of size (150*300mm). In addition, cured for 28 days. The findings indicate that there is an increase in split tensile with an increase in slag, and that (2.87 N/mm2) with usage of (w/c 0.5) [10]. Researchers also used slag generated; Table 1 provides the findings of the split tensile strength of various concrete mixtures. The range of (0.087-0.104) represents the split tensile strength to compressive strength ratio of various blends at 28 days [3].

Teble(1):- The relationship between the split tensile strength and compressive strength of various blends[3]

Replacement level (%)	Compressive Strength (MPa) 28days	Split Tensile Strength (MPa) 28 days	Value of 'n'	
			From Eq. 3	From Eq. 4
0.0	43.5	3.85	0.676	0.784
10.0	44.5	3.92	0.677	0.783
20.0	45.3	4.12	0.687	0.793
30.0	46.2	4.41	0.701	0.807
40.0	47.5	4.93	0.725	0.830
45.0	46.5	4.52	0.706	0.812
50.0	45.1	4.15	0.689	0.796
55.0	43.0	3.81	0.675	0.783

3.2.3. Flexural Strengt.

In this study, researchers used slag produced were casted and cured for 28 days for every combined replacement of GGBS the flexural strength increases [10].

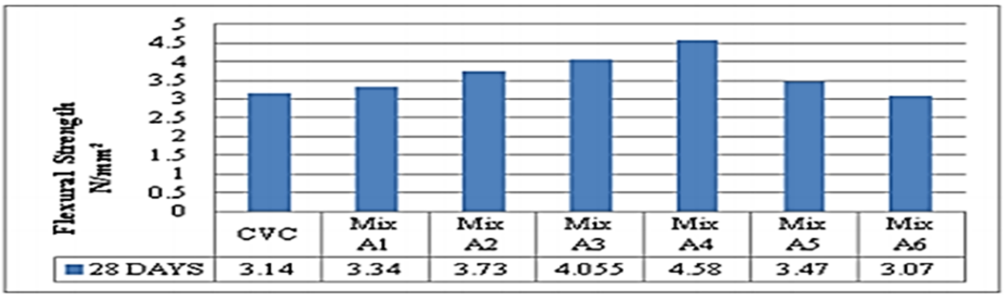

Fig.(5):- M12 Grade of CVC with a mix of AI and A flexural strength [10]

The researchers also employed slag. For each concrete mix, a flexural test was carried out after curing in three curing regimes for 28 days; the results showed that the replacement GGBS (70PC/30GGBS) and (50PC/50GGBS) flexural values were both 7.0 MPa [1]. The replacement of GGBS at age 28 days is 9.3 MPa, 40.0% is 9.5 MPa, 45.0% is 9.1 MPa, 50.0% is 8.4 MPa, and 55.0% is 8.1 MPa, according to the findings of flexural strength tests [3]. Used slag the results obtained for 28 and 90 days The flexural strength results obtained at the age of 28 days, the replacement of GGBS(30%) is (8.46 MPa),(40%) is (8.56 MPa),(50%) is (8.99)and Flexure strength test at 90 days. the replacement of GGBS(30%) is(10.37MPa),(40%) is (10.61 MPa),(50%) is (11.04 MPa)[4].

4 The literature review for green concrete makes use of fly ash.

Fortunately, there are a variety of standards that investigate and outline the types and characteristics of fly ash used as an additive in concrete. American Society for Testing and Materials (ASTM) developed the first version of the standards for using fly ash more than 40 years ago, which was ASTM C 618. This demonstrates the value and acceptance of fly ash as a pozzolanic component in concrete. Based on ASTM C 618-17a [6], Fly ash is mostly a fine residual substance that is carried by air following the combustion of powered or pulverized coal. Therefore. The characteristics of fly ash are largely influenced by raw coal. According to ASTM C 618, fly ash may be divided into three separate categories: Class N, Class F, and Class C. This categorization is mostly based on the ash that is produced and its chemical make up .

4.1 Properties of Fresh green Concrete use fly ash

Particles of fly ash are generally spherical in shape and reduce the need for water for a given slump. The spherical shape helps reduce friction between aggregates and between concrete and pump line, thus enhancing the workability and improving concrete pump ability. The use of fly ash in concrete increases volume of fine dust and lowers the water content and reduces concrete bleeding.

According to this study, fly ash in concrete generally improves the workability of fresh concrete, reduces bleeding, lowers the hydration temperature, reduces the permeability of hardened concrete, and increases the concrete's resistance to chemical effects [20]. The other the researcher found that fly ash is reduces the workability of fresh concrete. In order to ensure consistent workability, water-reducing super-plasticizer is utilized in FA concrete [11]. The researcher found when use the fly ash is makes concrete workability much better and increases the durability and strength of hardened concrete. Lastly, it might lessen the amount of water added to the combination. [22]. in this research, the researcher found that fly ash is the workability within the range of 55−65 mm [19]. When compared to Portland cement concrete of the same slump, the fly ash is a well-balanced fly ash concrete mixture will have enhanced workability. When vibrated, ash flows and consolidates concrete in a particular slump better than traditional Portland concrete. Fly ash use is another. increases concrete's cohesion and decreases segregation [18]. In this research, the researcher found that is using fly ash improves concrete mixture workability [6]

4.2 Properties made of hardened concrete make use of fly ash

Different combinations' compressive strength, split tensile strength, and flexural strength (modulus of rupture) were assessed

4.2.1. Compressive strength.

In this research, It should be mentioned that the FA fineness has an impact on the pozzolanic action of FA and the development of concrete compressive strength at young ages[26,27[. the researcher used the fly ash compressive strength from 28 days, used fly ash a partial replacement of(25%) is (34.31 N/mm2),(50%) is (39.21 N/mm2)[20]. And the researcher used the fly ash compressive strength from 28 days, Control is(31.6 MPa) and replacement of(20%) is(33.7 MPa),(40%) is (27.8 MPa)[12]. used the High-Volume fly ash compressive strength from 28days of HVFA(65%) and use (w/c 0.4) is (41.5 MPa),(80%) use (w/c 0.35) is (28.7 MPa)[19]. A fly ash concrete mix will often build strength more slowly as it ages, even if it is intended to function similarly to conventional concrete at normal ages [25].

Table (2):- Comparative Strengths and Age (Days) Experimental Analysis [25]

MIX	7 Days in N/mm^2	28 Days in N/mm^2	56 Days in N/mm^2	90 Days in N/mm^2	180 Days in N/mm^2
MIX A (Plain Concrete)	19.25	34.31	45.23	54.91	59.10
MIX B (Fly Ash Concrete)	19.23	39.21	54.23	64.80	75.73
MIX C (PP+Fly ash Concrete)	19.27	44.58	63.61	75.63	86.31

The other researchers used the fly ash in compressive strength from 28 days, used fly ash a partial replacement of(20%) with (w/c 0.4) is (48.96 MPa)&(30%) with (w/c 0.35) is(45.10 MPa)[16]. The researcher used the fly ash in compressive strength from 28 days, used fly ash a partial replacement of **(33%) is (35** MPa),(20%) is (25 MPa**)[18].** In this research, the researcher used the fly ash compressive strength from 28 days, used fly ash a partial replacement of(**20%) with (w/c 0.35)is (38**MPa)[5]. The researcher used high volume fly ash (HVFA) concretes with cement replacement levels 65% (HVFA–65) and 80% (HVFA–80). In her work and obtained, the results of the compressive strength test as shown in the table (3) [28].

Table(3):- Strength Activity Index (%) [28]

Duration	HVFA–65	HVFA–80
3 days	41.6	19.6
7 days	44.2	25.7
28 days	70.3	46.9
90 days	76.5	57.7

Additionally, despite the durability of standard pavement concrete meeting design specifications, its overall functionality may still be subpar because to an inconsistent pore-size distribution. Figure 6 depicts the mechanical characteristics, and Table 4 lists the testing findings for the durability

indicators the compressive strength [32].

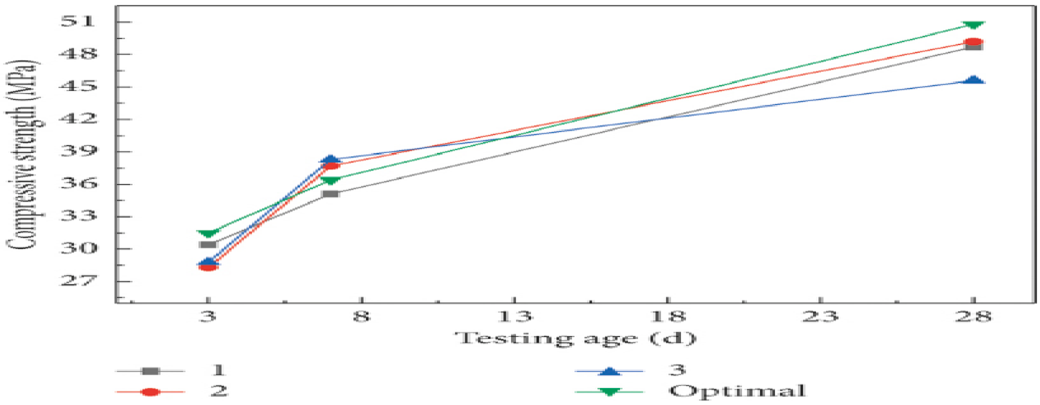

Fig.(6):- Mechanical properties of the contrast groups[32]

Table (5):- . The durability of contrast groups[32]

Group	Durability		
	Impermeability grade	D_{RCM} ($^*10^{-12}$ m^2/s)	Electric flux (c)
1	P10	8.0	2218
2	P8	8.4	2399
3	P10	8.9	2436
Optimal	P12	6.9	1828

4.2.2. Split Tensile strength.

To achieve concrete with a 28-day split tensile strength, cylinders were created

Split Tensile Strength = 2P/3.14DL

Where, P = Applied Load, D = Diameter of the Specimen, L = Length of the Specimen.

Table (5):- Split tensile strength test using a 5%, 10% combination of tea waste and fly ash in place of cement [29]

Days	0% Replacement	5% Replacement	10% Replacement
28	3.09	3.11	2.18

We can see that using 5% of fly ash and tea trash as a replacement for cement results in greater strength after obtaining the best results from compressive strength and split tensile strength tests. The durability test will now be conducted using the ideal amount of fly ash and tea debris [29]. In this research, the researcher used the fly ash in Split Tensile strength from 28 days is found replacement of (20%) is (1.2MPa)[5]. And the other researcher used the fly ash in Split Tensile strength from 28 days ,the Control is (2.6 MPa) found replacement of

(20%) is (2.4 MPa),(40%) is (1.75 MPa),(60%) is (1.27 Mpa)[11]. the researcher used the fly ash in Split Tensile strength from 28 days is found replacement of (60%) is (1.14).

4.2.3. Flexural Strength

n this research, the researcher used the fly ash in Flexural Strength from 28 days**,** found is replacement of(20%) is(2.2 MPa**)[6].** the researcher used the fly ash in Flexural Strength from 28 days ,the Control is(6.3 MPa**),** found replacement of(20%) is (6.5 MPa**),**(40%) is (4.5 MPa**)**,(60%) is (3.4 MPa)[12].And the researcher used the fly ash in Flexural Strength from 28 days found is replacement of(20%) is(3.02 MPa),(30%) is (3.55 MPa)[17]. The ability of the road to resist bending may be directly determined The ability of the road to resist bending may be directly determined by its flexural strength. The national standard stipulates that pavement concrete must have a flexural strength of at least 5 MPa that show in figur (7) [32].

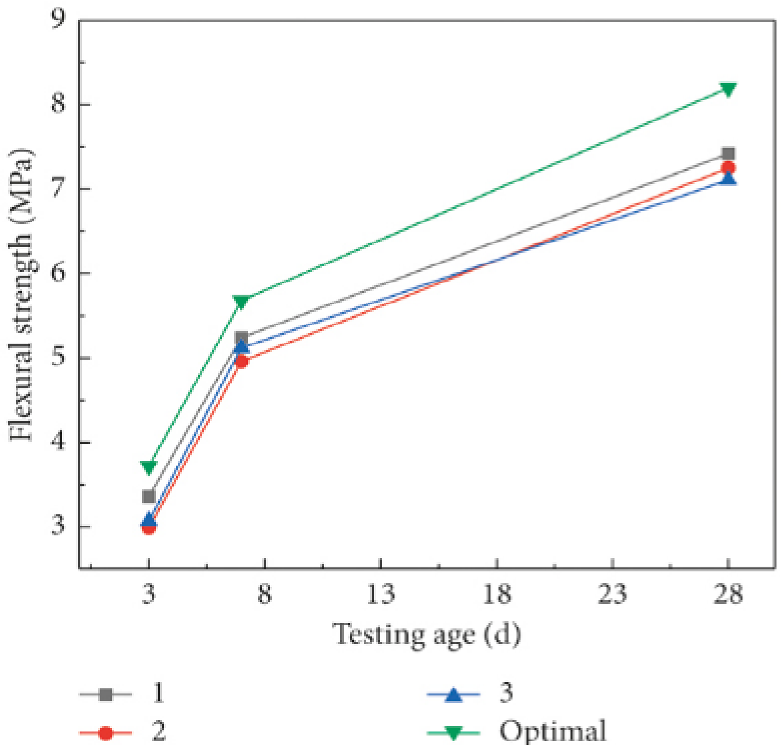

Fig.(7):- Mechanical properties of the contrast groups [32]

5. CONCLUSIONS

1- In this study, a review of the literature has been given to show the advantages of utilizing green concrete and several materials that may be used in lieu of cement and aggregates, such as fly ash and slag. The most important benefit of using industrial wastes in green concrete is that it preserves natural resources for future generations. In order to improve the concrete's characteristics and lessen its detrimental environmental impact, further measures were taken in the creation of green concrete.

2-The mixes and strength are influenced by the slag's chemical properties. This study found that for crucial components like SiO2, the strength decreased as the percentage increased.

3- When OPC is partially replaced by GGBS, the workability of the mixtures improves and is dependent on the replacement level.

4- At every level of replacement, the mechanical properties—compressive strength, flexural strength, and split tensile strength—increase.

5-When compared to the other cube curing techniques used, the compressive strength of the Green Concrete (under steam curing) is exceptionally high. It has been discovered that the strength obtained by the green concrete cubes during steam curing is 10% larger than that achieved during testing on cubes submerged in water.

6- FA and slag waste byproducts showed increased mechanical and durability qualities in concrete.

7- The primary objective of this project is to conduct research on various wastes and their potential use in concrete paving. Currently, one of the biggest sources of concern is the cost of construction materials.

8- Concrete made with fly ash has advantages in terms of cost, durability, and the environment.

9- However, the early strength of concrete is reduced by the inclusion of FA. The primary factors causing the strength development rate are the chemical compositions, shape, and fineness of FA.

10- The change in compressive strength and fracture toughness under tension are both strongly impacted by the FA addition at 20% and 30% of the cement's mass, respectively.

11- In any event, if the concrete is subjected to any load less than three days after the manufacture of the concrete mixture, it is not advised to use concretes with 20% and 30% FA addition.

12- The research's findings show that large volume fly ash in concrete can generate compressive strengths that are equivalent to design strengths, particularly for high strength concrete. Additionally, the combination of high strength concrete and 50% replacement fly ash is the ideal mix percentage to reach the design strength.

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