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Improving of Concrete's Performance by Using Mineral Additive

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ABSTRACT

This research scrutinize the effects of combine slag waste (Ground Granulated Blast Furnace Slag; GGBS) or/and fly ash or and Silica fume as cement surrogate in performance of concrete. GGBS or/and fly ash was used in different replacement ratios (15%, and 30%) while Silica fume was used by replacement ratio (10, and 20) %. The water cement ratio was constant for all mixes (w/c= 0.4) and high range water reducer chemical admixture Type F was used with variable ration (1-1.3% from cement) to keep the slump constant as control mix "in absent of mineral additive" it was 100 mm after mixing.Resulting properties of the developed concretes were evaluated. Compressive, tensile and flexural strength, for evaluating hydration attributes of the resulting concretes at ages 1, 3, 7, 28, and 56 days. The optimum ratio of GGBS, Fly ash, and Silica Fumeas cement replacement has been determined, in this study.

Results revealed that used of fly ash and GGBS recorded improvement in concrete strength and using silica fume as cement replacement by 10-20% lead to produce early strength concrete within 3 days.

Keywords: concrete; cement; slag, fly ash, silica fume, blending ratio; compressive strength; Early Strength.

I. INTRODUCTION

A serious problem is the steadily rising quantity of industrial trash brought on by the fast industrialization and urbanization of the world.One area of research that is constantly expanding is managing such wastes properly and efficiently. From a sustainability perspective, the use of natural resources to construct constructed environments has further caused major difficulties (Hanif et al., 2011; Shi et al., 2015). Just cement accounts for 5% of the world's total carbon dioxide emissions (Hanif, 2017; Lee et al., 2018; Naik and Moriconi, 2005), Utilizing suitable industrial wastes as supplementary cementing materials (SCM) is one way to address both of the aforementioned problems. By doing so, some cement can be replaced with any of these suitable materials, which will reduce the amount of cement needed and consequently reduce greenhouse gas emissions. Some additional benefits include lowering the dumping loads for landfills and making significant cost savings that enhance the economy. These advantages add up to the three pillars of "sustainability," which are societal acceptability, economic viability, and environmental bearing.
Slags, which have pozzolanic qualities, are among the many industrial wastes. They include suitably fast-cooled iron blast furnace slag, steel slag, phosphorus slag, copper slag and lead slag (Shi and Qian, 2000).
Several studies have examined the various characteristics of concretes made by substituting GGBS for cement in varying doses, including mechanical and durability-related characteristics. High

quantities of GGBS have also been included in an effort to significantly lower the cement usage in the manufacturing of regular concrete due to its promising effects on the mechanical characteristics and durability of concrete. (Further positive outcomes have been attained, further promoting the usage of GGBS in concrete (Gholampour and Ozbakkaloglu, 2017) and reactive powder concrete (Yazici et al., 2010). However, it's crucial to remember that the qualities of the resultant concrete depend on the GGBS's reactivity in concrete, which is connected to the slag properties, which might vary depending on the source of the slag, the kind of raw materials utilised, the process, and the cooling pace (Pal et al., 2003).

Whereas the appropriateness of GGBS in concrete has been thoroughly assessed by a number of published research, these are exclusively targeted at concrete made with ordinary Portland cement (OPC) as the binder. These studies on concretes including GGBS and fly ash as SCM. There have been no research focused on the impacts of adding GGBS or fly ash to precast concrete, which has a high early strength for a faster setting time and improved hydration rate, allowing for quick production and effective structural usage. By examining the hydration parameters of concrete including GGBS or/and fly ash as an additional cementing agent, the current work seeks to close these knowledge gaps (SCM).

This experimental study closes the existing research gap by investigating the possibility of employing GGBS or/and fly ash as SCM in the production of high early strength concrete so that it may be able to withstand a larger percentage of the design load at beginning stages of its life.

Dr. Sergio F. Brea et al. (2018) investigated the production of high early strength concrete for expedited bridge building close pour connections. Because of the reduced on-site operations, accelerated bridge building (ABC) has proven popular with existing bridge deck replacement and even certain new bridge construction projects. The primary purpose of this research effort was to design and test concrete mixes that acquire high early strength without sacrificing long-term performance. The compressive strength achieved by experimental batch concrete mixes in 12 hours ranged from 1000 to 5900 psi.In the next 12 hours, the compressive strength grew by an average of 2000 psi, and after 24 hours of curing, it was between 3800 and 7600 psi. The compressive strength after seven days of curing ranged from 6500 to 9400 psi, giving rise to an average compressive strength of 8000 psi for the whole seven-day period. The range of compressive strength after 28 days of curing was 7500 to 12000 psi, resulting in an average compressive strength of 10,000 psi after 28 days. The compressive strengths produced by these ranges are around 36, 55, and 80% of the 28-day compressive strength attained at 12 hours, 24 hours, and 7 days.

Industry byproducts like fly ash have been widely used to partially replace cement in concrete and other cementitious materials due to the benefits they provide on both the economic and environmental fronts. The main disadvantage of using more fly ash to replace cement is that the fly ash's sluggish pozzolanic reaction results in cement paste that has poor early age strength.

Using high performance basalt fibre concrete, Yao Dongdong (2020) investigated the impact of quartz sand on compressive strength. The production of HSC with a high compressive strength may be achieved by combining Portland cement 52.5, fly ash, silica fume, short-cut basalt fibre, polycarboxylate superplasticizer, and quartz sand.

High-strength concrete using ternary binder with high pozzolan content was the subject of a technical study by PavlaRovnanková et al. (2018).

It is established that high strength concrete will be manufactured utilising these ingredients—Portland Cement, Micro Silica, Silica Flour, Ceramic Powder, Super-plasticizer, and Aggregates.

II. MATERIALS

The aggregates were graded in line with EN 12620. 32 mm is the stated maximum aggregate size. Natural siliceous sand was examined for use as fine aggregates. According to EN 933-1 specifications, the physical and mechanical properties of both fine and coarse aggregates were assessed and regulated. The measured values were presented in Table No. (1).

Table 01 Properties of coarse and fine aggregate.

Specimen	*Specific weight*	*Volumetric weight (Kg/m^3)*	*Absorption %*	*Fine Particles %*	*Crushing Value %*	*Coefficient of Absorption %*
Dolomite	2.7	1.55	0.31	1.8	19.3	22.5
Sand	2.6	1.46	0.57	1.2	-	-

CEM I 42.5N compatible with Egyptian standard 4756-1 was used in all mixes Table No. (2)Showed cement properties.

Table 2 Properties of Cement.

Properties		Measured Values	Limits of the E.S.S*
Fineness (cm2/gm)		*3500*	
Specific Gravity		*3.15*	
Expansion (mm)		*1.2*	*Not more than 10*
Initial Setting Time (hrs : mins)		*1 : 40*	*Not less than 60 min*
Initial Setting Time (hrs : mins)		*3 : 20*	
Compressive strength (N/mm2)	*2 days*	*18.6*	*Not less than 10*
	7 days	*33.7*	
	28 days	*47.8*	*Not less than 42.5 and not more than 62.5*

High efficiency class F pozzolanic material confirming to EN 450, BS 3892, IS 3812 and ASTM C618, obtained by selection and processing of power station fly ashes resulting from the combustion of pulverized coal. As shown in Tables No. (3), (4), and (5)

Table 3 Physical Properties of Fly Ash

Presentation	*Finely divided dry powder*
Color	*Light grey*
Bulk Weight (t/m^3)	*0.90*
Specific density	*2.30*
Particle size	*90% < 45 micron*
Particle shape	*Spherical*

Table 03 Physical Properties of Slag

Specific Gravity	*2.80*
Bulk Density (t/m^3)	*1.15*
Specific Surface (cm^2/gm)	*4088*
Particle Size	*96% < 45 micron*
Insoluble Residue (%)	*1.40*

Table 4 Chemical Properties of Fly Ash & Slag& Silica Fume

Oxide (%)	Cao	SiO_2	Al_2O_3	MgO	Fe_2O_3	TiO_2	MnO	SO_3	K_2O	Na_2O	P_2O_5	L.O.I.	S
FA	2.35	59.05	23.3	1.85	4.84	1.03	0	0.65	1.82	0.91	0.73	3.47	-
Slag	36.87	35.4	17.4	6.83	1.4	0.11	0.35	-	-	-	-	-	0.24
Silica Fume	0.98	95.2	-	0.431	1.00	-	-	0.02	1.03	0.91	-	0.429	-

Each trial batch of concrete was mixed with a high-range water reducer (HRWR) Type F admixture, which complies with ASTM 494, to increase workability. In order to keep the constructability of the concrete within allowable bounds, HRWR was required due to the high cement content and low w/cm ratios.

III. EXPERIMENTAL METHODS

According to ACI mix design rules, the mix was created using a notional maximum aggregate size of 20 mm and a reference slump of 80-100 mm. The workability, aggregate volumes, and water/cement ratio (W/C) that were chosen to be suitable to validate each variable in this study. The specifics of the mix proportions are shown in Table No. (6).

Table 6 Mix design for all mixes

Mix	Water (l/m^3)	Cement (Kg/m^3)	Fly Ash (Kg/m^3)	Slag (Kg/m^3)	Silica Fume (Kg/m^3)	Sand (Kg/m^3)	Aggregate (Kg/m^3)	Type F (l/m^3)
M1	200	500	0	0	0	600	1200	12
M2		425	75	0	0	590	1180	
M3		350	150	0	0	580	1160	
M4		425	0	75	0	590	1180	
M5		350	0	150	0	580	1160	
M6		350	75	75	0	580	1160	
M7		450	0	0	50	595	1190	
M8		400	0	0	100	585	1170	

ASTM C 192 was followed for mixing and casting techniques, although certain modifications took field practises into account for ready mix operations. The components and ambient (laboratory) temperatures were tightly regulated during the fabrication of each specimen to ensure a consistent environment for all the cast specimens.

Fresh concrete was formed into cubes with 150 mm side length moulds (for compressive strength tests), cylinders with 150 300 mm side length moulds (for splitting tensile strength tests), and prisms with 100 100 500 mm side length moulds (for splitting tensile strength tests) (for flexural strength tests). The specimens were demolded 24 hours after casting and cured in water until testing age.

Following curing, all specimens were evaluated at 1, 3, 7, 28, and 56 days.

This investigation aims to improve concrete properties for mix design (M1) which considers as control mix its cement content is 500 kg/m^3 with w/c ratio is 0.40, by using fly ash or/and GGBS with several contents. Also, silica fume with several contents were used, the replacement percentages were obtained from previous studies that the rang of fly ash and slag were between 15-30% while silica fume was 10-20% toinvestigate the performance of concrete's properties.

To obtain the investigation objective the experimental program design and consisted of 4 groups. First group (I) consisted of 3 mixtures include control mix (M1) and other concrete mixes with different fly ash ratio (15, and 30) % as replacement of cement (mixes M2, and M3) respectively. Second group (II) consisted of 3 mixes include control mix (M1) and other concrete mixes with different GGBS ratio (15, and 30)% as replacement of cement (mixes M4, and M5) respectively.Third group consisted of 6 mixes include control mix (M1) and other mixes with different mineral admixture types Fly ash or/and GGBS M2, M3 with 15, and 30% fly ash respectively, M4, and M5 with 15, and30 % GGBS respectively, and M6 with (15% fly ash + 15% GGBS). Last group (IV) consisted of 3 mixes include control mix (M1) and other concrete mixes with different Silica Fume ratio (10, and 20)% as replacement of cement (mixes M7, and M8)

IV. RESULTS AND DESCUSION

The results of hardened concrete properties for studied groups shown in figures 1, 2, 3,….., and 12. Effect of fly ash content shown in figures 1, 2, and 3, while effect of GGBS shown in figures 4,5, and 6. Also, effect of using silica fume with several contents were shown in figures 7, 8, and 9. Finally effect of using fly ash with GGBS were shown in figures 10, 11, and 12

Results of concrete mixes:

The study of concrete mix test results and the effect of adding deffirant types of mineral additives such as fly ash, GGBS, and silica fume with various percentages as replacement of cement content resulted in the following: -

M1 (control mix):

- Control mix was designed to produce concrete with characteristic compressive strength equal 30 N/mm^2
- The test results for control mix shown in figures
- The goal of this study is to improve the mechanical qualities of control mix by utilising mineral additions.

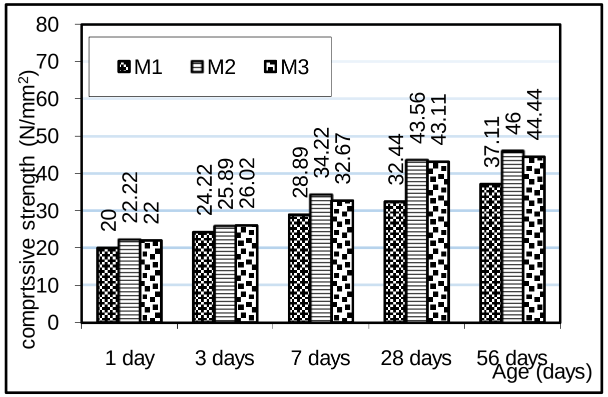

Figure (1) Effect of Fly Ash Percentage on Compressive Strength for Group I

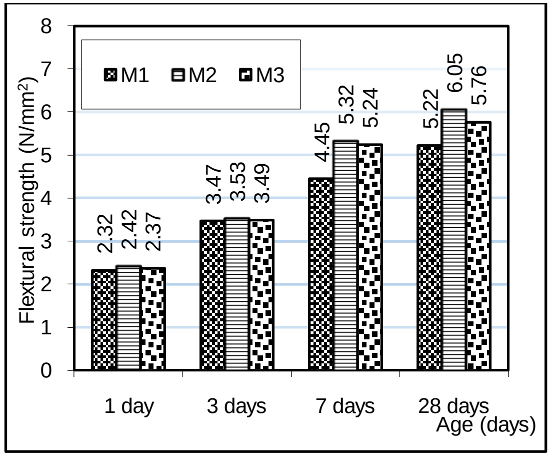

Figure (2) Effect of Fly Ash Percentage on Flexural Strength for Group I

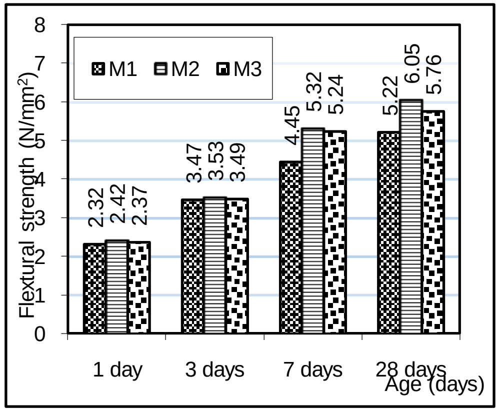

Figure (3) Effect of Fly Ash Percentage on Indirect Tensile Strength for Group I

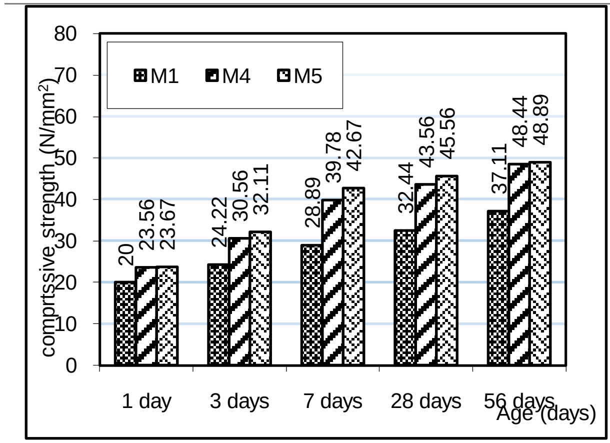

Figure (4) Effect of GGBS Percentage on Compressive Strength for Group II

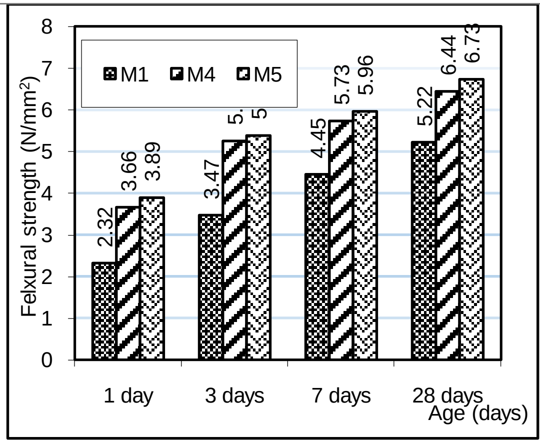

Figure (5) Effect of GGBS Percentage on Flexural Strength for Group II

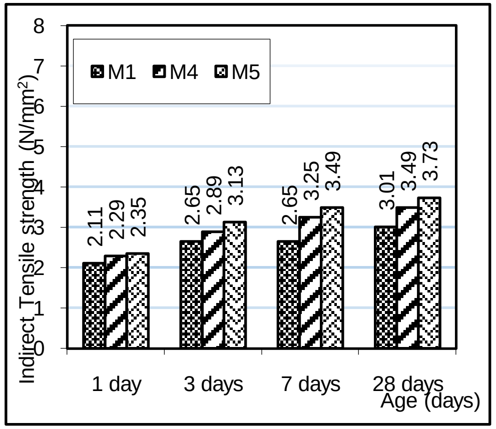

Figure (6) Effect of GGBS Percentage on Indirect Tensile Strength for Group II

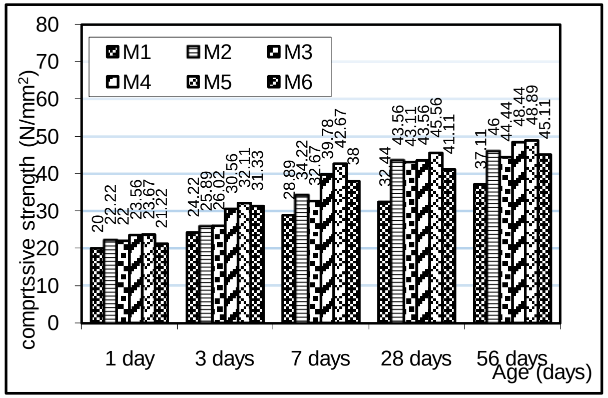

Figure (7) Effect of Fly Ash and GGBS Percentage on Compressive Strength for Group III

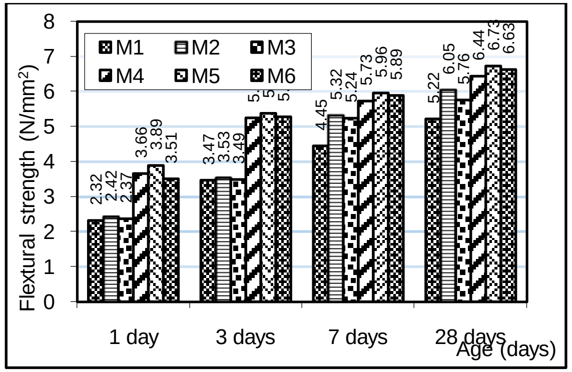

Figure (8) Effect of Fly Ash and GGBSPercentage on Flexural Strength for Group III

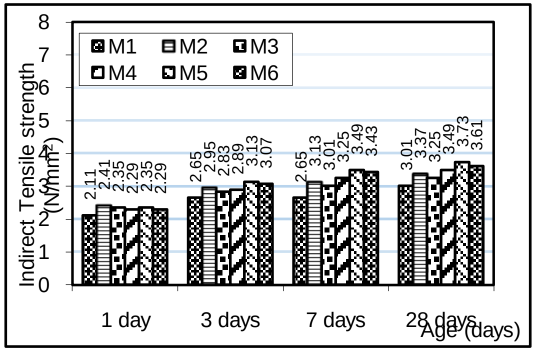

Figure (9) Effect of Fly Ash and GGBSPercentage on Indirect Tensile Strength for Group III

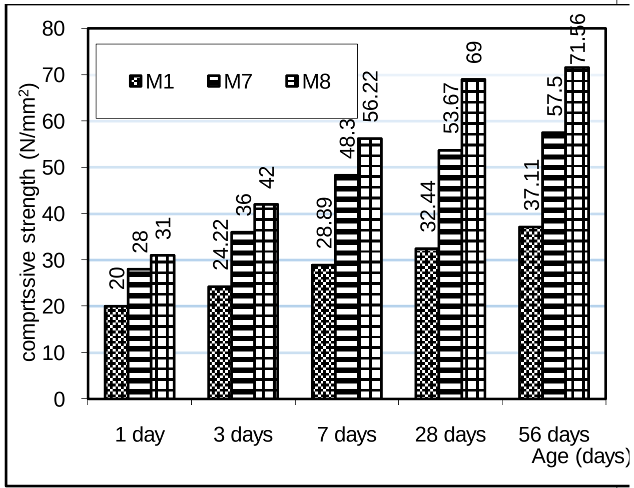

Figure (10) Effect of Silica Fume Percentage on Compressive Strength for Group IV

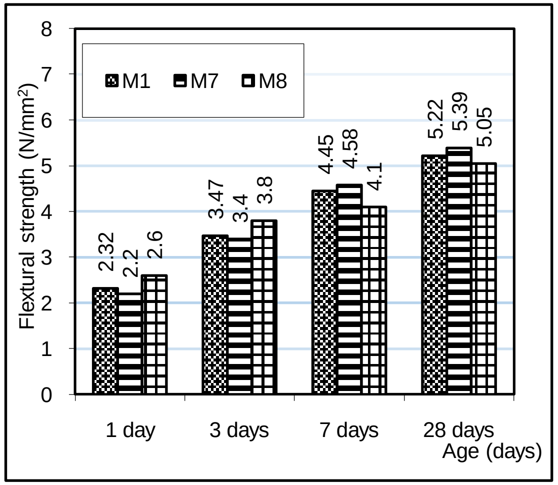

Figure (11) Effect of Silica FumePercentage on Flexural Strength for Group IV

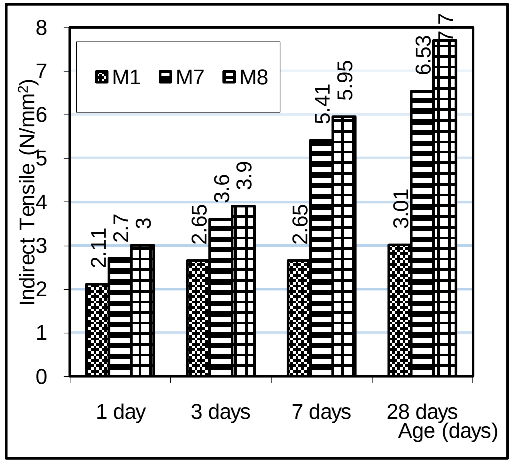

Figure (12) Effect of Silica FumePercentage on Indirect Tensile Strength for Group IV

M2 (using 15% fly ash as replacement of cement):

- The compressive strength was increased by about (11.1, 15.1, 18.4, 28.1, and 38)% at ages 1, 3, 7, 30 and 56 days respectivily when compared with control mix M1
- The flextural strength was increased by about (4.31, 8.2, 10.55 and 15.9)% at ages 1, 3, 7 and 28 days respectivily when compared with control beam M1
- splitting tensile strength was increased by about (3,5, 7.6, 8.5 and 14.7)% at ages 1, 3, 7 and 28 days respectivily when compared with control beam M1.

M3 (using 30% fly ash as replacement of cement):

- The compressive strength by (10, 11.6, 16.5, 29 and 32)% at ages 1, 3, 7, 30 and 56 days respectivily when compared with control mix M1.
- The flextural strength by (3.5, 7.6, 8.5 and 14.7)% at ages 1, 3, 7 and 28 days respectivily when compared with control beam M1.
- splitting tensile strength by (3.8, 10.6, 11.6, and 13.6)% at ages 1, 3, 7 and 28 days respectivily when compared with control beam M1.
- M2 and M3 recorded strength after 7 days almoste equale to the strength of M1 after 28 days.

As shown in figures No. 1,2,and 3

- The impact of utilising fly ash in hardend concrete parties is more obvious at ages 28, and 56 days compared to earlier ages (1,3, and 7 days), which is related to the pozlanic reaction of fly ash.
- Using fly ash as cement repleasment have significant increasing in strngth of concrete mix. on the other hand increaing in fly ash content from 15 % to 30% recorded decreasing in the improvement of using fly ash as cement replacement in concrete mix

M4(using 15% GGBS as replacement of cement):

- The compressive strength was increased by about (12.8, 17.9, 23.9, 28.1, and 38.6)% at ages 1, 3, 7, 30 and 56 days respectivily when compared with control mix M1
- The flextural strength was increased by about (6, 9.8, 13, and 23.4)% at ages 1, 3, 7 and 28 days respectivily when compared with control beam M1
- splitting tensile strength was increased by about (8.5, 12.8, 14, and 15.9)% at ages 1, 3, 7 and 28 days respectivily when compared with control beam M1.

M5 (using 30% GGBS as replacement of cement):

- The compressive strength by (13.3, 20.2, 26.9, 31.2, and 42.5)% at ages 1, 3, 7, 30 and 56 days respectivily when compared with control mix M1.
- The flextural strength by (7.3, 12.9, 15.9, and 28.9)% at ages 1, 3, 7 and 28 days respectivily when compared with control beam M1.
- splitting tensile strength by (11.4, 14.4,17.2, and 20.6)% at ages 1, 3, 7 and 28 days respectivily when compared with control beam M1.
- M4 and M5 exhibited more strength after 7 days than M1 did after 28 days.

As shown in figures No. 4,5,and 6

- The effect of using GGBS in hardend concrete proparties is more clear at age 28, and 56 days compared with early ages (1,3, and 7 days), this is attributed to the pozlanic reacteation of GGBS.

- Using GGBS as cement repleasment have significant increasing in strngth of concrete mix. on the other hand increaing in GGBS content from 15 % to 30% recorded increasing in the improvement of using GGBS as cement replacement in concrete mix

M6 (using 15% Fly ash+ 15 % GGBS as replacement of cement):

- The compressive strength increased by (16.1, 19.5, 24.6, 26.7, and 29.6)% at ages 1, 3, 7, 30, and 56 days as compared to the control mix M1.
- Flextural strength increased by (6, 10.4, 14.4, and 19.3%) at ages 1, 3, 7, and 28 days as compared to control beam M1.
- Tensile strength splitting increased by (8.5, 15.1, 16.8, and 18.9%) at ages 1, 3, 7, and 28 days as compared to control beam M1.
- M2 and M3 strength after 7 days was nearly equivalent to M1 strength after 28 days.

As shown in figures No. 7,8,and 9

- Applying GGBS reported rising in concrete strength more than fly ash.
- The effect of utilising fly ash and/or GGBS on compressive strength was more obvious than its influence on flextural and indirect tensile strength.

M7(using 10% silica fume as replacement of cement):

- The compressive strength was increased by about (15.5, 23.9, 32.6,39.1, and 42.3)% at ages 1, 3, 7, 30 and 56 days respectivily when compared with control mix M1
- The flextural strength was increased by about (7.7, 13.6, 16.4, and 32)% at ages 1, 3, 7 and 28 days respectivily when compared with control beam M1
- splitting tensile strength was increased by about (12.3, 16.7, 19.7, and 40.8)% at ages 1, 3, 7 and 28 days respectivily when compared with control beam M1.

M8 (using 20% silica fume as replacement of cement):

- The compressive strength by (17.5, 25.9, 35.4, 42.4, and 47.8)% at ages 1, 3, 7, 30 and 56 days respectivily when compared with control mix M1.
- The flextural strength by (10, 15.1, 16.8, and 33.1)% at ages 1, 3, 7 and 28 days respectivily when compared with control beam M1.
- splitting tensile strength by (11.5, 20.7, 24.2, and 45.8)% at ages 1, 3, 7 and 28 days respectivily when compared with control beam M1.
- M7 and M8 recorded strength after 3 days near the strength of M1 after 28 days.

As shown in figures No. 10,11,and 12

- The effect of using silica fiume in hardend concrete proparties is more clear at age 28, and 56 days compared with early ages (1,3, and 7 days), this is attributed to the pozlanic reacteation of GGBS.
- Using silica fiume as cement repleasment have significant increasing in strngth of concrete mix. on the other hand increaing in GGBS content from 10 % to 20% recorded increasing in the improvement of using GGBS as cement replacement in concrete mix
- Silica fume has more effect on the hardend concrete proparties than fly ash and GGBS

V. CONCLUSIONS

The present study showed that fly ash, slag and silica fume can be successfully used for enhancing improvement in concrete strength. The experimental study on the compressive, flexural and splitting tensile strengths led to the conclusions summarized below:

1. All admixtures fly ash, slag and silica fume affected in the strengthening and acquisition of some mixtures their early strength when tested after 3 and 7 days of treatment.
2. Adding fly ash of 15 % (M2)or 30 % (M3) results an increase in early strength and the strength at age 7 days near the 28 days strength for control mix (M1).
3. Using 15 % slag in mix (M4) or 30% slag (M4); resulted the target strength of control mix (M1) after 7days only
4. Generally, slag give strength more than fly ash.
5. Silica fume has more effect on strength than fly ash and slag
6. Silica fume can used to produce early strength concrete after 3 days
7. Using mineral additives such as fly ash , slag type GGBS, and silica fume improve the hardened properties of concrete

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