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A Research on study Behaviour of Concrete by Partial Replacement of Cement with Metakaolin and GGBS

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ABSTRACT

Concrete has been used as a major construction material for many decades. With the rapid increase in the infrastructure of our country there is a need to upgrade concrete properties by incorporating various materials in the design mix. Hence a lot of research work is being carried out for this purpose. There is nascent concern in the use of supplementary cementing material as production of binary and ternary concrete matrices. This study presents the effect of incorporating Metakaolin (MK) and Silica Fumes (SF) on strength parameter of ternary pavement concrete blending cement (CEM) with Ground Granulated Blast Furnace Slag (GGBS) for a constant water/binder ratio of 0.33. Twenty-two mixtures prepared by replacing of cement with GGBS (20%, 40%, and 60%), SF (10%, 15%, and 20%) and MK (10%, 15%, and 20%) were designed for target strength 48 Mpa. From the results, it was observed that 45% replacement of cement with GGBS in binary blend concrete (Cement + GGBS) show optimum level in terms of compressive strength at 28 days and also 56 days, beyond the 45% replacement level strength decreases. In ternary blend concrete mix S40MK15 (CEM-40%, GGBS-40% & MK-15%) and S40SF15 (CEM-40%, GGBS-40% & SF-15%) shows the optimum strength. Splitting tensile strength and flexural strength values have also followed the same trend. Finally this study concludes that the ternary concrete blends cement with 40% GGBS and 15% MK show the desired properties which is almost equal as compared to the ternary concrete blends cement with 40% GGBS and 15% SF. Hence both of these mixes can be used economically depending upon their availability.

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INTRODUCTION

There is emergent interest in the construction of concrete pavements, due to its better serviceability, durability, high strength and overall economy in the long run. Cement is a foremost ingredient material of concrete. As cement industry put in five to eight percentage of total CO, expulsion global. Mineral admixtures are utilize in concrete mixes may help in reducing impact of cement production to environment. And these materials also enhance concrete performance. Utilization of industrial byproducts or mineral admixture saves energy and through reduction in carbon di oxide emission it is beneficial to environment. Mineral admixtures (or "Supplementary cementing materials" SCMS), silica fume, fly ash, ground granulated blast furnace slag, Metakaolin, rice husk ash etc. are widely used in concrete matrices to reduces cement content, increase strength, improve workability and enhance durability through pozzolanic or hydraulic activity. Although cement combinations concrete has been used in construction industry for ages, the literature indicates that these have tended to be relatively limited particularly in the application of ternary cement and high addition levels in concrete systems. Thus, this project describes a study performed on the strength parameters of GGBS-based ternary concrete, strength in compression, strength in tension and flexural strength. The concretes matrices were formulated by combining cement (CEM) with various proportions of GGBS for the combinations of binary concretes and the use of silica fume (SF) or metakaolin (MK) for the combinations of the ternary concretes. 1.2 Definition of Ternary Concrete Typical concrete is composed of Portland cement, fine aggregate such as sand, coarse aggregate (crushed stone and gravel), and water. The water hydrates the cement to form a paste that clenches all the aggregate jointly. The concrete could be modified in several ways as using other binder material rather than cement and by incorporation of admixture to enhance or simply say changes concrete properties in fresh mix and hard stage. When two different cementitious materials used as binder either as partial cement replacement or addition apart from cement, concrete matrices known as binary concrete or binary blend concrete. The additional cementing material are generally supplementing cementing material, they alone not shown any extensively cementing property but they react with calcium hydroxide in cement paste to form secondary calcium silicate hydrates. And when three different cementitions materials (in this case Portland cement, Ground Granulated Blast-furnace Slag, and metakaolin/silica fume) used as bind in concrete matrices, concrete known as ternary concrete. 1.3 Concrete pavement Concrete pavement are successively fashioned or constructed since 1893. Concrete has been used extensively for concrete pavement due to its better serviceability, durability, high strength and overall economy in the long run. Concrete pavement is a structure that consists of a layer of ordinary Portland cement concrete which is usually supported by a sub-base layer on the sub-grade is known as concrete pavement.

Literature Review

Huiwen Wan et al. (2014) studied "the analysis of geometric characteristics of GGBS particles and their influences on cement properties." They inferred that with the help of particle size distribution and surface area, strength influence with GGBS introduction recognized. The initial strength of concrete recorded higher when finer particle GGBS used with equal surface area. Compressive strength and long-term haul strength of mortar increases as GGBS content increases.

O. Çakir and F. Akoz (2018) studied the effect of curing conditions on properties of mortars with and without GGBS. In this study mortal is modified by cement replacement with GGBS by weight at replacement level 0%, 30%, and 60%. The whole work divided with two groups as one with standard condition that is 20 °C kept in water and other with temperature at 40 °C kept in moisture condition. The results of this research indicate that, mortar with GGBS showed lower strength (compressive as well as flexural) as compare to cement mortar. The specimen exposed to lower humidity and elevated temperature shows high strength at early age as compare to specimen kept in water. For both curing condition the coefficient of capillarity and porosity of mortar with GGBS decreased as GGBS content increases, thus, it improves the durability of mortar against aggressive solutions and water.

Rafat Siddique and Rachid Bennacer (2016) investigated the use of steel and iron industry by-product (GGBS) in cement mortar and paste. The results of this research indicate that, utilization of GGBS quickens the early hour's hydration of OPC, with the expansion in slag content the cement consistency was diminished. The blends cement concrete/mortar showed extensively superior sulfate resistance with GGBS replacement level 60%. The mortar/concrete containing GGS showed that there was an increment in strength, workability and setting time.

FathollahSajedi et al. (2012) investigated the interaction between strength parameter (compressive strength) of cement-GGBS mortars under water and air curing. For those twelve mortars mixes using binder content 380 and 500 kg/m prepared with different GGBS replacement level i.e., 0%, 50% & 100%. For curing of mortar specimens kept in water and at room temperature. The results of this work showed the optimum strength of mortar in term of compressive strength was achieved at binder content 380 kg/m3 with water curing for cement-GGBS binder as well as for cement binder. Hence it is concluded from this study, for higher strength mortar it is not necessary to take higher binder content and it is also important in environment. and economical point of view. There was no strength decrement observed at 90 days as compared to 28 days. Up to 50% replacement level, as slag content increases the strength was increased with water curing.

Aveline Darquennes et al. (2015) studied the hydration advancement monitored for concretes with different GGBS contents using several techniques such as adia-baticcalori-metry, thermo-gravimetry and analysis by scanning electron-microscopy. Three mix matrices were prepared in the experimental campaign presented hereafter: MIX I (0% slag), MIX 1I (42% slag), MIX III (71% slag). The result of this research indicates that, the hydration was slow-down as slag content increased. Although product of cement-slag hydration was similar to that of cement hydration the quantities vary. S. Krishna Rae et al. (2016) studied the mechanical properties and abrasion resistance of roller compacted concrete with slag. In this exploratory examination, seven distinct blends of concrete received in which binder material cement was mostly supplanted by six replacements level i.e., 60%, 50%, 40%, 30%, 20% and 10%of cement by slag. At curing period of 90 days, 28 days, 7 days and 3 days, strength parameter tests were performed that were split tensile, flexural compressive and abrasion resistance. Up to 50% replacement level the strength was successively increased as age of concrete. Although at the early age (3 days) strength recorded was diminished, the strength after 14 days increased as compare to control mix. It was also recorded as slag content expanded resistance to abrasion was expanded.

Alaa M. Rashad and Dina M. Sadek (2017) studied the prospect of enlightening strength in compression of high-volume GGBS (HVS) mix using micro size metakaolin (MK) at standard temperature and elevated temperature. For this study cement initially supplanted by seventy percent slag, by weight, to make high volume slag mix. And further replacement of cement by 10%, 8%, 6%, 4% and 2% of metakaolin. At temperature of 1000, 800, 600 and 400 °C, test specimens were exposed for two hours. The consequences of this study show that, particles of metakaolin particles were substantially finer than slag. Greater pozzolanic reaction recorded as metakaolin had higher Al,O, content, which results in expanded strength in compression, Although metakaolin content increased it expanded the pozzolanic activity, the 10% metakaolin content showed extensively better results due to fully utilization of free lime.

Objective of the work

The aim of this study is to formulate ternary concrete and find out the effect of supplementary cementing material i.e., GGBS, MK and SF on strength parameter of ternary concrete.

The aim is achieved with the help of following various objectives.

To design concrete mix by replacing cement with various proportions of GGBS and Silica Fumes.

To determine the following strength parameters of various concrete specimens-

- Flexural strength
- Compressive strength
- Split tensile strength

To compare results of various mix designs and determine optimum mix design that can be used economically.

Scope of present work

This study work help to formulate ternary blend concrete and binary blend concrete with GGBS. For further study on ternary concrete, the result obtained in this work help as a baseline. The overall this study focuses to determine optimum mix design for ternary concrete that can us economically without compromising strength parameters.

Materials and Methodology

In this study, rubber is used as the partial replacement of coarse aggregate by different amount of percentage. The coarse aggregate is replaced by 10%, 30%, and 40% by the rubber. The materials used for the preparation of concrete

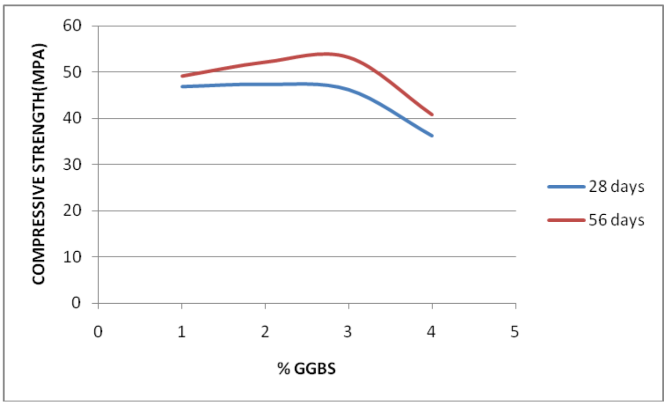
- Cement
- Fine aggregate
- C0arse aggregate
- Metakaolin
- GGBS
- Water

Several test methods will be used to complete this project, these are:

- Compressive strength
- Workability Test
- Flexural strength Tests
- Split Tensile Test

Compressive strength Test

Mix No.	MIX Code	Compressive strength	
		28 days	56 days
1	CEM100	46.82	49.21
2	GGBS20	47.32	52.23
3	GGBS40	46.14	53.25
4	GGBS60	36.21	40.85
5	GGBS20MK10	49.52	54.65
6	GGBS20MK15	54.32	61.02
7	GGBS20MK20	53.21	59.56
8	GGBS40MK10	52.88	58.81
9	GGBS40MK15	56.21	63.24
10	GGBS40MK20	51.24	57.51
11	GGBS60MK10	37.20	40.25
12	GGBS60MK15	34.21	37.25
13	GGBS60MK20	30.54	32.89
14	GGBS20SF10	48.84	54.18
15	GGBS20SF15	52.36	58.74
16	GGBS20SF20	52.04	57.89
17	GGBS40SF10	49.21	55.54
18	GGBS40SF15	54.20	62.21
19	GGBS40SF20	48.20	52.74
20	GGBS60SF10	36.22	40.14
21	GGBS60SF15	33.09	36.12
22	GGBS60SF20	26.87	30.31



Graph Influence of varying GGBS content on compressive strength

Conclusion

An experimental program was devised to study the strength characteristics of ternary concrete containing GGBS and MK/SF. Tests were performed on hard concrete cured under standard laboratory conditions, and compressive, flexural and split tensile strengths were observed at curing ages of 28 and 56 days. A discussion of results was carried out and the major conclusions drawn from the study are elaborated here in. 5.2 Compressive Strength of Pavement Quality Concrete The maximum compressive strength of binary blend concrete is achieved when cement is replaced with 20% GGBS at 28 days (= 47.37 MPa) and with 40% GGBS at 56 days (53.04 MPa). The strength is observed to slightly decrease when GGBS replacement level increases. The maximum compressive strength of ternary blend concrete (CEM-GGBS-MK) is achieved when cement is replaced with 40% GGBS and 15% metakaolin (= 56.72 MPa at 28 days and 63.53 MPa at 56 days).

The maximum compressive strength of ternary blend concrete (CEM-GGBS-SF) is achieved when cement is replaced with 40% GGBS and 15% silica fume (= 55.42 MPa at 28 days and = 62.07 MPa at 56 days).

Flexural Strength of Pavement Quality Concrete

The maximum flexural strength of binary blend concrete is achieved when cement is replaced with 40% GGBS (= 6.5 MPa at 28 days and 7 MPa at 56 days).

The maximum flexural strength of ternary blend concrete (CEM-GGBS-MK) is achieved when cement is replaced with 40% GGBS and 15% metakaolin (- 7.75 MPa at 28 days and 8.25 MPa at 56 days).

The maximum flexural strength of ternary blend concrete (CEM-GGBS-SF) is achieved when cement is replaced with 40% GGBS and 15% silica fume (-7.5 MPa at 28 days and -8.25 MPa at 56 days).

Split Tensile Strength of Pavement Quality Concrete

The maximum split tensile strength of binary blend concrete is achieved when cement is replaced with 40% GGBS (= 3.74 MPa at 28 days and - 4.12 MPa at 56 days). The maximum split tensile strength of ternary blend concrete (CEM-GGBS-MK) is achieved when cement is replaced with 40% GGBS and 15% metakaolin (= 3.94 MPa at 28 days and = 4.22 MPa at 56 days)

The maximum split tensile strength of ternary blend concrete (CEM-GGBS-SF) is achieved when cement is replaced with 40% GGBS and 15% silica fume (- 3.91 MPa at 28 days and 4.21 MPa at 56 days).

Hence it is concluded that the optimum design mix is the one with 40% GGBS and 15% Metakaolin/Silica Fumes. But as Silica Fumes are cheaper in comparison to Metakaolin, it is recommended to be used from economic point of view.

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