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Mix Design And Strength Characteristics Of Reactive Powder Concrete

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ABSTRACT

Concrete is typically the most massive individual material element in the built environment. If the embodied energy of concrete can be reduced without decreasing the performance or increasing the cost, significant environmental and economic benefits may be realized. Ground Granulated Blast Furnace Slag (GGBFS) concrete is a type of concrete in which a part of the cement is replaced by ground granulated blast furnace slag, which is an industrial waste. When used in concrete, ground granulated blast furnace slag is a cementations material that can act as a partial substitution for Portland cement without significantly compromising the compressive strength. Calcium nitrate also called norgessalpeter (Norwegian salt peter) and kalksal peter is a white color soluble salt with formula $Ca(NO_3)_2.4H_2O$. The main reason for the inclusion of calcium nitrate in the concrete serves as a set accelerator i.e. (reducing setting time) giving high initial strength, reduce bleeding and improve workability. In this investigation the effect of calcium nitrite at 0.5%, 1%, 1.5% and 2% by weight of cement in concrete containing GGBFS as mineral admixture to improve the strength of concrete was studied. Experimental results show that addition of GGBFS decreases the strength of concrete. But at the same time addition of calcium nitrate is increasing the strength of concrete.

INTRODUCTION

Concrete is typically the most massive individual material element in the built environment. If the embodied energy of concrete can be reduced without decreasing the performance or increasing the cost, significant environmental and economic benefits may be realized. Concrete is primarily comprised of Portland cement, aggregates, and water. Although Portland cement typically comprises only 12% of the concrete mass, it accounts for approximately 93% of the total embodied energy of concrete and 6 to 7% of the worldwide CO_2 emissions. If concrete is mixed with ground granulated blast furnace slag as a partial replacement for Portland cement, it would provide environmental and economic benefits and the required workability, durability, and strength necessary for the design of the structures. Some of the recent studies in various parts of the world have revealed that Ground granulated blast furnace slag concrete can protect the steel reinforcement more efficiently, so that it can resist corrosion, and thus the structure as a whole.

GGBFS concrete is a type of concrete in which a part of the cement is replaced by ground granulated blast furnace slag, which is an industrial waste. Thus the implementation of GGBFS concrete can minimize corrosion in an effective way. Moreover it can lead to much durable structure without considerable increase in cost. Ground granulated blast furnace slag from modern thermal power plants generally does not require processing prior to being incorporated into concrete and is therefore considered to be an environmentally free input material. When used in concrete, ground granulated blast furnace slag is a cementations material that can act as a partial substitution for Portland cement without significantly compromising the compressive strength. GGBFS is used to make durable concrete structures in combination with ordinary Portland cement and other pozzolanic materials. Two major uses of GGBFS are in the production of quality-improved slag cement, namely Portland Blast Furnace Cement (PBFC) and High-Slag Blast-Furnace Cement (HSBFC), with GGBFS content ranging typically from 30 to 70%; and in the production of ready-mixed or site batched durable concrete. Concrete made with GGBFS cement sets more slowly than concrete made with ordinary Portland cement, depending on the amount of GGBFS in the cementitious material, but also continues to gain strength over a longer period in production conditions. This results in lower heat of hydration and lower temperature rises, and makes avoiding cold joints easier, but may also affect construction schedules where quick setting is required. From structural point of view, GGBFS replacement enhances lower heat of hydration, higher durability and higher resistance to sulphate and chloride attack when compared with normal ordinary concrete. On the other hand, it also contributes to environmental protection because it minimizes the use of cement during the production of concrete. Another major hurdle of extensive use of GGBFS concrete lies in the little source of supply of GGBFS. Some of the merits of GGBFS in concrete are listed below.

- Reduce heat of hydration
- Refinement of pore structures
- Reduce permeability to the external agencies
- Increase resistance to chemical attack
- Better workability, making placing and compaction easier.
- Lower early-age temperature rise, reducing the risk of thermal cracking in large pours.
- Elimination of the risk of damaging internal reactions such as ASR high resistance to chloride ingress, risk of reinforcement corrosion.

NEED FOR THE STUDY

Most of the studies on the usage of GGBFS as a substitute for cement in concrete were carried out to judge the properties of fresh concrete and strength properties. Numerous studies were carried out to investigate the use of mineral admixtures and corrosion inhibitors in enhancing the corrosion resistive properties of conventional concrete. Studies on the strength and corrosion resistance performance of concrete having GGBFS as mineral admixture and calcium nitrate as a corrosion inhibiting substance are not discussed much in the technical literature. Therefore, the objectives of the present work are given below

OBJECTIVES OF THE STUDY

- To study the strength properties of concrete containing calcium nitrate and GGBFS as mineral admixture.
- To study the significance of partial replacement of cement by ground granulated blast furnace slag on the strength properties of concrete
- To find out the inhibitive effect of calcium nitrate on the strength properties of concrete.

GROUND GRANULATED BLAST FURNACE SLAG

Ground Granulated Blast Furnace Slag which is a by-product of steel manufacturing industry is an accepted mineral admixture for use in concrete due to its glassy nature and chemical composition which makes it pozzolanic and a cementitious material. According to ACI 116 R-85 (1985), granulated blast furnace slag is defined as, ‘the glassy granular material formed when molten blast furnace slag is rapidly chilled, as by immersion in water’. This granulated material when further ground to less than 45micron is called Ground Granulated Blast Furnace Slag (GGBFS). The rough and angular-shaped ground slag in the presence of water and with an activator, NaOH or CaOH, supplied by Portland cement, hydrates and sets in a manner similar to Portland cement. However, air-cooled slag does not have the hydraulic properties of water-cooled slag. It consists essentially of silica glass which contains calcium, magnesium and aluminum. The cementitious action of slag is largely dependent on the glass content. When compared to rapidly cooled slag, slowly cooled slag is predominantly crystalline and therefore does not possess significant cementitious property. The glassy structure of slag mainly consists of clear isotropic transparent grains with rough structure which enhances the strength and durability characteristics when used in concrete. The incorporation of GGBFS into concrete mixes is pronounced in enhancing the properties of concrete in the aspects of workability, strength and durability. It has also been reported that inclusion of GGBFS in concrete resulted in reduction of cracks in concrete structures. Ground granulated blast furnace slag also has a lower heat of hydration and, hence, generates less heat during concrete production and curing. As a result, GGBFS is a desirable material to utilize in mass concrete placements where control of temperatures is an issue. Percentage replacements by weight of GGBFS for cement have ranged from 10 to 90%. Utilization of these materials into concrete mixes effectively results in reduction of environmental pollution since these waste materials pose environmental problem. As per ASTM C989 (1995), with regard to strength there are three grades of slag: Grade 80, Grade 100 and Grade 120. Each number corresponds to a minimum of 28-day compressive strength ratio of a mortar cube made with only Portland cement and a mortar cube made with 50% Portland cement and 50% slag. Just as fly ash is used as an admixture in concrete GGBFS is also used as an admixture in making concrete. In case of GGBFS, IS456:2000 permits slag conforming to IS: 12089: 1987 for blending with Portland cement.

Exclusive research works have shown that the use of slag leads to enhancement of intrinsic properties of concrete in both fresh and hardened conditions.

The major advantages recognized are,

- Reduced heat of hydration
- Refinement of pore structures
- High ultimate strength with low early strength
- Increased resistance to chemical attack
- Improved alkali-silica reaction resistance
- Reduced permeability to other external agencies
- Resistance to sulfate and seawater
- Better finish and light colour

EXPERIMENTAL PROGRAM

The parameters varied in this investigation are calcium nitrate (0 to 2 %) and GGBFS (75 to 85 %). This experimental study to investigate the effect of calcium nitrite at 0 %, 0.5%, 1%, 1.5% and 2% by weight of cement in concrete containing GGBFS as mineral admixture (75 to 85 % replaced for cement) in resisting corrosion and to improve the strength of concrete. The compressive, split tensile and flexural strength of concrete specimens containing GGBFS and calcium nitrate were carried out.

TEST RESULTS

The preliminary test for the Reaction of GGBFS with Calcium nitrate was carried out in the laboratory. Five test tubes were taken. In each test tube 10 gms of GGBFS was taken, then it added with 30ml of water. Except 1st test tube, Calcium Nitrate solution in the dosage of 0.5%, 1.0%, 1.5% and 2% was added and stirred well, and then it kept free for 24 hours. After 24 hours, weight of GGBFS was measured and it is tabulated in table 1. Fig. 1 shows the weight of GGBFS varying based on Calcium Nitrate dosage. The weight of GGBFS was increased by 2.1% at the addition of 1% of calcium nitrate, it is the maximum value. Further increase in % of calcium nitrate leads to the decrease in weight. Compressive, Split and flexural strength of specimens are presented in table 2, 3 and 4 respectively.

Table 1 Weight of GGBFS

% of Calcium Nitrate	Initial weight of GGBFS (gms)	Final weight of GGBFS (gms)
0	10	9.94
0.5	10	10.18
1	10	10.21
1.5	10	10.04
2	10	9.51

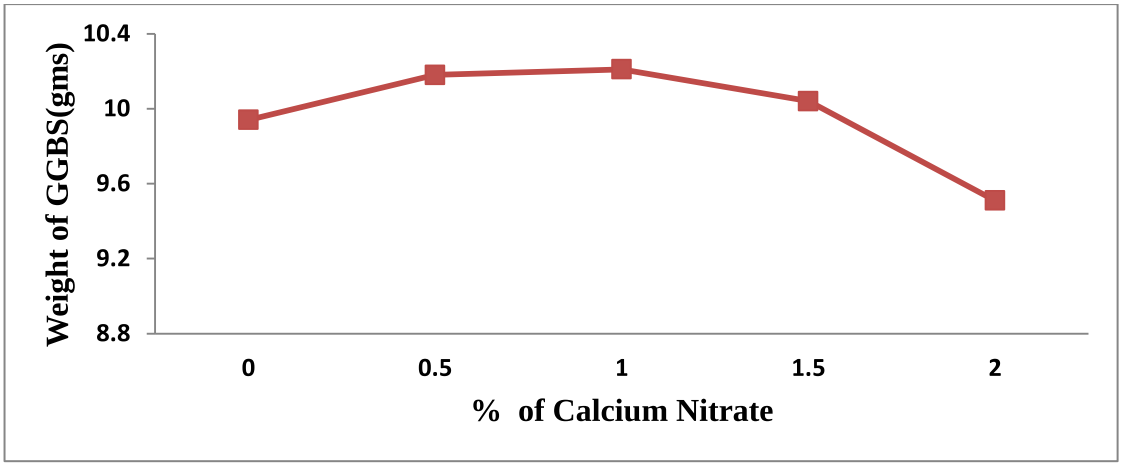

Fig. 1 Weight of GGBFS

Table 2 Compressive strength of concrete cubes

% replacement of Cement by GGBFS	**Compressive strength**					
	Average Compressive Strength (N/mm^2)			Average Compressive Strength (N/mm^2) With the addition of Calcium Nitrate (1%)		
	3rd day	7th day	28th day	3rd day	7th day	28th day
0	15.26	19.70	29.18	-	-	-
75	13.68	17.67	26.88	16.35	19.92	30.97
80	12.34	16.57	25.37	13.13	17.18	26.42
85	11.67	15.34	24.25	12.14	16.02	25.23

Table 3 Split tensile strength of concrete cylinders

% replacement of Cement by GGBFS	**Split Tensile Strength**					
	Average Split Tensile Strength (N/mm^2)			Average Split Tensile Strength (N/mm^2) With the addition of Calcium Nitrate(1%)		
	3rd day	7th day	28th day	3rd day	7th day	28th day
0	1.47	2.30	3.02	-	-	-
75	1.44	2.05	2.74	1.51	2.41	3.12
80	1.14	1.95	2.35	1.33	2.22	2.76
85	1.07	1.680	2.08	1.26	1.82	2.54

Table 4 Flexural strength of concrete prisms

% replacement of Cement by GGBFS	Flexural Strength					
	Average Flexural Strength (N/mm^2)			Average Flexural Strength (N/mm^2) With the addition of Calcium Nitrate (1%)		
	3rd day	7th day	28th day	3rd day	7th day	28th day
0	1.53	2.41	3.14	-	-	-
75	1.48	2.25	2.88	1.54	2.48	3.22
80	1.30	2.08	2.69	1.34	2.24	2.82
85	1.17	1.76	2.28	1.28	1.86	2.62

CONCLUSION

Exclusive research works have shown that the use of GGBFS leads to enhancement of intrinsic properties of concrete in both fresh and hardened conditions. The purposes of using calcium nitrate and the advantages resulting from the use of this admixture are many. Thus, the use of calcium nitrate in concrete provides a shortening of setting time and/or an increase in early strength development. At higher levels of GGBFS, up to 85% delays in setting time and strength development are much more apparent.

This report deals with the experimental study to investigate the effect of calcium nitrite at 0.5%, 1%, 1.5% and 2% by weight of cement in concrete containing GGBFS as mineral admixture to improve the strength of concrete.

Experimental results show that addition of GGBFS decreases the strength of concrete. But at the same time addition of calcium nitrate is increasing the strength of concrete

- The strength of concrete containing calcium nitrate and GGBFS as mineral admixture is found.
- The significance of partial replacement of cement by ground granulated blast furnace slag on the strength and corrosion resistive properties concrete is studied
- The inhibitive effect of calcium nitrate on the strength and corrosion resistive properties of concrete is found.

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