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Improvement of Durability of Concrete by Complex Mineral

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Abstract —*KG powder is a complex mineral superfine powder made by grinding the mix of calcined coal gangue and slag along with fly ash, silica fume in certain proportion. The concrete cement content was reduced by 20% to 40%. Durability related properties include resistance to sulphate attack and acid rain was enhanced greatly. Application of complex mineral superfine powder is an effective way to reduce environment pollution and improve durability of concrete under severe conditions.*

When KG powder mix with concrete, it will increase the durability of concrete with improved pozzolanic reaction and micro-aggregate filling. As a result of this experimental study, it is noted that the use of 20%, to 40% replacement of KG powder instead of cement, has significant effect on compressive strength of concrete over time and will withstand sulfate attack and acid rain.

Keywords- *Durability of Concrete, mineral admixture, KG powder, Compressive strength, Slump test.*

I. INTRODUCTION

Coal gangue is waste residue during coal mining and coal washing. Generally, coal gangue wide-ranging discharge capacity takes the 15%~20% of the output of raw coal. Statistics according to national state economic & trade commission shows that the annual production of coal gangue in China is near to one-hundred billions tons [3], which is now amounted to more than 3000 billion tons.

Because of different mineral contents of the coal in different place, the chemical composition is comparatively difficult, which is about 10 kinds of element possibly [11]. The major composition normally is silicon and aluminum. Most of the coal gangue is a clay rock; whose main mineral composition consists of clay mineral, mineral quartz, potassium fledspar, anorthite, siderite, pyrite, and calcite. The bonding of gel role of fresh coal gangue is very weak, because these kinds of coal gangue have stable crystal structure, whose atom, ion, and member etc. are put according to certain law by order, even if its chemical composition is proper and lowly active, however, coal gangue has certain activity after burning. After calcined at a definite temperature, the clay mineral is dewatered and disintegrated; the carbon component is removed with the deteriorative impurity burned out. The crystal is disintegrated and transformed into amorphous non-crystal, which makes the coal gangue active. This paper presents wide-ranging experimental results of a quantitative analysis of the hydration of blended cement pastes with different percentages of calcined coal gangue powder.

General features of use of mineral admixtures are that their use save energy and conserve natural resources but their technical benefits are the strongest. They affect the progress of hydration, reduce the water demand and improve workability. The concrete containing GGBFS, on vibration becomes ‘mobile’ and compacts well. Silica fumes greatly reduces, or even eliminates bleeding, the particles of Pozzolanic Fly Ash (PFA) are spherical and thus improves the workability. Their inclusion has the physical effect of modifying the flocculation of cement, with a resulting reduction in the water demand. The pore size in concrete is smaller. The fine particles ‘fit in between cement particles, thereby reducing permeability.

II. METHODOLOGY

In order to compare the durability, Conventional concrete and concrete with replacement of KG powder, samples of different mix proportions will be taken. The concrete will be tested for

Permeability, Durability test by resistance to sulfate attack & acid rain attack and compressive tests will also be carried out.

2.1 Mixing of KG powder

Samples containing fly ash, GGBS, and calcined coal gangue will be mixed for replacement of OPC as following.

Table -1: Replacement of cement by KG powder(%)

	Percentage Replacement of cement by KG powder		
OPC cement	80	70	60
KG powder	20	30	40

2.2 Durability Test

2.2.1 Permeability of the KG powder concrete

Test on permeability of the KG powder concrete will be carried out according to the Indian Standard, "Test methods for elongated term properties and durability of conventional concrete." Due to that the low w/c for high-performance concrete and the pozzolanic and filling effects of the ground KG powder, there is more cementitious material formed with dense structure; therefore, it is easy to prepare a high impermeable concrete in case of using crushed stone with excellent grading and addition of proper admixture [3].

2.2.2 The resistance to sulfate attack

The resistance to sulfate attack will study by storage of specimens cured under standard condition for 28 and 90 days in 5% solutions of sodium sulfate, then, compressive strength of specimens will be determined after 28 and 90 days corrosion, the results will compare with those of specimens stored in fresh water.[3]

III. RAW MATERIALS AND TEST METHODS

3.1 Raw materials

3.1.1. Cement

In the tests the Ordinary Portland cement manufactured in India.

3.1.2 Coal gangue

The coal gangue is from the Chandrapur mine in Maharashtra and treated by calcination.

Fig. No. -1: Calcined coal gangue powder

Table 2: Chemical composition of coal gangue and slag

	Slag	**Coal gangue**	**Fly ash**
SiO_2	36.90	58.10	41.10
AL_2O_3	9.73	24.54	25.9
Fe_2O_3	3.85	5.31	1.02
CaO	35.93	5.73	3.2
MgO	2.33	1.05	0.55
SO_3		2.97	0.56
IL			7.9
Specific surface (cm^2/g)	4300	4100	3900

3. 1.3. Slag

Blast furnace slag is produced as a by-product in the manufacture of pig iron from iron ore in the blast furnace. The molten slag is tapped from the blast furnace and quenched by pouring it over high pressure jets of water.

During this process slag is split into small granules and hence called 'granulated blast furnace slag'. Granulated slag is a latent hydraulic material which is ground into a superfine state under controlled conditions. The end product is called "ground granulated blast furnace slag" which when mixed with ordinary Portland cement gives unexpected properties to concrete as well as mortar. [7]

3.1.4. Fly ash

Fly ash is the ash progressive electro-statically from the exhaust fumes of coal fired power station. In India nearly 70 million tons of fly ash is being produced every year while a very small quantity is used in manufacturing of cement. It is an eco-friendly product. The fly ash particles are spherical and are generally of higher fineness than cement so that the silica is readily available for reaction [9]. The percentage of silica and alumina should be minimum 70% and maximum loss on ignition 12%. Much superior quality fly ash is available from thermal power plants than specified in IS code.

The Portland Pozzolana Cement makes concrete more impermeable and denser as compared to Portland cement. The long term strength (90 days and above) of cement blended with fly ash (>25%) is better compared to OPC.

The blended Cement with fly ash produces less heat of hydration and offers great resistance to the attack of aggressive waters than normal Portland cement.

It is necessary that quality of Fly ash is estimated by presumed laboratory. It should be tested for chlorides, sulphate, alkalinity and heat of hydration. The fly ash should be mixed with cement and the concrete made available from it should be suitable for corrosion resistant properties.

3.2 Fine aggregate

Medium size natural sand with a modulus of fineness F. M. =2.46; normal grading with the silt content 0.8%.

3.3 Coarse aggregate

Coarse aggregate with a size of 12.5 mm & 20mm and normal constant grading. According to British Standard BS 882 of 1992 limits the flakiness index 40.

3.4 Admixture

A composite retarding super-plasticizer FDN with slight air entraining, water reduction rate 23% and other properties conforming to the requirements for first class.

The dosage of the admixture is 1.0%.

3.5 KG powder

The KG powder is a mix by grinding the calcined coal gangue with slag, fly ash and silica fume. Its specific surface is 4900 cm2/g.[3]

3.6 Mix proportion of concrete

Based on properties of raw materials, the effect of fly ashes (FA) and ground granulated blast furnace slag (GGBFS) on properties of super plasticizer(SP) added concrete will be examined experimentally against sulfate effect. FA, calcined coal gangue powder and GGBFS will be added to Portland cement partially by weight of the cement. KG powder replacement concretes will compare with Portland cement concrete. Firstly 15 cm cube specimens will be prepared with produced concrete mix and cured at 7, 28, and 90 days [11]. For this purpose, high density sulfate of soils will be examined. In the laboratory, KG powder will be added to the mix as replacement of 20% by weight of the Portland cement. The 0.50 water/cement ratio and 300 kg/m^3 cement quantity are selected for the mix. A control concrete sample is also produced having the same dosage. The performance of mineral additives concrete will obtain in both the sulfate and water cures. In this setting, four series of concrete samples will be produced; in three concrete samples a series with constant ratio of KG powder will be used as additives, and one series of sample will be used without additives. In order to see the effect of strength and durability of concrete at high-rate sulfate, concrete samples will be rested in a solution of sodium sulphate or magnesium sulphate. To examine the destructive effect of sulfate on concrete one group of specimens will be kept continuously in sodium sulfate solution with concentration of in 5% sulfate solution for 28 days. During this period the other group samples will be rested in water.

At the end of each curing period, a total of 3 specimens will be tested for each concrete property. Surface hardness and compressive strength of concrete samples exposed to sulfate effect will be measured frequently. At the same time, the surface distortions and changes of weight of the samples will be observed periodically [11].

1m^3	**Plain concrete sample**	**KG Powder added sample**
Water	192 kg	170 kg
Portland cement	**457 kg**	**365.6 kg**
KG Powder (20%)	—	**91.4 kg**
Coarse aggregate	708.6 kg	708.6kg

(20mm)		
Coarse aggregate (10 mm)	472.4 kg	472.4 kg
Fine aggregate	536 kg	536 kg
Admixture	-	1%
Slump (mm)	113	100

Table 3: Mix ratio of $1m^3$ concrete and slump values.

In this study, the ordinary Portland cement and KG powder obtained from Chandrapure coal mine,will be used for the mix designs. The chemical component of the fly ash and cement is shown in Table 2.
The effect of particle size distribution is one of the main parameters on the compressive strength and sulfate resistance of blended cement mortars including Portland cement and natural pozzolan [11]. It is seen in chemical analysis, cement and KG powder show similarity in fineness.
Mix design for $1m^3$ fresh concrete for reference sample 20% KG powder used as replacement of cement are shown in Table 3.

IV. TEST RESULTS AND DISCUSSION

In this chapter the description of experimental tests investigation carried out on M25 grade concrete to determine its Workability test, hardened state properties and durability of concrete when cement is replaced by KG powder are presented. The following tests were conducted to assess the various properties.

1. Workability test on concrete-
   Slump cone test.
2. Hardened concrete tests-
   Compressive StrengthTest.
   Split tensile strength test.
3. Durability tests-
   Weight loss due to SULPHATE ATTACK.

1. Workability of KG powder concrete

1. SLUMP CONE TEST

The higher the slump flow (SF) value, the greater its ability to fill formwork. Test results are tabulated as below:

Table No: 4 Slump Value

Sr. No.	% of KG powder	Slump (mm)
1	0	115
2	20	105
3	30	95
4	40	80

• Due to the micro filling and dispersing effects of the KG powder, the slump loss for the concrete mix with KG powder is less than that of one without addition. For example, the slump loss for concrete mix without additives 113 mm and that for concrete with 20% addition is 100 mm and for 30% addition 90 mm. The reduction of spread has the same character. Such effect is beneficial to the ready mixed concrete.

2. Hardened concrete tests

1. COMPRESSION STRENGTH TEST

Compressive strength of concrete mixes made with various percentage of partial replacement of cement by KG powder was determined at curing period of 28 days. The results are as follows:

Table No: 5 Average compressive strength of 28 days

Sr. No.	Replacement of KG powder	Average compressive strength of 28 days
1	0	31.70
2	20	29.50
3	30	32.36
4	40	31.21

• Experimental results proves that, as percentage of KG powder increases in concrete it leads to the increase in compressive strength of concrete only up to partial replacement of 30% of cement by KG powder and beyond that percentage of KG powder there is reduction in strength of concrete. Also the KG powder concrete acquires strength at faster rate beyond 28 days, due to pozzolonic action of KG powder.

2. SPLIT TENSILE STRENGTH TEST:

The results of split tensile strength for various replacements of partial replacement of natural sand by pond ash are as follows:

Table No: 6 Average Split Tensile strength

Sr. No.	Replacement of KG powder	Average Split Tensile strength of 28 days (N/mm^2)
1	0	3.89
2	20	2.80
3	30	2.58
4	40	3.14

It is observed from results that the splitting tensile strength of concrete increases as partial replacement of cement by KG powder increases.

3. Durability test of the KG powder concrete

1. Resistance of KG powder concrete to sulfate attack

In this project tests, the resistance to sulfate attack were studied by storage of specimens cured under standard condition for 28 days in 3% solutions of sodium sulfate then the compressive strength of specimens were determined after 28 days corrosion, the results then compared with those of specimens stored in fresh water.

Table No:7 Compressive strength variation due to Sulphate attack on Concrete after 28 days:

Sr. No.	Replacement of KG powder	Average Compressive strength of 28 days (N/mm^2)	
		Fresh Water	Na_2SO_4
1	0	32.75	34.64
2	20	30.55	31.71
3	30	35.36	35.46
4	40	30.36	34.32

Experimental results show that there is increased in strength of concrete when specimen cured in fresh water were compared with sulfate solution when partial replacement of cement by KG powder is used in concrete. The solution is affect on the compressive strength of concrete.

Table No: 8 Split Tensile strength variation due to Sulphate attack on Concrete after 28 days:

Sr. No.	Replacement of KG powder	Average Split Tensile strength of 28 days (N/mm^2)	
		Fresh Water	Na_2SO_4
1	0	3.80	3.50
2	20	2.75	3.40
3	30	2.47	2.45
4	40	2.99	2.38

Experimental results show that Split Tensile strength of specimen were decreases when cured in sulphate solution.

Table No: 9 Weight loss variation due to Sulphate attack on Concrete after 28 days:

KG powder %	Initial wt.	Final wt.	% wt. loss
0	7.882	7.896	
	7.736	7.748	
	7.96	7.975	
Avg	**7.859**	**7.873**	**-0.18**

20	8.601	8.632	
	8.725	8.778	
	8.631	8.674	
Avg	**8.652**	**8.695**	**-0.49**
30	8.740	8.760	
	8.645	8.662	
	8.618	8.635	
Avg	**8.668**	**8.686**	**-0.21**
40	8.701	8.718	
	8.755	8.776	
	8.706	8.728	
Avg	**8.721**	**8.741**	**-0.29**

Experimental results show that there is increase in strength of concrete by sulfate solution when partial replacement of cement by KG powder is used in concrete. That mean when cement is replaced by KG powder then there is no any adverse effect on durability of concrete.

V. CONCLUSIONS

The calcined coal gangue when mix with slag and fly ash can support as additives for OPC concrete. Loading up of coal gangue in large amount seriously caused the pollution of environment. However, the utilization of coal gangue fell behind that of other industrial wastes such as fly ash, slag etc. a series of experiments carried out and it is verified that like other similar industrial wastes, the coal gangue can be used for concrete, provided that the proper mix proportion will be chosen and high quality admixture used to improve the properties of concrete, even the high performance concrete can be prepared with the characteristics of green concrete.

Permeability of concrete depends upon the content of alumina in mineral admixtures, higher the alumina content lesser the permeability causes higher resistance to sulfate attack.

1. Indian Standard method is easy method for the mix design of M25 grade concrete.
2. KG powder requires the less water cement ratio as compared to OPC.
3. 30% of KG powder as cement replacement is found to be the optimum amount in order to get a favourable strength.
4. The KG powder concrete acquires strength at faster rate beyond 28 days, due to pozzolonic action of KG powder.
5. Compressive Strength of KG powder concrete increases with increase in percentage of replacement of cement by KG powder.
6. It is observed from results that the splitting tensile strength of concrete increases as % of KG powder were increases.
7. There is increase in compressive strength when cured in sulfate solution.
8. Finally it is concluded that there is no any adverse effect of replacement of cement by KG powder in optimum percentage.

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