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EFFECTS OF THERMAL VARIANCE ON THE BOND STRENGTH OF SLAG CEMENT CONCRETE

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ABSTRACT

This work examine the effects of thermal variance on the bond strength of slag cement concrete. In this research, slag cement was prepared by blending 50% Portland cement with Ground Granular Blast Furnace Slag and used as the binder. Concrete cubes of 100mmx100mm were prepared using slag cement, the samples were cured for 28

Introduction

Ground Granular Blast Furnace Slag (GGBS) is obtained by quenching molten iron slag from a blast furnace in water or stream, to produce a glassy, granular product that is then dried and ground into a fine powder. GGBS is used to make durable concrete structures in combination with ordinary Portland cement and/or other pozzolanic materials. GGBS has been widely used in Europe, and increasingly in the United States and in Asia for its superiority in concrete durability,

days to achieve strenght. Therafter, some samples were selected and tested to determine the bond strength using pull out test while some were subjected to varying thermal conditions of 150, 200, 250 and 300C at time intervals of 30, 45 and 60 minutes after which pull out test was conducted on the heated samples to determine effects of varying temperature conditions. At the end of the research, it was observed that concrete has good thermal performance compare to ordinary Portland cement.

extending the life span of buildings from fifty to a hundred years. GGBS reacts like Portland cement when in contact with water. Bulk GGBS is stored and handled in conditions identical to that of Portland cement.Bulk storage is in watertight silos. Transportation is by bulk tankers, as for Portland cement. GGBS can also be moved by air slides, cement screws and bucket elevators. Dust control is the same as that required for Portland cement. GGBS dust does not present any fire or explosion hazard

Fire resistance is a measurement of the ability of the structure to resist collapse, fire spread or other failure during exposure to a fire of specified severity or in other words it is the duration a structural member (system) exhibits resistance with respect to temperature transmission, structural integrity, and stability under fire conditions. The fundamental step in designing structures for fire safety is to verify that the fire resistance of the structure or each part of the structure is greater than the severity of the fire to which the structure is exposed. The current prescriptive methods for fire resistance are derived from data obtained from standard fire resistance tests and do not consider the effect of many of the important parameters such as load level, fire scenario, and concrete strength (Kodur and Dwaikat, 2008).

Damages caused by a fire on a concrete structure can be observedfrom simple discolored spots or tarnish produced by smoke to the structural element complete destruction as a result from the loss of its mechanical strength. The effects of fire, as well as its intensity and extension, are directly connected to the capacity a building has to resist or not to the development of a fire. Unfortunately, there is no absolute safety against fires and, therefore, several preventive measures are used with the intent of reducing risks.

Concrete must at times resist the effects of artificially induced high temperatures such as might be encountered near furnaces or in atomic reactors, in pavements subjected to jet engine blast, and in areas exposed to fire. Applications of concrete involving extremely high temperatures, such as landing pads for missiles, are considered expendable, but in most instances it is desired to avoid deterioration of the concrete physical properties as much as possible. A number of factors will enter into a decision regarding the type of concrete to use under conditions of elevated tempera t u re s. These include the following: length of exposure, rate of temperature rise, temperature to which the concrete mass will be raised, temperature of concrete at initiation of exposure to high temperature, degree of water saturation of the concrete, age of the concrete, type of aggregate used, type of cement used, aggregate/ cement ratio, and loading conditions at time of exposure. Concrete appears to sustain no appreciable damage when exposed to temperatures up to 400 degrees Fahrenheit. If temperatures above 400 degrees Fahrenheit are to be experienced, it is wise to investigate the exposure conditions and the concrete which will be employed.

Fire safety measures to structural members are measured in terms of fire resistance which is the duration during which a structural member exhibits resistance with respect to structural integrity, stability, and temperature transmission. Concrete generally provides the best fire resistance properties of any building material. This excellent fire resistance is due to concrete's constituent materials (i.e., cement and aggregates) which, when chemically combined, form a material that is essentially inert and has low thermal conductivity, high heat capacity, and slower strength degradation with temperature. It is this slow rate of heat transfer and strength loss that enables concrete to act as an effective fire shield not only between adjacent spaces but also to protect itself from fire damage.

The behaviour of a concrete structural member exposed to fire is dependent, in part, on thermal, mechanical, and deformation properties of concrete of which the member is composed. Similar to other materials the thermophysical, mechanical, and deformation properties of concrete change substantially within the temperature range associated with building fires. These properties vary as a function of temperature and depend on the composition and characteristics of concrete. The strength of concrete has significant influence on its properties at both room and high temperatures. The properties of high strength concrete (HSC) vary differently with temperature than those of normal strength concrete (NSC). This variation is more pronounced for mechanical properties, which are affected by strength, moisture content, density, heating rate, amount of silica fume, and porosity.

In practice, fire resistance of structural members used to be evaluated mainly through standard fire tests. In recent years, however, the use of numerical methods for the calculation of the fire resistance of structural members is gaining acceptance because these calculation methods are far less costly and time consuming. When a structural member is subjected to a defined temperature-time exposure during a fire, this exposure will cause a predictable temperature distribution in the member. Increased temperatures cause deformations and property changes in the constitutive materials of a structural member. With knowledge of deformations and property changes, the usual methods of

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structural mechanics can be applied to predict the fire resistance performance of a structural member. The availability of material properties at an elevated temperature permits a mathematical approach for predicting fire resistance of structural members.

The bond strength which is a mechanical property is due to surface roughness and friction (Hannant, 1963), concrete has good fire resistance ability, this implies that the period under which the concrete can still perform satisfactorily under fire is relatively high and no toxic fumes are emitted. The relevant criteria for this are, load bearing capacity are load bearing capacity, resistance to flame penetration and resistance to or low rate of heat transfer when use as fire protective material for steel. It preserve structural action over a desired length of time (that is fire rating), (Nagarain and Sinha, 1994). At temperature below 250° C, the bond strength between concrete and steel remains relatively unchanged, but at higher temperature, the expansion of steel increase while the strength of concrete decreases. Mild steel bars loses 75%of their bond strength at 450°C while high yield bars have the same bond strength as at 250°C (Milovanoov, 1963).

Methodology

Materials

The materials used for this research were portable water obtained at University Of Ibadan water works, well graded sand as fined aggregates, granite as coarse aggregates and Slag Cement as the binder. The binder was prepared by blending 50% of Ordinary Portland Cement with Ground Granular Blast Furnace Slag

Methods

Procedures for Pull Out Test

Concrete mix of 1:2:4 having water cement ratio equal to 0.56 were prepared. Concrete cubes of 100mm x 100mm were casted with the steel

reinforcements of 10mm diameter. A plumb was used to ensure the bars were vertically aligned, after 24 hours, the samples were demoulded and immersed in water for 28 days. After 28 days, the concrete samples were removed for heating and testing. The samples were heated in a furnace machine at varying temperatures of 100, 150, 200, 250 and 300°C at varying times of 30 minutes, 45 minutes and 60 minutes respectively.
A Universal Testing Machine (UTM) was used for this test. The samples were placed in the UTM and the steel was grip by the upper jaw while the concrete section was held firm by the lower jaw of the machine. A gradual load was applied to pull out the embedded steel out of the concrete until the steel was finally removed. The load at which the steel was wholly pulled out of the concrete was read and recorded.
The ultimate bond stress was calculated using the following formula σ_{bu}= Pb / (π x d x l) where,σ = ultimate bond stress, Pb = Bond failure load, d = dia of bar, l = length of bar (in this case it is 100 mm)

Table 1.2 Pull out Test Result

Temperature (°C)	Time(Minutes	Sample A Load (kN)	Sample B Load (kN)	Sample C Load (kN)	Average Load (kN)
0°C	00	46.20	45.75	45.3	45.75
100°C	30	45.69	45.33	45.90	45.63
	45	45.30	45.87	45.18	45.48
	60	45.24	45.78	45.30	45.42
150°C	30	45.18	45.54	45.60	45.42
	45	45.36	45.27	45.27	45.30
	60	45.24	45.39	45.33	45.27
200°C	30	45.30	45.18	45.24	45.24
	45	45.18	44.70	45.30	45.06

	60	44.55	45.00	44.28	44.61
250°C	30	43.11	45.90	42.90	44.04
	45	42.90	43.50	40.08	42.90
	60	42.30	40.20	41.40	41.31
300°C	30	40.20	37.50	40.20	39.09
	45	39.00	37.80	39.45	37.11
	60	37.20	36.75	36.30	36.75

Bond Strength at Varying Times and Temperature

The results obtained from the tests are as seen and presented in the table above to enable comprehension. The maximum loss in bond strength was 0.72% at 100°C, 1.05% at 150°C, 2.49% at 200°C, 9.7% at 250°C and 19.67% at 300°C, Normal concrete losses over 20% of its compressive and bond strength at 300°C (. This shows that Slag cement has higher resistance to heat attack than Ordinary Portland Cement in terms of both compressive and bond strength.

Conclusion

From this research, the following conclusions were made:

1 Slag cement concrete has a considerable higher bond strength than Ordinary Portland cement.

2 It was observed that from a temperature of 100-200°C, there was no significant effects of temperature on the bond strength of the slag concrete (0.26-2.49

3 Above a temperature of 200°C and up to 300°C the effects of temperature on the bond strength concrete became significance. At 250°C (5.98%) at 60 minutes but was still not significance at 30 and 45 minutes (3.15-4.27%) , but at 300°C, a significance effect was noticed from 45 minutes to be 6.10%.

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4 It was also observed that the time interval at which the concrete was subjected to heat has a significance influence on the concrete strength, the more the concrete stays under heat, the lesser the strength.

5 Slag Cement concrete has slightly higher but approximately the same thermal resistance ability as compared to Ordinary Portland Cement. Hence, Structural design for fire safety for Ordinary Portland Cement can be applicable for slag cement.

Recommendations

The following recommendations were made:

1 Higher temperature values should be use to examine much of the effects of temperature on the bond strength slag cement concrete.

2 Other mechanical properties like, flexural strength, fracture toughness e.t.c. should also be investigated to properly examine the performance of slag cement on thermal conditions.

3 Much work should be done to bring out a balance design of slag cement for fire safety.

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