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EFFECT OF PARTIAL REPLACEMENT OF CEMENT WITH GROUND GRANULATED BLAST FURNACE SLAG IN CONCRETE

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ABSTRACT

The present paper examines the effect of using Ggbs as partial replacement of cement in producing a engineered cementitious composites. In recent years Ggbs when replaced partial with cement has emerged as a major alternative to conventional concrete and has rapidly drawn the concrete industry attention during to its energy savings, cement savings, cost savings, environmental and socio-economic benefits. Effect of replacement was seen on compressive strength, tensile strength and modulus of rupture by casting mixes of grades M20, M30 and M40 and cement replacement adopted was 0 %, 15%, 30%, 40%, 50%. Here an effort is made towards a specific understanding of the efficiency of Ggbs in the concrete, strength develop, low heat of hydration, resistance to chemical attack, better workability, good durability and cost effective.

KEYWORDS: GGBS, Blast Furnace Slag, Sustainability

INTRODUCTION

In India we produce about 7.8 million tons of Ggbs slag as a byproduct obtained in the manufacture of pig iron in the blast furnace. It is a nonmetallic product consisting essentially of silicates and aluminates of calcium and other bases. The molten slag is rapidly chilled by quenching in water to form a glassy sand like granulated material.

The disposal of such slag even as a waste fill is a problem and may cause serious environmental hazards with the projected economic growth and development in the steel industry, the amount of production is likely to increase many folds and environmental problem will thus pose a large threat.

It is seen that high volume ecofriendly replacement by such slag leads to the development of concrete which not only utilizes the industrial wastes but also saves a lot of natural resources and energy. This in turn reduces the consumption of cement.

This paper presents the strength development of concrete with Ggbs as a partial replacement material for cement to make concrete with satisfactory material properties similar to that shown by normal concrete. The research work overall aimed to compare the different properties of fresh and hardened concrete made with different cement replacement levels of Ggbs with concrete having pure ordinary Portland cement.

ORIGIN OF BLAST FURNACE SLAG

In the production of iron, the blast furnace is continuously charged from the top with iron oxide (ore, pellets, sinter, etc), fluxing stone (limestone and dolomite), and fuel (coke). Two products are obtained from the furnace. Molten iron that collects in the bottom of the furnace (hearth) and liquid iron blast-furnace slag floating on the pool of iron. Both are periodically tapped from the furnace at a temperature of about 1500c.

Research Paper

Chemical and physical properties

The composition of blast furnace slag is determined by that of the ores, fluxing stone and impurities in the coke charged into the blast furnace. Typically, silicon, calcium, aluminum, magnesium, and oxygen constitute 95 percent or more of the blast-furnace slag. Table 1.1 indicates the chemical analysis range for elements (reported as oxides) in blast-furnace slag.

The ranges in composition from source to source shown in Table 1.1 are much greater than those from an individual plant. Modern blast-furnace technology produces very low variability in the compositions if both the iron and the slag from a single source. To maximize hydraulic (cementitious) properties, the molten slag must be chilled rapidly as it leaves the blast furnace.

Rapid quenching or chilling minimizes crystallization and converts the molten slag into fine aggregate sized particles (generally smaller than a 4.75 mm (No.4) sieve, composed predominantly of glass. This product is referred to as granulated iron blast-furnace slag. The cementitious action of granulated blast-furnace slag is dependent to a large extent on the glass content, although other factors will also have some influence. Slowly cooled slag is predominately crystalline and therefore do not possess significant cementitious properties.

Table 1: Range of chemical composition of blast furnace slag.

Sl.no	Chemical constituents (as oxides)	Range of composition percent by mass
1	Sio2	32-42
2	Al2o3	7-16
3	Cao	32-45
4	MgO	5-15
5	SO	7-2.2
6	Fe2O3	0.1-1.5
7	MnO	0.2-1.0

OBJECTIVES

1. To evaluate different strength properties of concrete mixtures with GGBS replaced in percentage in concrete making workable high strength and durable concrete containing GGBS to reduce the usage of ordinary Portland cement
2. To reduce the use of Portland cement and to improve the usage of other products such as GGBS
3. To study the early age (28 days) strength development of concrete containing various proportions of GGBS under normal curing and the effect of curing duration on strength development
4. To design mix proportions for M20, M30, M40 as per IS 10262-2000
5. To test the moulds like cylinder 150×300 mm beams 100×100×500 mm, to determine split tensile strength and flexural strength.
6. Parameters of study

a. To conduct preliminary test on various ingredients used in concrete

b. To vary the percentage of GGBS from 0% to 50%

c. Study the strength properties of concrete with variation in GGBS

d. To draw the graph of compressive strength vs percentage replacement of cement for different grades of concrete

e. To draw the graph of flexural strength vs percentage replacement of cement for different grades of concrete

g. To draw the graph of split tensile strength vs percentage replacement of cement for different grades of concrete.

MATERIALS AND METHODS

GGBS:

The composition of blast furnace slag is determined by that of the ores, fluxing stones, and impurities in coke charged into the blast furnace typically silicon, calcium, aluminium, magnesium, and oxygen constitute 95 percent or more of the blast-furnace slag. Table 3.2 indicates the chemical analysis range for elements in blast-furnace slags produced in the united state and Canada in 1988.

The ranges in composition from source shown in table 3.2 are much greater than those from an individual plant. Modern blast furnace technology produces very low variability in the compositions of both iron and the slag from a single source. To maximize hydraulic properties, the molten slag must be chilled rapidly as it leaves the blast furnace.

Rapid quenching or chilling minimizes crystallization and converts the molten slag into the fine aggregate sized particle. This product is referred to as granulated iron blast-furnace slag.

MIX DESIGNS

i) Mix design for M20 grade

Water	Cement	Fine aggregate	Coarse aggregate
0.55	1	2.02	3.38

ii) Mix design of M30 grade

Water	Cement	Fine aggregate	Coarse aggregate
0.45	1	1.59	2.66

iii) Mix design of M40 grade

Water	Cement	Fine aggregate	Coarse aggregate
0.4	1	1.38	2.30

RESULTS

Compressive strength:

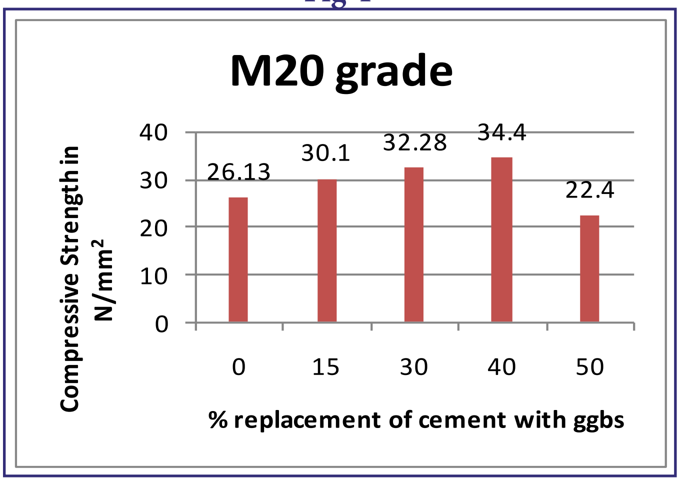
Compressive strength of concrete mixes made with and without ggbs was determined at 28 days. The cubes of size 150 mm were tested in a compression testing machine of capacity 2000KN.

M20 grade:

Table -Compressive Strength (M20) at Different Percentages of GGBS

SL NO:	Percentage of GGBS	Average compressive strength (N/mm2)
1	0	26.13
2	15	30.1
3	30	32.28
4	40	34.4
5	50	22.4

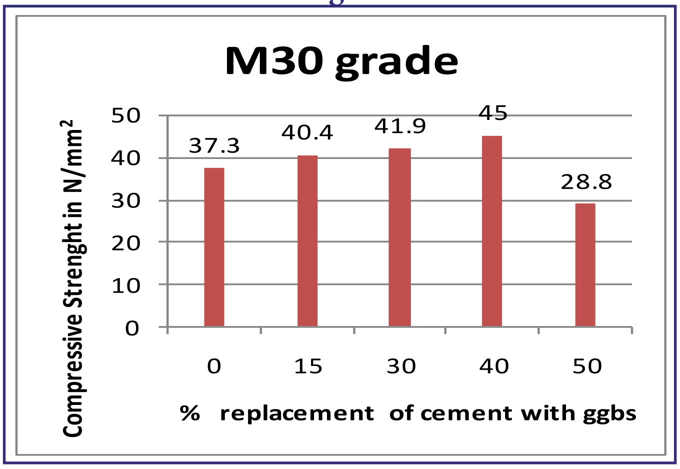
Fig-1



M30 grade:

SL NO:	Percentage of GGBS	Average compressive strength (N/mm2)
1	0	37.3
2	15	40.4
3	30	41.9
4	40	45
5	50	28.8

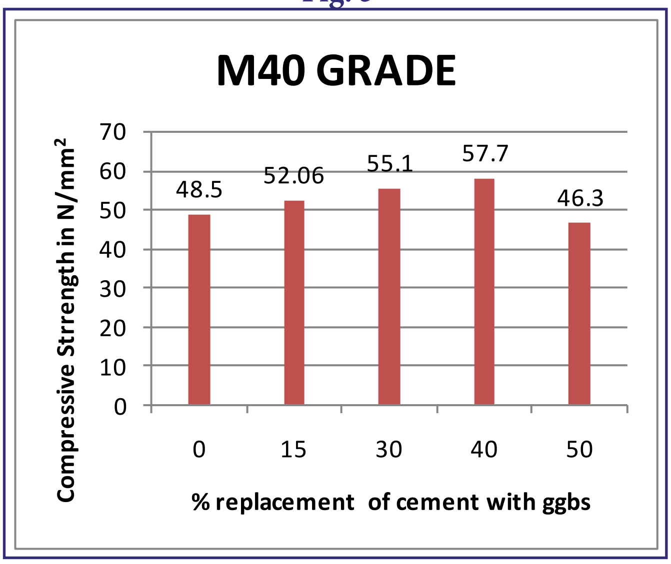
Fig. 2



M40 grade:

SL NO:	Percentage of GGBS	Average compressive strength (N/mm2)
1	0	48.5
2	15	52.06
3	30	55.1
4	40	57.73
5	50	46.3

Fig. 3



Test for split tensile strength:

The tensile strength of concrete was obtained by subjecting cylinder to the action of compressive force. the test were carried out as per specifications of IS 58166-1970 on 2 number of cylinders. The specimen was placed between two patterns of compression testing machine .steel strip of 3mm thick, 12mm wide and 300mm wide were placed between the patterns and the surface of the cylinder. The load was applied at a uniform rate of 100 kn/minute till the specimen failed along the vertical diameter. The tensile strength of the concrete was calculated using the formula

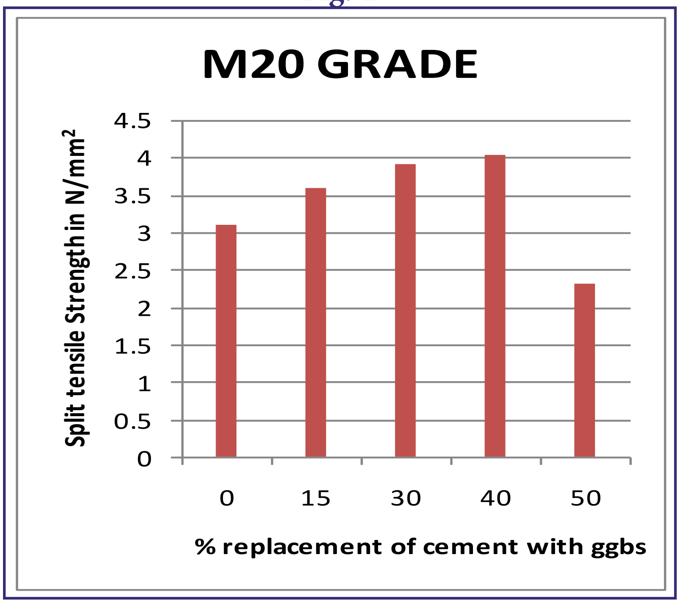
Split tensile strength=2p/(Πdh)

Split tensile strength:

M20 grade:

SL NO:	Percentage of GGBS	Average Split Tensile strength (N/mm2)
1	0	3.05
2	15	3.6
3	30	3.9
4	40	4.03
5	50	2.3

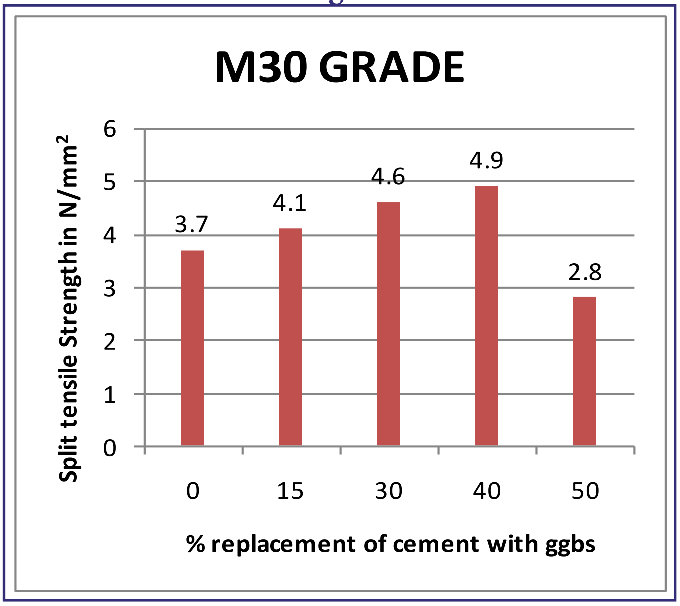
Fig. 4



M30 grade:

SL NO:	Percentage of GGBS	Average Split Tensile strength (N/mm2)
1	0	3.7
2	15	4.1
3	30	4.6
4	40	4.9
5	50	2.8

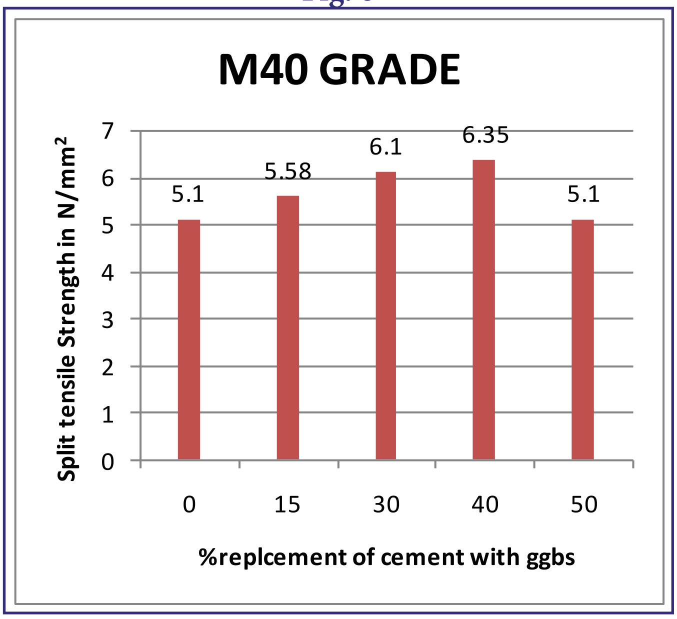
Fig. 5



M40 grade:

SL NO:	Percentage of GGBS	Average Split Tensile strength (N/mm2)
1	0	5.1
2	15	5.58
3	30	6.1
4	40	6.35
5	50	5.1

Fig. 6



Flexural Strength:

Another common test performed for determination of tensile strength is flexural test in which sample plain concrete beam of size 100×100×500 is subjected to two point load. The test is performed in accordance with IS 516-1959.

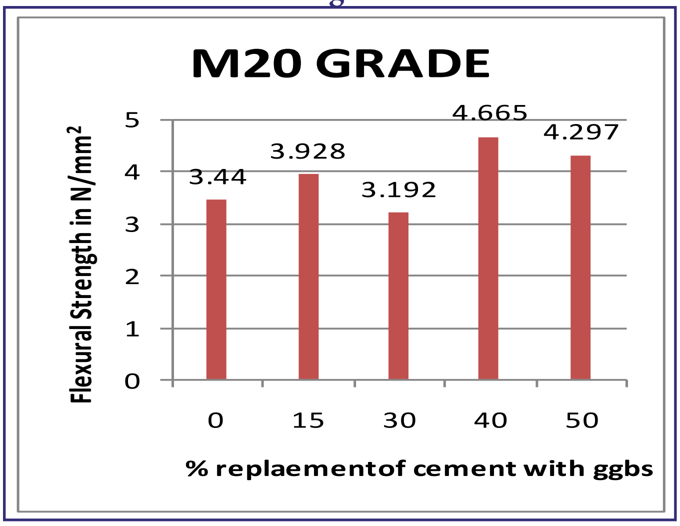
The maximum tensile stress readed is called modulus of rupture and is computed from standard formula, Flexural strength=$Pl/(bd^2)$

Where P=load in Newton
l=length of the beam=500mm
d=depth of beam=100mm
b=width of beam=100mm

M20 grade:

SL NO:	Percentage of GGBS	Average Flexural strength (N/mm2)
1	0	3.44
2	15	3.192
3	30	3.928
4	40	4.665
5	50	4.297

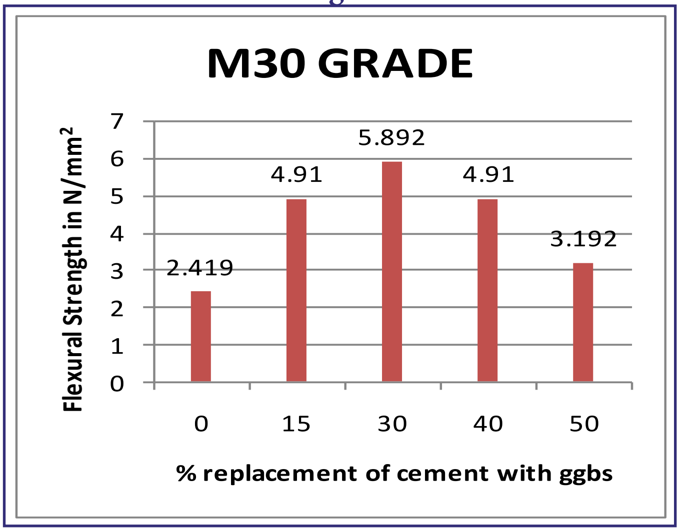
Fig. 7



M30 grade:

SL NO:	Percentage of GGBS	Average Flexural strength (N/mm2)
1	0	2.419
2	15	4.91
3	30	5.89
4	40	4.91
5	50	3.192

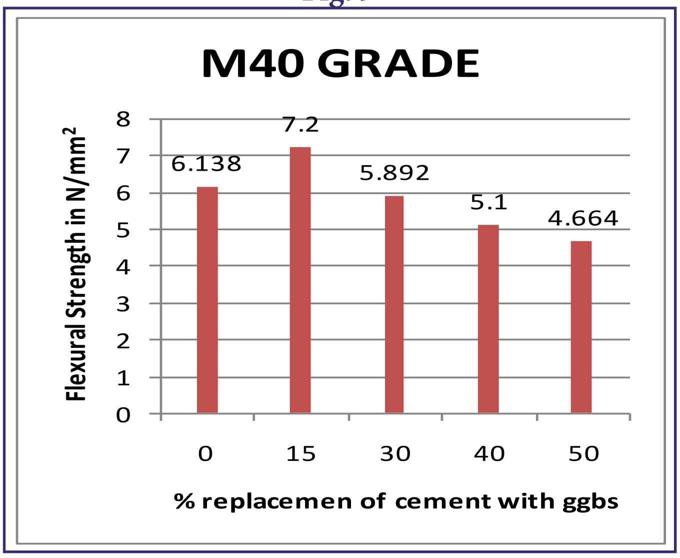
Fig. 8



M40 grade:

SL NO:	Percentage of GGBS	Average Flexural strength (N/mm2)
1	0	6.138
2	15	7.2
3	30	5.892
4	40	5.1
5	50	4.664

Fig. 9



COMPARATIVE RESULTS

Fig. 10

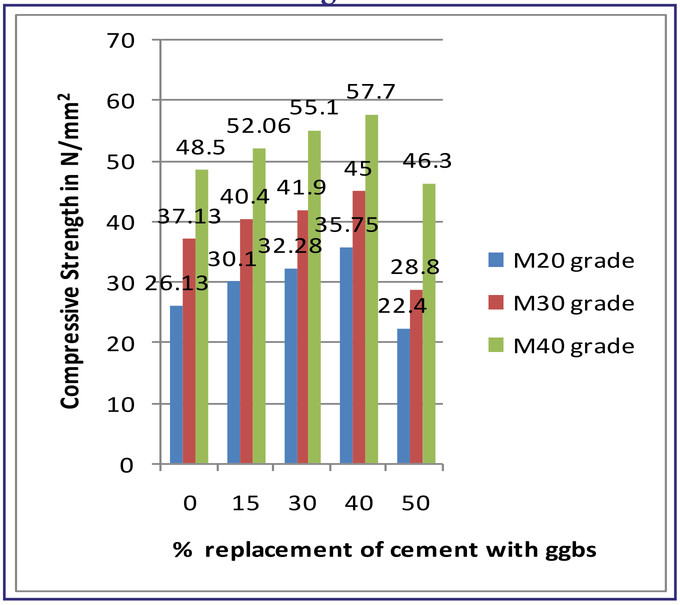


Fig. 11

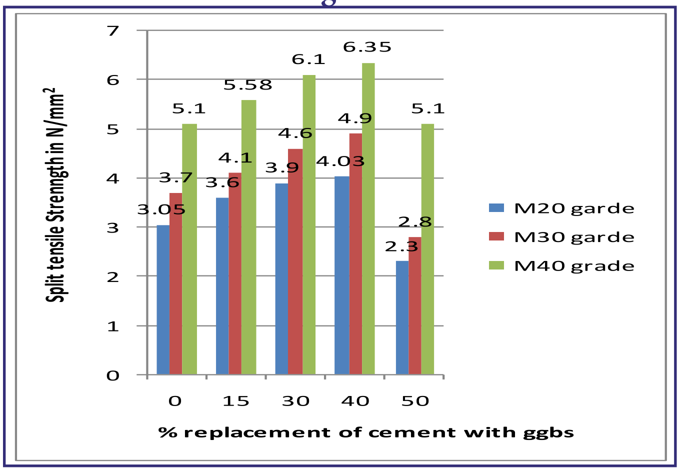
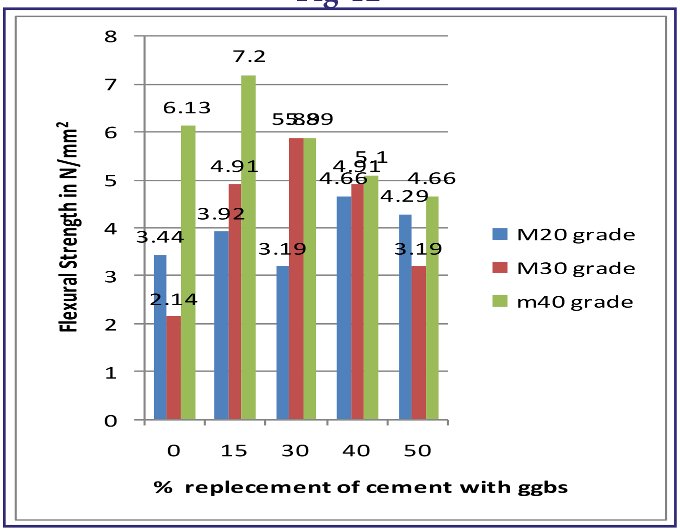


Fig-12



CONCLUSIONS:

1. This study concluded that the effect of ground granulates blast furnace slag replacement not only increased the strength but also created a better fiber bridging property that resulted in better ductility of the ECC
2. Split tensile strength of GGBS concrete is 18.23% more than that of conventional concrete as compared with conventional concrete. 30.19% increase in flexural strength was noticed in the GGBS concrete comparatively with the conventional concrete as compared with conventional concrete.
3. The cracking due to restrained drying shrinkage of concrete containing slag is less than that for concrete without slag.
4. At higher temperatures strength gain is much more rapid and the improvement in early age strength is more significant at higher levels ggbs
5. Degree of workability of concrete was improved up to 50% replacement for M25 grade concrete.
6. GGBS concrete is more sensitive to curing condition than Portland cement concrete. Due to lower hydration rate of slag, curing time should be prolonged than Portland cement concrete.
7. Effect of partial replacement was very small tensile strength and modulus of rupture. I.e. between strength of control mix and the blended cement concrete. GGBS is a waste product and only grinding makes it fit for use.
8. The chemically bound chloride content increased with the increasing GGBS replacement in concrete.

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