Detailed comparative study of concrete by partially replacement of cement with GGBS and glass powder

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Abstract:The production of cement results in emission of greenhouse gas impacting adversely on the environment. The cost of cement is also increasing and the raw materials for manufacture of cement are also depleting. Hence, the researchers are trying to use waste materials having cementitious properties , which can be added in cement concrete so that the emission of green house gas can be reduced and sustainable management of waste materials can be done. The ground granulated blast furnace slag is by product obtained from iron manufacturing industry which can be used as partial replacement and the finely grounded waste glass powder can also be used as partial replacement .This paper presents experimental study of compressive , flexural and tensile split strength test prepared with ordinary Portland cement partially replaced by GGBS and glass powder in varying percentage of 10%,20%,30% . The results obtained from compressive strength test , tensile split strength test and flexural strength test are compared between GGBS and glass powder. The compressive strength, flexural strength and split tensile strength of concrete partially replaced cement with glass powder was found to be more than the concrete partially replaced cement with GGBS.

Keywords: GGBS , Glass powder , compressive strength , split tensile strength , flexural strength.

1. INTRODUCTION

Concrete is generally used in construction as it has properties like high compressive strength, high stiffness and high sturdiness when it is subjected to hazardous environmental conditions. However , production and utilization process of cement in concrete yields emission of greenhouse gases to the environment. Hence researchers are trying to replace cement partially or completely with other suitable material so that emission of greenhouse gases could be reduced.

In concrete production, either there will be replacement of cement by some waste material or some other addition to reduce cost of utilising cement and reduction of greenhouse emission gases in to the environment, leading to environmentally sustainable concrete. In this study, Glass powder and GGBS has been utilized additionally in varying proportions to concrete to analyse the mechanical properties of partially replaced concrete.

Glass powder

Glass can be obtained by melting a combination of silicon oxide , soda , dolomite, ($CaMg(CO_3)_2$), and rock ($CaCO_3$) at a temperature 1600^o C. the mixture is the allowed to cool down quickly so that it does not crystallise. For colour development , special additives can be used.

Glass is an inert material that could be recycled without changing its chemical properties. Glass is an amorphous material having high silica content which makes it pozzolanic. Studies have found that when glass is finely grounded and used as pozzolanic material, it does not contribute to alkali silica reaction. In the recent research, efforts are being made to use waste glass powder as partial replacement of cement in concrete production as a part of green house management.

Table 1 Chemical composition analysis of glass

Oxide contents	Contenet(%)
SiO_2	72.6
Al_2O_3	1.6
CaO	12.1
MgO	0.2
Na_2O	12.1
K_2O	1.0

Ground Granulated Blast Furnace slag (GGBS)

Ground Granulated Blast furnace Slag is basically a by-product of iron manufacturing industry. Iron ore, coke and limestone are fed into the furnace, and the resulting molten slag floats above the molten iron at a temperature of about 1500 ^{o} C to 1600 ^{o} C. The molten slag consists of 30% to 40% Silicon Dioxide (SiO2) and approximately 40% Calcium Oxide (CaO), which is near to the chemical composition of portland cement. The molten iron is then taken off and the remaining molten slag, which mainly consists of siliceous and aluminous residues, is then rapidly cooled down, resulting in the formation of a glassy granulate.

In India, we produce about 7.8 million tons of GGBS yearly. In india with the projected economic growth and developing steel industry, disposal of such slag as a waste fill is a serious problem and it may even cause environmental hazards. The amount of production is going to increase many folds, which will pose a large threat to the environment. It is seen that replacement by such slag leads to the development of concrete which not only utilises the industrial wastes but also saves a lot of natural resources and energy. This in turn reduces the consumption of cement.

Some of the recent studies in various parts of the world have revealed that GGBS can be efficiently used as a supplementary cementitious material in concrete. It has also proved its versatility and durability in the application of structures significantly supporting the visionary of sustainable construction. When used in concrete, GGBS is a cementitious material that can act as a partial substitution for portland cement without significantly compromising the compressive strength. It would also provide environmental and economic benefits with required workability, durability, and strength necessary for the design of the structures.

1.1 Objectives

This study has been carried out to study the mechanical properties of concrete by replacing ordinary portland cement by 10 %,20%, 30% GGBS and glass powder by conducting various test on compressive strength, split tensile and flexural strength. The structural behaviour of concrete with GGBS and concrete with glass powder is also to be studied in order to utilize it in the building construction. Hence it was proposed to study the flexural behaviour of Concrete beams after optimizing the replacement percentage of GGBS and glass powder with the results obtained from mechanical properties. The experimental investigation is carried out with the main objectives as:

- To study the effect of addition of different percentages of GGBFS i.e 10%,20% & 30% on strength properties such as compressive strength , flexural strength and split tensile strength of concrete.
- To study the effect of addition of different percentages of glass powder i.e 10 %, 20% & 30% on strength properties such as compressive strength , flexural strength , and split tensile strength of concrete.
- To investigate the practicality, versatility and feasibility of utilizing recycled glass and GGBFS as a partial replacement to cement.
- To determine the best waste glass powder and GGBFS percentage to be added as a partial replacement of cement.

2. LITERATURE REVIEW

Santosh Kumar Karri have used GGBS as partial replacement of cement with varying percentage of 30%, 40%, 50% in M20 and M40 concrete. The curing was done upto 28 days and 90 days. The workability of concrete increased with increase in GGBS replacement. The maximum compressive strength , maximum flexural strength and maximum split tensile strength was achieved at 40% GGBS replacement of cement in both M20 and M40 concrete. The concrete cubes were also kept in H_2SO_4 solution of 1% concentration and in HCl solution of 5% concentration for 28 days and 90 days.they were tested for compressive strength and it was noticed resistance power increased up to 40% replacement of cement with GGBS with respect to normal concrete. The GGBS concrete was found to more affected in HCl solution than H_2SO_4 solution.

Magandeep observed that the slump values increases with increase in cement replacement with GGBS from 10% to 40 %. Compressive strength and flexural strength at 7 and 28 days was also found to be decreasing with increasing percentage of GGBS , but it increased at the age of 56 days. The split tensile strength was found to increase in 20% and 30% cement replacement and decrease in 40% cement replacement at the age of 56 days.

M. Ramalekshmi studied compressive strength of concrete partially replaced cement with 50% -80% GGBS at 7 , 14 and 28 days. She observed decrease in strength for shot period whereas strength increased for long period in GGBS replaced cement concrete with respect to normal concrete. The maximum compressive strength was observed in 50% replacement at 28 days. She also studied beam column with and without 50% replacement. Constant axial loading and varying lateral load were applied on specimen of 28 days age, load carrying capacity increased by 6.6% in GGBS replaced cement than normal specimens. Hence it was concluded 50 % GGBS replacement can be utilised in RC specimens.

S.P. Kanniyappan , studied design of self-compacting GGBS concrete based on efficiency concept. In this study,M40 grade concrete partially replaced cement with GGBS at 40%,50% 60% proportions were used to determine optimum replacement of cement for maximum compressive strength in self-compacting concrete. The results indicate maximum replacement can be utilised in self compacting concrete.

Jangid Jitendra B. and Saoji A.C. observed that the workability of concrete with glass powder replaced cement decrease as percentage of glass powder increase.

Khatib J.M in his research observed that there is increase in slump value with increase in percentage of glass powder in concrete partially replaced cement with glass powder .

Chikhalikar S.M. and Tande S.N. studied properties of steel reinforced fiber concrete having waste glass as pozzolana. He observed 20 % replacement of cement with waste glass powder yields better workability results.

Vasudevan Gunalaan and Kanapathy pillay Seri Ganis in his research observed that glass powder used as partial replacement of cement in concrete gives another benefit of higher workability compared to the normal mix.

R .Vandhiyan in his research , he found workability decrease as percentage of glass powder replacement with cement increase. He concluded that reduction in workability was due to increase in surface area of the glass powder and the angular shape of the glass particles.

Kumarappan N. in his study, showed systematic increase in slump as the partial replacement of cement with glass powder increase. The slump was found 40 mm at 0% glass powder replacement to 160 mm at 40% glass powder replacement.

Patel Dhirendra in his study , he made concrete blocks incorporating waste glass powder. He observed that compressive strength decrease moderately with increase in glass powder content after the age of 28 days.

Vasudevan Gunalaan and Kanapathy pillay Seri Ganis studied the compressive strength properties of concrete partially replaced cement with glass powder at 10%,15% and 20% propotions. He got maximum compressive strength in concrete with 20% replacement at 28 days.

Nwaubani Sunny O. and Poutos Konstantinos I. in his study , he observed that with increasing amount of glass in mortar it causes general decrease in compressive strength. He also observed that the decrease in strength becomes less evident with prolonged curing time. The particle size distribution of glass is major factor in imparting strength to the concrete.

Bajad M.N. observed 20 % replacement of cement with glass powder is optimum for sulphate attack resisitance.

Chikhalikar S.M. and.Tande S.N. studied the effect of glass powder replacement of cement on the flexural strength of concrete beam. He found 20% replacement the optimum replacement for maximum flexural strength.

Dali J.S. and Tande S.N. studied the effect of the alternate wetting and drying ,high temperature, on the properties of concrete containing admixtures. He observed 20 % replacement of cement with glass powder gives higher strength in both cases when concrete subjected to alternate drying and wetting and not subjected to alternat wetting and drying.

Jangid Jitendra B. and Saoji A.C studied the flexural strength of concrete beam partially replaced cement with glass powder and they found maximum increment was achieved at 20 % replacement beyond which it decreases.

Vandhiyan R. experimented on replacement of cement by waste glass powder and concluded that a considerable improvement in the flexural strength was seen at 10% replacement of cement.

Chikhalikar S.M. and Tande S.N. in this study , they used steel reinforced fiber concrete with partially replaced cement with glass powder. They found maximum value of tensile split strength at 20 % replacement of cement with glass powder.

Vijayakumar G in his study , he found that the tensile split strength in concrete partially replaced cement with glass powder is more than the normal concrete.

Dr. G.Vijayakumar, Ms. Vishaliny, Dr. D. Govindarajulu studied the strength properties of concrete partially replaced cement with glass powder. The main test performed compressive strength test, flexural strength test , and tensile strength test. They found following results:

- Replacement of cement with glass powder by 20%, 30% and 40% proportions increases the compressive strength by 19.6%, 25.3% and 33.7% respectively.
- Replacement of cement with glass powder by 40% increases the split tensile strength by 4.4%.
- Replacement of cement with glass powder by 20%, 30% and 40% increases the flexural strength by 83.07%, 99.07% and 100% respectively.

3. MATERIALS AND METHODS

Cement, water and Aggregates: Concrete is prepared by mixing various constituents like cement, aggregates, water etc. which are economically available. Ordinary Portland cement of grade 53 (Khyber) conforming to IS 12269 Will be used throughout the work. The fine aggregate to be used in this investigation is clean river sand collected from wahid-pora Ganderbal whose maximum size is 4.75 mm, conforming to IS 383 1987 grading zone II. Machine crushed stone angular in shape will be used as coarse aggregate conforming to IS 383 1987,also collected from Ganderbal . The origin of both fine and coarse aggregates being stream Sind. Two sizes of coarse aggregate is used; one 10 mm and other 20mm in the ratio of 70:30.

Glass powder: Glass is available locally in shops is been collected and made into glass powder. Glass waste is very hard material. Before adding glass powder in the concrete it has to be powdered to desired size. In this studies glass powder ground in ball/ pulverizer for a period of 30 to 6o minutes resulted in particle sizes less than size 150 µm and sieved in 75 µm.

The GGBS should be finely grounded into particle size of less than 45 micron to be used for replacing in cement. The GGBS was having specific gravity of 2.9 and Blaine fineness value of 4490 cm^2/gm. As shown in table below GGBS was having a high content of SiO_2 of 73.47 % and lime as 12.4 %.

Table 2: Composition of GGBS

Constituents	Composition(%)
CaO	12.4
SiO_2	73.47
Al_2O_3	4.35
SiO_3	5.48
MgO	2.14

3.1 Casting of specimens

Seven types of mix will be considered; of which One control mixture S-1 (without glass powder/GGBS) will be designed according to Indian Standard Specification IS: 10262(1999) .

The other six concrete mixes will be made by replacing the cement with 10%, 20%, 30% of glass powder by weight and 10% ,20 %,30% of GGBS by weight of cement.

3.2 Apparatus and instruments

Different instruments and apparatus are required for this project work . Cubical moulds of size 150 x 150 x 150mm made of steel are used for the determination of compressive strength. Cylindrical steel moulds of diameter 150mm and height 300mm are required for the determination of split tensile strength. Steel beams of size 100mm x 100mm x 500mm are required for the determination of flexural strength .

Various instruments such as UTM is used for strength determination .Vicat apparatus is used for determination of consistency of cement ,initial and final setting times of cement. Compaction factor apparatus is used for the determination of compaction factor. A pycnometer is used for the determination of specific gravity of sand, glass powder, GGBS .A wire basket method is used for the determination of specific gravity of coarse aggregate. A set of sieves is used for determining the zoning of sand. A table vibrator is also needed for the compaction of concrete moulds.

3.3 Results obtained via material testing

- Sand conforms to zone II.
- Sand is poorly graded.
- Fineness modulus of sand is 2.58, hence the sand is fine sand.
- Specific gravity of sand is 2.63
- Specific gravity of coarse aggregate is 2.67
- Standard consistency of cement is 30%
- Initial setting time of cement is 3hr 40min
- Final setting time of cement is 5hr 20min
- Compaction factor of concrete is obtained as 0.85

3.4 Mix design results

Mix design as 1: 1.3: 2.8 with w/c ratio 0.45.

constituent	Quantity Kg/m^3
cement	419.5
Fine aggregate	554
Coarse aggregate	1195

3.5 Compression strength test

Seven different mixes (Mix1, Mix2, Mix3, Mix4, Mix 5,Mix 6, & Mix 7) were prepared using cement replaced by glass powder at varying percentage of **10, 20,and 30** ans in mix (5,6,7,) cement was replaced by GGBS at varying percentage of **10 %, 20%and 30 %** . Fourty two number standard specimens of dimensions 150 × 150 × 150 mm were cast according to the mix proportion and cured in water at room temperature in the laboratory for 7 and 28 days. At the end of each curing period, three specimens for each mixes were tested for compressive strength and the average strength was recorded. The size of the specimen is as per the IS code 10086 – 1982. The compressive strength test on conventional concrete, glass added concrete and GGBS added concrete was performed on standard compression testing machine of 3000kN capacity, as per IS: 516-1959.

The load shall be applied slowly without shock and increased continuously at a rate of approximately 140 kg/sq.cm/min until the resistance of the specimen to the increased load breaks down and no greater load can be sustained.

Compressive strength is calculate using the following formula

Compressive strength = Wf / Ap

Where, Wf = Maximum applied load just before failure,

Ap = Plan area of cube mould.

3.6 Split Tensile Strength test

Seven different mixes (Mix1, Mix2, Mix3, Mix4, Mix5, Mix6, Mix7) were prepared using cement replaced by glass powder(mix 2 mix 3 mix 4) and by GGBS (mix 5 mix 6 mix 7 at varying percentage of **10, 20, and 30** . Forty two number standard specimens of dimensions 300 mm length and 150mm diameter were cast according to the mix proportion and cured in water at room temperature in the laboratory for 7 and 28 days. The test is carried out by placing a cylindrical specimen horizontally between the loading surfaces of a compression testing machine and the load is applied until failure of cylinder along the vertical diameter.

Split tensile strength, (T) =2P/πDL

Where, P= compressive load on cylinder ,L= length of cylinder ,D= diameter of cylinder

3.7 Flexural strength of concrete

Seven different mixes (Mix1, Mix2, Mix3, Mix4, MIX5, Mix6, Mix7) were prepared using cement replaced by glass powder(mix 2 mix 3 mix 4) and by GGBS (mix 5 mix 6 mix 7) at varying percentage of **10, 20, and 30**. Forty two number standard specimens of 500× 100× 100mm were cast according to the mix proportion and cured in water at room temperature in the laboratory for 7 and 28 days. The test is carried by placing specimen on flexural testing machine after marking the specimen.

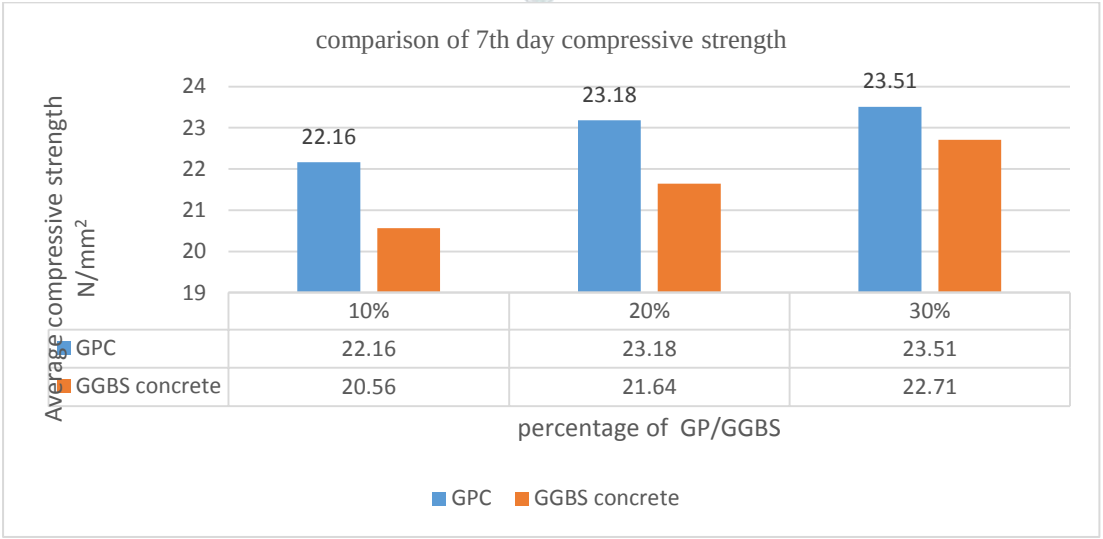
Flexural strength, fb = P×L/bd^2

Where, P=load at failure ,L= length of specimen ,b & d are width and depth respectively**.**

4. RESULTS

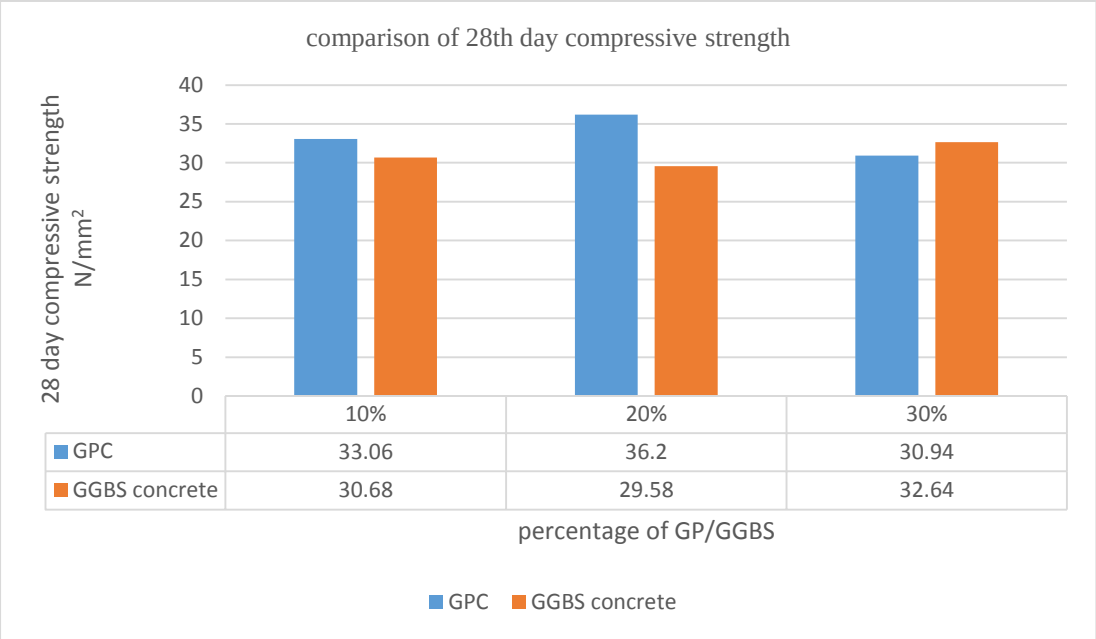
4.1 Comparison of 7th day compressive strength of partially replaced GGBS and Glass powder concrete

The compressive strength of this study is increasing up to 30% partially replaced cement with GGBS and 30% partially replaced cement with glass powder .The cube specimens 150mm x 150mm x 150mm was used for testing the compressive strength after 7 days for an M30 grade of concrete as per IS: 516-1959. Specimens have been made for control mix and compared with different percentages replacement of cement with GGBS and Glass powder i.e. for 10%, 20%, and 30 %. The compressive strength after 7 days has discussed in the given figure below.



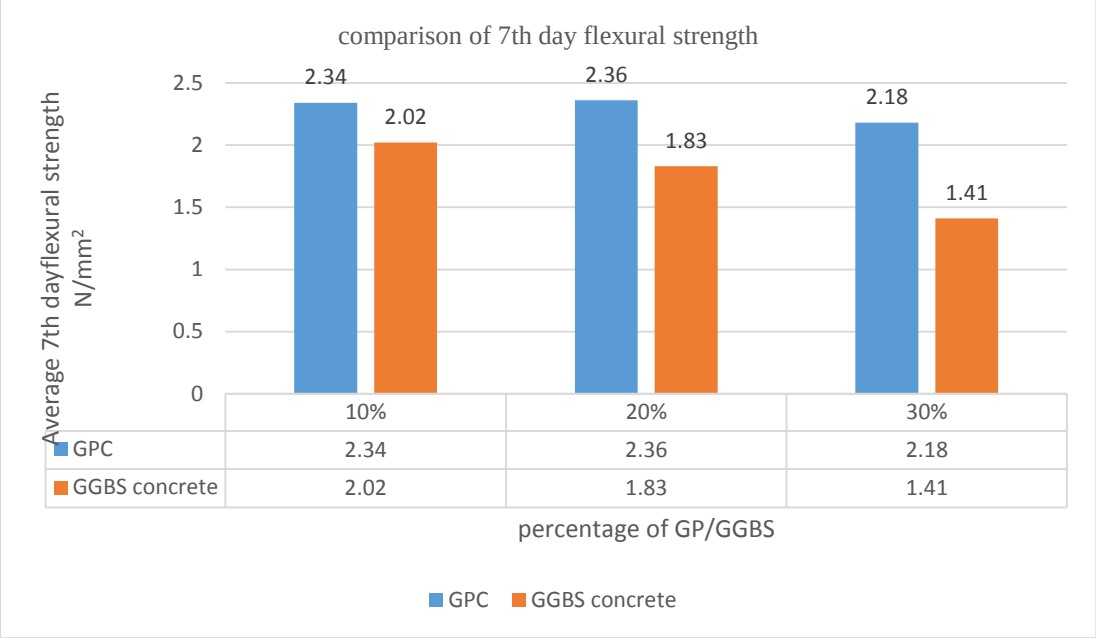
4.2 Comparison of 28th day compressive strength of partially replaced GGBS and Glass powder concrete

The compressive strength of this study is increasing up to 30% partially replaced cement with GGBS and 20% partially replaced cement with glass powder .The cube specimens 150mm x 150mm x 150mm was used for testing the compressive strength after 28th day for an M30 grade of concrete as per IS: 516-1959. Specimens have been made for control mix and compared with different percentages replacement of cement with GGBS and Glass powder i.e. for 10%, 20%, and 30 %. The compressive strength after 28 days has discussed in the given figure below.



4.3 Comparison of 7th day flexural strength of partially replaced GGBS and Glass powder concrete

The most common concrete structures are subjected to flexure is a highway or the airway pavement and the strength of the concrete for pavements is commonly determined by means of bending tests. The flexure strength in this study is decreasing up to 30% partially replaced cement with GGBS and increasing up to 20% partially replaced cement with glass powder. The beam specimens 100mm x 100mm x 500mm was used for testing the flexural strength after 7 days, for an M30 grade of concrete as per IS: 516-1959. Specimens have been made for control mix and compared with different percentages replacement of cement with GGBS and glass powder i.e. for 10%, 20%, and 30 %. The flexural strength after 7 days, has been discussed in the given figure below.



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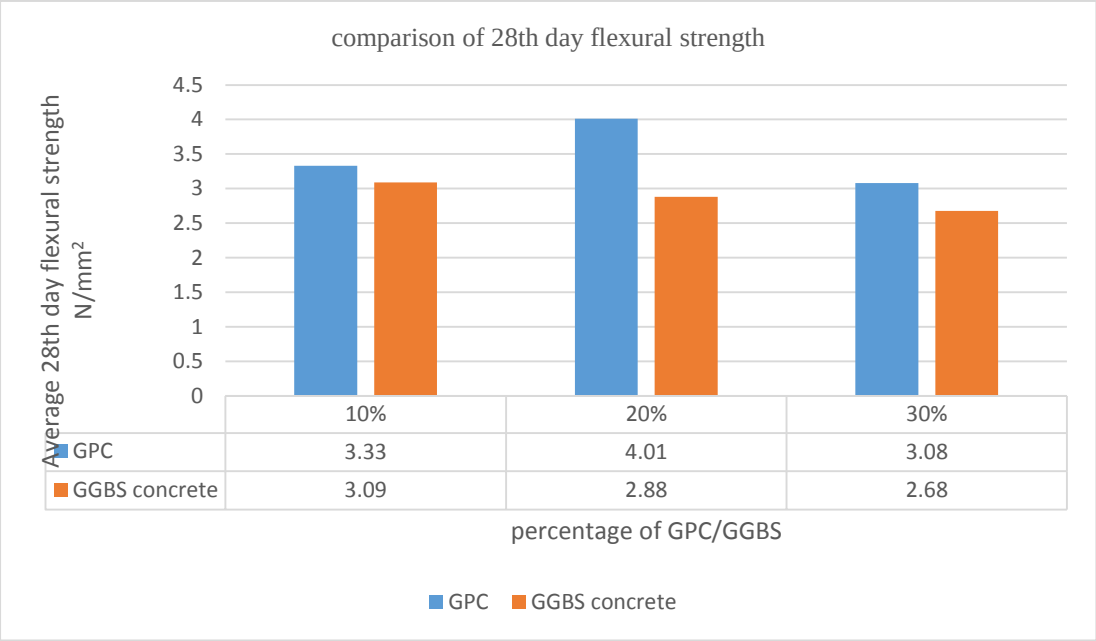
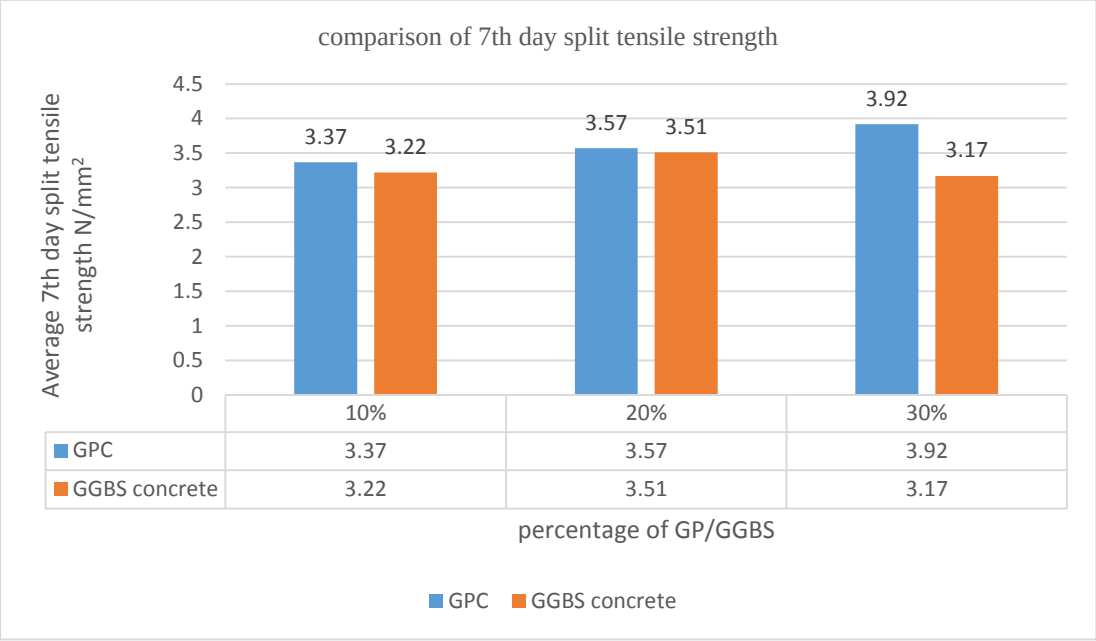


4.5 Comparison of 7th day split tensile strength of partially replaced GGBS and Glass powder concrete

The split tensile strength in this study is increasing up to 20% partial replacement of cement with GGBS glass powder. The cylinder specimens 150mm diameter with 300mm length were used for testing the split tensile strength after 7 days, for an M30 grade of concrete as per IS: 516-1959. Specimens have been made for control mix and compared with different percentages replacement of cement with GGBS and Glass powder i.e. for 10%, 20%, and 30 %. The split tensile strength after 7 days, has discussed in the given figure below



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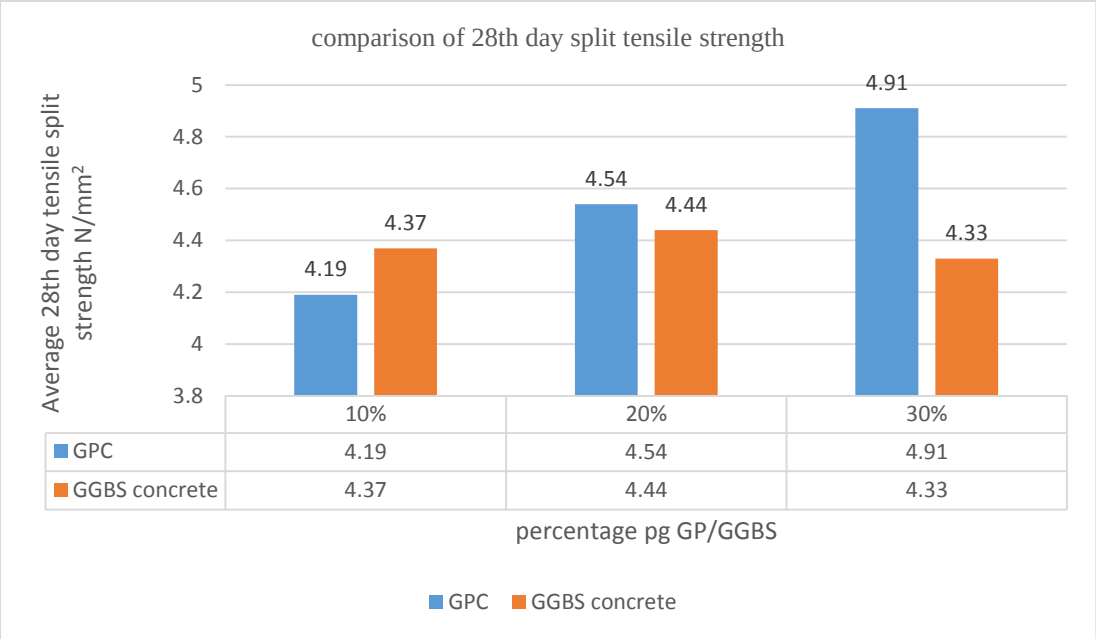

5. CONCLUSION

From the study we conclude the following results:

- The 7th day compressive strength of M30 concrete is increasing as the percentage of glass powder is increasing. The maximum value of 7th day compressive strength is 23.51 N/mm2 at a percentage of 30% Glass powder
- The 28th day compressive strength of M30 concrete is increasing as the percentage of glass powder increased upto 20%. The maximum value of 28th day compressive strength is 36.20 N/mm2 at a percentage of 20 %.
- The 7th day compressive strength of M30 concrete decreased up to 20% GGBS replacement and then increases at 30% of GGBS replacement of cement. The maximum 7th day compressive strength at 30% GGBS is 22.71N/mm2.
- The 28th day compressive strength of M30 concrete also decreased up to 20 % GGBS partial replacement and the it increases at 30% partial replacement. The maximum value of compressive strength at 30 % partial replacement is 32.64 N/mm2.
- The 7th day compressive strength increased in both partially glass powder and GGBS replaced cement concrete. The glass powder concrete showed more 7th day compressive strength than GGBS concrete.
- The gain of 28th day compressive strength of partially replaced glass powder concrete is more than the partially replaced GGBS concrete. The maximum value of compressive strength for glass powder concrete is 36.2 N/mm2 and for GGBS concrete is 32.64 N/mm2.
- The 7th day flexural strength of M30 concrete partially replaced with glass powder showed increase in strength up to 20% and the maximum value of 7th day flexural strength is 2.36 N/mm2.
- The 28th day flexural strength of M30 concrete partially replaced with glass powder showed increase in flexural strength up to 20 % and the maximum value of 28th day flexural strength is 4.01 N/mm2.
- The 7th day flexural strength of M30 concrete partially replaced with GGBS decreased with increase in percentage of GGBS and the maximum value was found on 0% GGBS content with a value of 2.22 N/mm2.
- The 28th day flexural strength of M30 concrete partially replaced with GGBS decreased with increase in percentage of GGBS and the maximum value was found on 0% GGBS content with a value of 3.20 N/mm2.
- The 7th day and 28th day flexural strength of partially replaced glass powder concrete was found to be more than that of the partially replaced GGBS concrete. The flexural strength increased in partially replaced in glass powder up to 20 % while as it decreased in case of partially replaced GGBS concrete.
- The 7th day split tensile strength of partially replaced glass powder M30 concrete increased with increase in percentage of glass powder. The maximum value of 7th day split tensile strength is 3.92 N/mm2 on 30% of glass powder.
- The 28th day split tensile strength of partially replaced glass powder M30 concrete increased with increase in percentage of glass powder. The maximum value of 28th day split tensile strength is 4.91N/mm2 on 30% of glass powder.
- The 7th day split tensile strength of partially replaced GGBS concrete increased with increase in percentage of GGBS up to 20% and the maximum value of split tensile strength is 3.51 N/mm2.
- The 28th day split tensile strength of partially replaced GGBS concrete increased with increase in percentage of GGBS up to 20% and the maximum value of split tensile strength is 4.44 N/mm2.
- The 7th day and 28th day split tensile strength of partially replaced glass powder concrete was found to be more than that of partially replaced GGBS concrete. In case of glass powder concrete split tensile strength increased up to 30% while as split tensile strength of GGBS concrete increased up to 20 %.

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