INTERNATIONAL JOURNAL OF ADVANCE RESEARCH, IDEAS AND INNOVATIONS IN TECHNOLOGY

ISSN: 2454-132X

Impact factor: 4.295

(Volume 4, Issue 2)

Available online at: www.ijariit.com

An experimental study on the strength properties of concrete using waste glass and GGBS

Abhinav Kumar Singh
abhinavkrsingh99@gmail.com
Lovely Professional University, Phagwara, Punjab

Geeta Mehta
geeta.18262@lpu.co.in
Lovely Professional University, Phagwara, Punjab

ABSTRACT

The usage of waste materials from the industries has been continuously emphasized within the research work. There is a developing interest in the usage of recycled glass (RG) and ground granulated blast furnace slag (GGBS) as an aggregate creation materials specifically for non-structural packages. Although the recycled glass is capable of reducing the water absorption and drying shrinkage in concrete products because of its close to zero water absorption characteristics, the potential adverse effect of the use of glass because of alkali-silica reaction (ASR) in cementitious materials is a real issue. GGBS is such waste which is by-product of the iron production industries, whose use and production has increased in many years. GGBS can be used in experimental work as opportunity binder and filler materials for Ordinary Portland Cement (OPC) and River Sand respectively in concrete due to their pozzolanic behavior. In this experiment, cement is substituted by GGBS at 50%, 60% and 70% and sand with glass powder at 20% in numerous percentages. Mechanical strength were calculated at 7, 28 and 56 days of M20 grade concrete. The mechanical strength in the study is increasing at 7th days for all replacement levels of GGBS and sand but, later on, strength was only increasing at 50% and 60% GGBS and 20% sand in 28th and 56th days in comparison to control mix. The maximum mechanical strength is achieved when 60% cement is substituted by GGBS and 20% sand is substituted with glass powder. The mechanical strength starts reducing at 70% GGBS and 20% sand. 100-micrometer glass size is good for achieving the strength. GGBS and glasses are the waste merchandise. Therefore, the disposal problem of stuff is solved aspect by way of aspect the saving of cement and sand will be done. There will be environmental and the economic benefits from the utilize of recycled waste glasses and GGBS to concrete production. 3R 's, (Reuse, Recycle, and Reduce) are going to be useful in reducing environmental and health hazards.

Keywords: *Mechanical strength, Glass powder, GGBS.*

1. INTRODUCTION

Nowadays, concrete is mostly employed in construction purpose as a result of its fascinating properties like compressive strength, high stiffness and high sturdiness beneath sensible environmental conditions. However, concrete on the opposite hand has low lastingness and is brittle naturally. A high strength material must be used to create a good quality of the structure.

In the present era, the main aim is to cut back the value of construction materials used to make concrete. To beat the value of construction materials either there'll be replacement by waste materials or some addition is required to cut back the value of concrete. In this study, glass powder and GGBS has employed additionally to concrete to analyze the mechanical properties and cut back the value of the concrete.

Glass powder

The first manufactured glass was found in the geographic area regarding 3000 B.C. The initial glass vessels were created in 1500 B.C., geographic area in Egypt. In that time, the glass trade was slow and high-demand because of the limited furnaces, clay ports of poor quality, and the warmth was hardly ample for melting raw materials. Due to Invention of a blowpipe, in thirty B.C., made the production of glass easier and cheaper and the glass became offered for people for the first time in history. The colorless glass initially appeared throughout the primary A.D. century, by the introduction of the metal compound. In 1688 a replacement technique was developed for the assembly of the sheet in France. This development helped among the assembly of

the high-quality mirrors. Glass could also be manufactured by melting a combination of oxide (silicon oxide), soda, dolomite (CaMg(CO3)2) and rock (CaCO3) at a heat, up to 1600 C. Then, the mixture is to be cooled to solidify whereas not crystallization. Special additives are added to the glasses for their colors development. The additives used, such as quartz, alkali-silicates, soda-lime glass (containers, float, sheet, light-weight bulbs and tempered ovenware), salt glasses (pharmaceutical and chemical element sealing), lead glasses. Alcohol containers alone consists 44% of wastes recycled material by 2015, that containers are anticipated to make a contribution of 116,000 tonnes of wastes to the collection move.

Table: - 1 Chemical compositions analysis of glass

Oxide Contents	**Content (%)**
Sio_2	72.5
Al_2O_3	1.7
Cao	12.0
Mgo	0.2
Na_2O	12.2
K_2O	1.0

Ground-granulated blast-furnace slag (GGBS)

GGBS is acquired by quenching molten-iron from the blast furnace by water, for the supply of a glassy and granular product which is dried and ground in to a a fine powder. GGBS is the waste matter of the iron-producing trade, whose use and production has exaggerated several folds. Throughout last decades, it is employed in the experimental work as a different binder and the filler materials for ordinary Portland cement (OPC) and sand in the concrete respectively. GGBS are generally used for making durable concretes structure in mixture with the OPC. GGBS had been mostly used in Europe and increased more within United State also in Asia (mainly in Japan and Singapore) due to its superior durability in concrete, extension in the lifespan of homes from 50 years to approximately 100 years. Two essential uses of the GGBS are for the manufacturing of quality-improved scum cement, mainly Portland Blast-furnace cement (PBFC) and the high slag blast-furnace cement (HSBFC), by the GGBS contents materials ranging commonly from thirty to seventy percent and within the production of the ready-mixed or the site-batched durables concretes. GGBS cements are automatically specified the in concretes to offer safety against the sulphate attack and the chloride attack. GGBS is now effectively changed in to sulphate-resisting Portland cements (SRPC) in the market due to its sulphate resistance action and advanced overall performance and significantly decreased price than OPC. To protect towards chloride assault, GGBS used for a substitute of fifty percent in the concrete. Instances of chloride attack arises in strengthened concrete inside marine environments and in road bridges where concretes are subjected to splashing from the de-icing salts at the road.

Utilization of the GGBS in the bridge piers also the abutments can increase the life of structures by 50%. Concrete which contains GGBS cement gives higher final strengths than concrete made up of Portland cement. It is having strength enhancing metallic-elements in higher proportions. Concrete created with GGBS continues to develop the strength as the passes of time, and it had seen that 28-days strengths became double over the periods of 10 to 12 years. Due to less lime content materials, permeability is decreased. That's why GGBS is powerful in stopping efflorescence when GGBS used at replacement ranges from fifty to sixty percent.

Table: - 2 Chemical composition analysis of GGBS

Oxide Contents	**Content (%)**
Cao	30 – 50
Sio_2	28 – 38
Al_2O_3	08 – 24
Mgo	01 – 18

2. LITERATURE REVIEW

Rakesh Sakale et. Al. studied the alternative of cement by waste glass powder in steps of 10%, 20%, 30% and 40% respectively via volume of cement It is discovered that the compressive, flexural and break up tensile strengths of concrete increase to start with as the replacement percent of cement by means of glass powder increases and become maximum at about 20% and later lower. The workability of concrete reduces monotonically as the alternative percentage of cement by glass powder will increase. **Oluko et. Al.** investigated the compressive power of Compressed Stabilized Earth Block (CSEB) by way of in part replacing the cement (stabilizer) inside the block with Waste Glass Powder (WGP) and it became found from the effects that, as WGP is delivered to compressed stabilized earth block, its power reduces. Although, the strength for CSEB without waste glass had the very best electricity, CSEB with WGP indicated strengths better than 3N/mm2 encouraged as minimal energy for CSEB at 28 days for the proportion of replacements used in this study, the very best of which became 60%. No greatest cost become determined for WGP addition to the CSEB as replacement for cement, however, enough strengths appropriate sufficient for handling at early ranges of the CSEB whether or not at particle length of one hundred fifty μm or seventy five μm had been executed at 20% alternative of cement with WGP in CSEB. It may be concluded that the position of WGP in CSEB is extra of filler than a binder. **Shuhua Liu et. Al.** Accomplished a research to ascertain the inhibitory effect of waste glass powder (WGP) on AlkaliSilica Reaction (ASR) growth

triggered by means of waste glass mixture. These research confirmed that there is ASR risk with an ASR enlargement charge over 0.2% while the sand incorporates extra than 30% glass mixture. However, WGP can successfully manipulate the ASR enlargement and inhibit the enlargement price triggered by way of the glass aggregate to be below zero.1%. The ASR enlargement can be controlled in a safe variety while WGP content is 10%, 20% and 30% with its specific surface place greater than 1137.40, 604.37 and seventy one.34m2/kg, respectively, or with low average particle size in step with the calculation. **Raghavendra K. And Virendra Kumara K. N investigated** about the compressive energy, break up tensile strength and water absorption of M40 grade of concrete mixes with 20% consistent substitute of waste glass powder in cement and partial alternative of waste foundry sand in first-class mixture. From the check effects, power became completed very less on seventh and 14th days but it will increase on the 28^{th} day. High strength values have been observed at forty% replacement degree in energy parameters. The compressive strength and break up tensile energy of concrete at 7, 14 and 28 days will increase. **Ana Mafalda Matos** aimed to assess using waste glass powder in powder kind SCC. It could be concluded that waste glass powder can be used effectively in SCC further enhancing chloride penetration and water absorption via capillarity, keeping energy degrees. Although soda lime glass affords a excessive alkali content material, use of floor waste glass as cement replacement in mortar, stepped forward resistance to ASR. These results corroborate the pozzolanic nature of glass powder and its behaviour with time. Although glass powder is a bit coarser than cement, it still brings advantages whilst included in cement. **Jitendra B. Jangid and A.C. Saoji** studied the alternative of Glass Powder varying partially from zero to 40%, at c programming language of 10% and examined for its Workability, Compressive Strength, Split Tensile Strength, Alkalinity check, Density Measurement, Water Absorption test, Volume of permeability check and Ultrasonic Pulse Velocity check for the age of seven, 28 and fifty six days and turned into compared with those of conventional concrete. The common test result showed that Waste Glass Powder will be applied in concrete as a great replacement of cement. It turned into additionally discovered that Workability of concrete decreases as percent of glass powder increases. Slump value of test's concrete degrees from 60 to 80 mm highest compressive electricity become observed while Glass Liquid Powder (GLP) alternative is ready 20%. Highest break up tensile strength became determined while GLP replacement is approximately 20%. **Reginald Kogbara et al. (2011)** investigated the ability of GGBS activated by cement and lime for stabilization/solidification (S/S) remedy of a mixed contaminated soil. The outcomes showed that GGBS activated by cement and lime could be powerful in lowering the leachability of contaminants in infected soils. **Shariq et al.(2008)** studied the impact of curing system on the compressive energy development of cement mortar and concrete incorporating ground granulated blast furnace slag. Tests effects show that the incorporating 20% and 40% GGBFS is quite considerable to boom the compressive strength of mortar after 28 days and one hundred fifty days, respectively. **Er. Kimmi Garg, Er. Kshipra Kapoor** studied and experimented, it's miles proved that GGBS may be used as an opportunity cloth for cement, reducing cement consumption and lowering the price of construction. Use of commercial waste products saves the environment and conserves natural assets. **Vinayak Awasare, Prof. M. V. Nagendra** made a examine work to analyse power homes of partly replaced GGBS concrete. The flexural strengths carried out are three.01Mpa, three.45Mpa, three.58Mpa, 3.44Mpa and 3.12Mpa at 0%, 20%, 30%, 40%, and 50% for GGBS concrete respectively for M20 grade concrete of OPC cement and beaten sand. This record indicates that tensile strength also gives good performance for 20%, 30 % and 40% alternative which is extra than ordinary plain concrete. **Yasutaka SAGAWA, Daisuke Yamamoto and Yoshikazu HENZAN** in a look at concluded that the specimens which encompass normal-electricity concrete and excessive-strength concrete through converting W/B from sixty five% to 35% were tested. The effectiveness of GGBS on chloride ion diffusion coefficient become investigated via migration check. Moreover, the utility of GGBS which has the floor vicinity of 6000 cm2/g for bridge superstructures changed into presented.

3. MATERIALS AND METHODS

A. **Cement**

Cement is a grey powder which is mixed to sand and water for making concrete. The cement used for experiment is of OPC 43 grade.

B. **GGBS**

GGBS stands for ground granulated blasts furnace slag. GGBS powder used for an experiment to replace cement. It is the by-products of irons and their parts making industries.

C**. Fine Aggregates**

River sand of zone 2 was used for the experiment. The consequences of sieve analysis allotted as in step with IS: 383-1970.

D. **Glass powder**

Waste glass mainly crushed bottled glass of alcohols were used for an experiment for the investigation.

E. **Coarse aggregates**

Coarse aggregates used is crushed (angular) according to IS 383: 1970. The maximum length of aggregate taken is twenty millimeter IS sieve passing and the minimum length is 12.5mm IS sieve passing. The results of sieve analysis are carried out as per IS: 383-1970.

F. **Water**

For this experimental work, clean potable water is employed for casting and curing operations. The water equipped within the field is of the potable in style of pH scale = 7.50 has been used.

Combine Proportion

Concrete combine layout with M20 grade has been designed according to IS: 10262-2009. Cubes of sizes 150x150x150mm, beams with size 500mmx100mmx100mm and cylinders with diameter 150mm with a height of 300mm has been cast ansd are examined at seven, twenty-eight and fifty-six days.

Table:- 3 Properties of OPC 43 grade Cement

S .no.	Characteristics	Value obtained Experimentally
1.	Specific Gravity	3.15
2.	Standard Consistency	30.5%
3.	Initial Setting Time	150 minutes
4.	Final Setting Time	255minutes
5.	Compressive Strength	
	3 days	32.9 N/mm^2
	7 days	42.6 N/mm^2
	28 days	47.5N/ mm^2

Hardened Concrete Properties

Compressive strength of cubes, flexural strength for beams and split tensile strength for cylinders of various mixes is also determined.

Compressive Strength

The cubes of edges 150mm have been cast for varying percentages of GGBS replaced with cement by (50%, 60%, and 70%) and (WG) is kept to be constant at 20% replaced with natural sand. The cubes are cured and tested for seven, twenty-eight and fifty-six days for each replacement with GGBS and (WG). Testing was conducted in a 2000kN testing device with a load of 140kg/cm/m^2 . The mean strength of three cubes are tested for each activity to get compressive strengths of concrete.

Tensile Strength

3 cylinders, 300m long and with 150mm diameter has been cast for varying percentages of GGBS replaced by cement by (50%, 60%, and 70%) and (WG) is kept to be constant at 20% replaced with natural river sand. Then, cylinders are cured and tested for seven, twenty-eight and fifty-six days for each replacement with GGBS and (WG). Testing was conducted in two thousand kilo-newton testing machine as (1.2 to 2.4) (π/2) l*d, N/min. The average strength of three cylinders for each activity is noted to get the tensile strength.

Flexural Strength

It is represented as the potential to face deformation beneath the load. Beams of size 100mm×100mm×500mm has been cast for varying percentages of GGBS replaced by cement by (50%, 60%, and 70%) and (WG) is kept to be constant at 20% replaced with natural sand. The beams are cured and tested for seven, twenty-eight and fifty-six days for each replacement with GGBS and (WG). The average strength of three beams for each activity is noted to determine the flexural strength.

Table:- 4 DESIGN OF CONCRETE CUBE OF 1M^3

Cement (kg)	365.50
Sand (kg)	548.25
Coarse aggregates (kg)	1096.5
Glass powder (At 20% fine sand substitution) in kg	109.65
GGBS powder (At 50% cement Replacement) in kg	182.75
GGBS powder (At 60% cement Replacement) in kg	219.30
GGBS powder (At 70% cement replacement) in kg	255.85

4. TEST RESULTS AND DISCUSSION

Compressive Strength

The compressive strength of this study is increasing up to 60% of GGBS and 20% glass powder but, later on, the strength starts decreasing at 70% GGBS and 20% glass powder.The cube specimens 150mm x 150mm x 150mm was used for testing the compressive strength after 7 days, 28 days and 56 days for an M20 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 i.e. for 50%, 60%, and 70 % and sand with glass powder at 20%. The compressive strength after 7 days, 28 days and 56 days has discussed in the given figure 1.

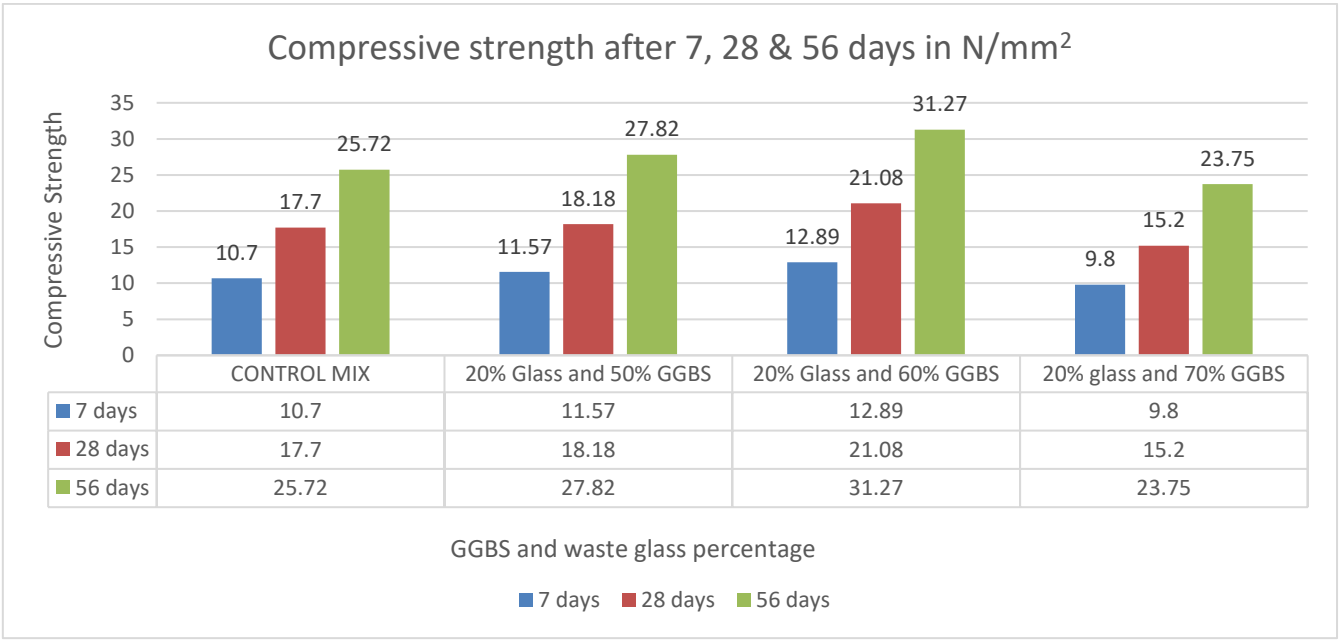

Fig 1: Compressive Strength after 7, 28 & 56 days

Flexural Strength

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 increasing up to 60% of GGBS and 20% glass powder but, later on, the strength starts decreasing at 70% GGBS and 20% glass powder. The beam specimens 100mm x 100mm x 500mm was used for testing the flexural strength after 7 days, 28 days and 56 days for an M20 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 i.e. for 50%, 60%, and 70 % and sand with glass powder at 20%. The flexural strength after 7 days, 28 days and 56 days has discussed in the given figure 2.

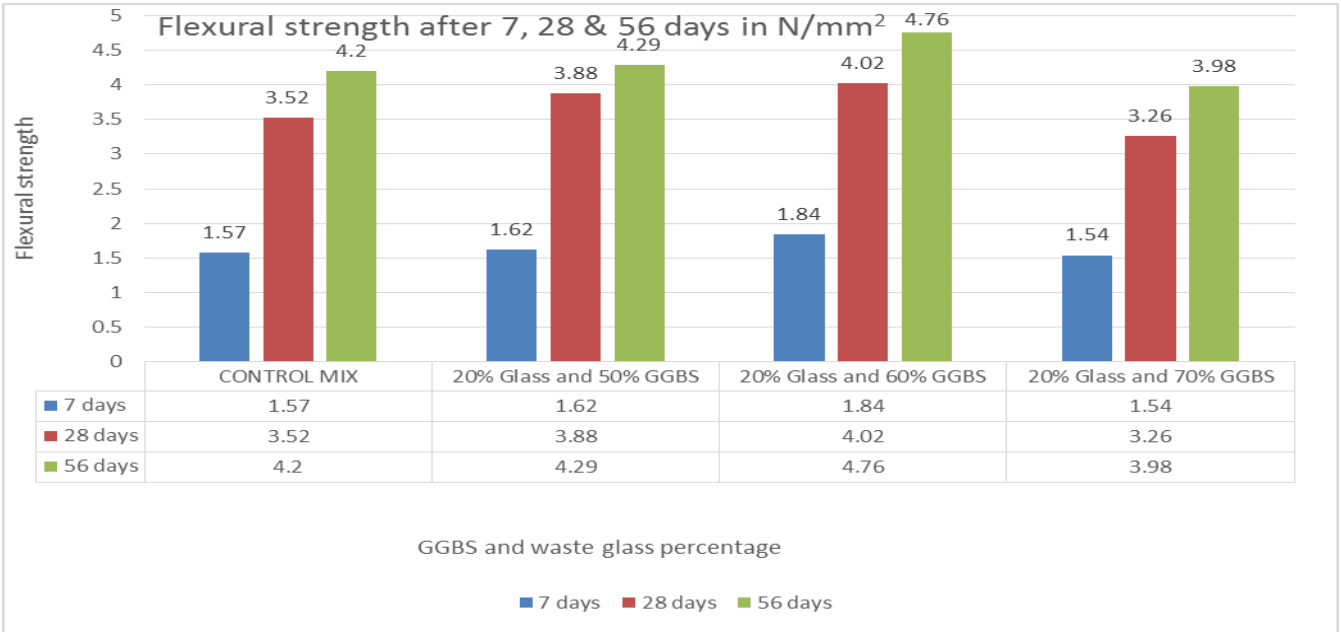

Fig 2: Flexural Strength after 7, 28 & 56 days

Split Tensile Strength

The split tensile strength in this study is increasing up to 60% of GGBS and 20% glass powder but, later on, the strength starts decreasing at 70% GGBS and 20% glass powder. The cylinder specimens 150mm diameter with 300mm length were used for testing the split tensile strength after 7 days, 28 days and 56 days for an M20 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 i.e. for 50%, 60%, and 70 % and sand with glass powder at 20%. The split tensile strength after 7 days, 28 days and 56 days has discussed in the given figure 3.

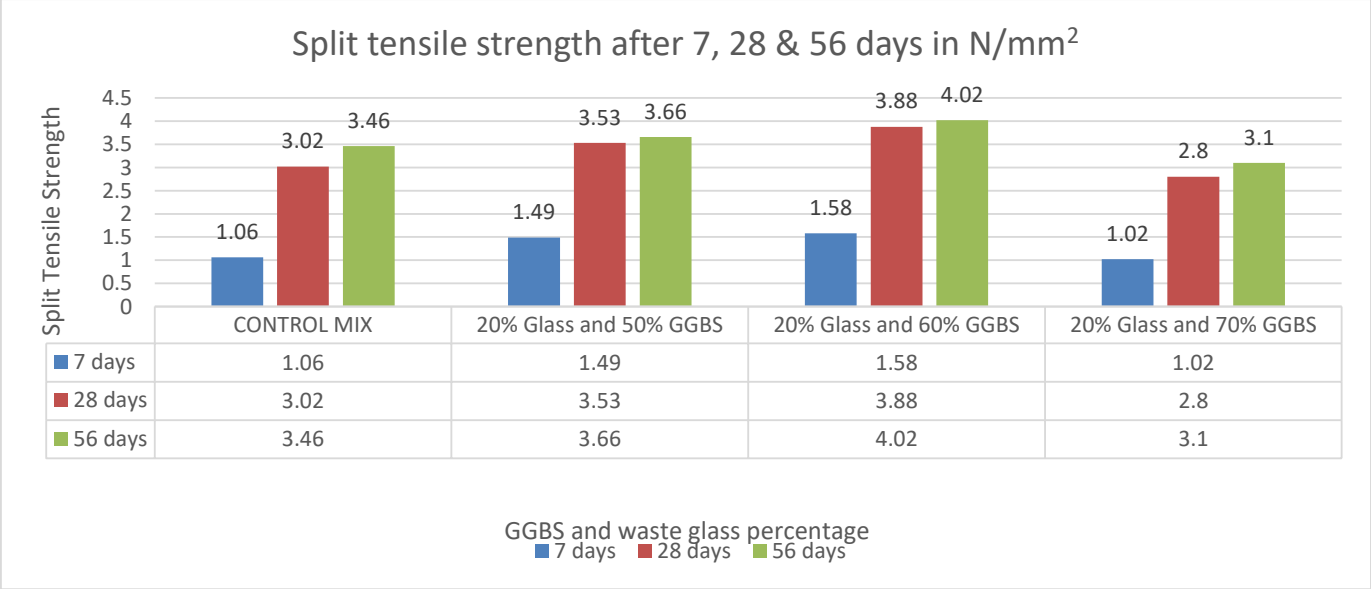

Fig 3: Split tensile strength after 7, 28 & 56 days

5. CONCLUSION

From this study we can conclude the following results:

- The compressive strength is increasing as the glass powder and GGBS is increasing and the maximum compressive strength is attained at 20% glass and 60% GGBS substitution to concrete. The maximum compressive strength is 12.89 N/ mm2, 21.08 N/mm^2 and 31.27 N/mm^2 after 7, 28 and 56 days of curing.
- The flexural strength is increasing as the glass powder and GGBS is increasing and the maximum flexural strength is attained at 20% glass and 60% GGBS substitution to concrete. The maximum flexural strength is 1.84 N/ mm2, 4.02 N/mm^2 and 4.76 N/mm^2 after 7, 28 and 56 days of curing.
- The split tensile strength is increasing as the glass powder and GGBS is increasing and the maximum split tensile strength is attained at 20% glass and 60% GGBS substitution to concrete. The maximum split tensile strength is 1.58 N/ mm2, 3.88 N/mm^2 and 4.02 N/mm^2 after 7, 28 and 56 days of curing.

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