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Effect of Waste Glass as Partial Replacement for Coarse Aggregate in Concrete

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Abstract— : Decreasing of the natural resources is a common phenomenon in emerging countries like India due to increasing urbanization and Industrialization involving Construction of Infrastructure and other amenities. In view of this, professionals have started searching for suitable alternative materials for concrete so that the existing natural resources might be preserved to the possible extent, for the future generation. In this process, different industrial waste materials such as blast furnace slag, fly ash, tiles waste, quarry dust brick bats, fresh aggregates from destruction of structures, ceramic soundproofing waste, etc. have been tried as a feasible additional material in concrete and have also been successful. At present, although a small proportion of the post-consumer glass has been recycled and reused, a significant proportion, which is about 84% of the waste glass generated, is sent to landfill. Laboratory experiments were conducted on strength characteristics of concrete made with utilizing broken waste glass as 10%,20%,30% and 40% by weight of coarse aggregates for M-20 mix. These mixes were prepared following a specific W/C ratio of 0.5 and adding Alkali-silica reaction inhibitor agents. The concrete specimens were tested for compressive strength and durability at differ ages of concrete and the results obtained were compared with those of normal concrete. This results determined the permissibility of using waste glass as partial replacement of coarse aggregates up to 20% by weight glass can be used as an alternate construction material to coarse aggregates up to 20% by weight for glass as coarse aggregate size up to 12mm.This paper recommends that broken waste glass can be used as an alternate construction material to coarse aggregate in concrete without substantial change in strength and gives an overview of the current progress and recycling situation of waste glass and point out the direction for the proper use of waste glass as replacement of cement. These will not only help in the reuse of waste glass but also create a greener environment. Its use has advantage of being light weight and thus reducing the total cost of construction there by bringing economy in construction .

Keywords- Compressive strength, split tensile strength, Workability, Durability, Waste Glass Concrete, Strength properties, environmental friendly.

I. INTRODUCTION

The investigational program for this research study is mainly concerned with investigating the possible usefulness of using waste glass in the concrete mixtures. Currently, the waste glass generated in India is treated like any other solid waste material and thrown away into the dump areas. Waste glass is generally formed from empty glass containers and different construction and reconstruction remaining waste materials[11]. The waste glass is to be crushed into small pieces that resemble the size of gravel and sand. After that the crushed glass is mixed into fresh concrete and then observing the outcome of waste crushed glass on the compressive properties of concrete. The idea is that the glass can be used as an aggregate in the concrete mix by replacing some of the natural aggregates such as gravel and sand. Then, there is possibility of benefits such as follows: a minor amount of the glass is thrown away which saves the good decent landfill space, also with the use of less natural aggregates as the main components with the concrete mixes also help in the saving of time and overall cost.[1] Therefore the experimental program of the current research was done and carried out to monitor the effect of using crushed waste glass as an aggregate component in the fresh concrete mixes on the compressive properties of the hardened concrete. All materials used in this study are locally available.

The ordinary Portland cement is been used in this investigation with the fine aggregate as the river originated natural sand of 4.75 mm maximum particle diameter, in addition to the natural crushed stone aggregate with the maximum size of 30 mm, coarse crushed waste glass is been used in this program as partially with 10%, 20%, 30%, 40% of the coarse aggregates by weight. The concrete mixes are to be cured for 3days and 28 days testing. The using of waste glass as coarse aggregate in concrete creates a problem in concrete due to ASR (Alkali Silica Reaction)[12]. The reaction between alkalis in Portland cement and silica in aggregates forms silica gel. This gel is prone to swelling. It absorbs water and the volume of the gel increases. Therefore with the detention by the cement matrix and by aggregate, the bulging of ASR gel causes hydrostatic compression and if presence of reaction is there and still it is continued and also the internal pressure surpasses the tensile strength of matrix, then cracks will be there and formed around the reactive aggregate components[12]. After the results were obtained and compared with results the normal concrete mix and if it was found that maximum rise in compressive strength will occur for the concrete mix containing 10% waste glass as a coarse aggregate. Further with the increase in waste glass quantity, the water absorption will be decreased representing the increase in the durability[16].

II. LITERATURE REVIEW

Meyer et al.[23] deliberated the various steps that need to be taken by recyclers to collect the glass, separate it from the other materials, clean it and crush it to obtain the suitable grading and to meet the require specifications for the detailed applications as an aggregate in the concrete, moreover in the commodity products, the main concern was to achieve the only objective being to using as much glass as probable, or in value-added products that make the full use of the physical and the aesthetic properties of the colour-sorted crushed glass.

Zainab and Enas.[13] investigated the properties of concretes containing waste glass as fine aggregate. The strength properties and the alkali silica reaction (ASR) expansion were analysed in terms of waste glass content. Then the total quantity of 80 kg of crushed waste glass was partially swapped with sand at 10%,15%, and 20% within the 900 kg quantity of the concrete mixtures. Therefore then the results shows 80% of pozzolanic strength activity given by the waste glass after the 28 days.

Top cu and Can Baz.[10] Considered waste glass as coarse aggregates in the concrete mix. The effects of waste glass on workability and strength of the concrete with fresh and hardened concrete tests were analysed. As per the result of the research conducted, the waste glass was shown not to have a important effect on the results of the workability on the concrete and later it only show small decreasing in its strength.

Kou and Poon.[20] examined the properties of recycled glass cullet on the fresh and the hardened properties of self-compacting concrete. The Recycled glass was added to replace the river sand (in the different proportions of 10%, 20% and 30%), and also 10 mm granite in (5%, 10% and 15%) and hence making the self-compacting concrete mixes. Therefore the results shows that the compressive strength, tensile splitting strength and static modulus of elasticity of the recycled glass self-compacting concrete mixes were decreasing with increasing in the recycled glass aggregate quantity.

Caijun & Keren.[2] studied the three probable uses of the waste glasses in the manufacture of cement and in concrete, whereas, their results shown can be summarized as follows: Firstly, with the use of waste glasses as an concrete aggregates has a little negative effect on the workability, strength and the action of freezing-thawing resistance of cement concrete. Also, the waste glasses can be used in the raw materials for cement production as a siliceous sources. Therefore the effect will be reliant on the quantity of waste glass used. Therefore it may be said that If the percentage of waste glass used in the raw materials is lesser, the effects will be very minimal.

Wang.[27]stated that the re-use of rejected liquid crystal display (LCD) glass & adding it in the concrete (LCDGC) after it changing a portion of the usual river sand by the sand prepared from rejected LCD glass. Three different mix design were planned by the ACI system and considered as (fc28 = 21, 28, & 35 MPa) with the 0%, 20%, 40%, 60% and 80% LCD glass sand replacement investigated; after that their engineering properties were determined. Test outcomes discovered that, when compared to design slump of the 15 cm,& the 20% glass sand concrete aimed at the three different mix designs kept decent slump and also the slump flow. The main results shows that with the partial addition of 20% LCD glass sand to concrete satisfy the requirements of the slump and also by improving the engineering properties and the durability of concrete. Thus it recommends that the LCD glass sand used can potentially be used as an recycled material in different concrete applications. Results demonstrated that the use of waste glass as aggregate facilitates the development of concrete towards a high architectural level besides its high performances, thereafter, the increasing market in industry.

III. MATERIAL USED AND METHODOLOGY

A. Research Methodology:

The following tasks are to be carried out in order to achieve the research objectives:

1)Collecting the required information and documents related to the waste glass.

2)Visiting the City to obtain related information and collect samples.

3)Undertaking a comprehensive literature review on relevant subjects focused on the usage of waste glass in construction field.

4)Emerging an satisfactory experimental program to learn the use of waste glass in the concrete mixtures.

5)Analysing the experimental output test results to draw the various conclusions.

B. Cement and Aggregates:

For the experimental investigation of this research study, the normal Portland Cement was used. In this experimental work, Ordinary Portland cement (OPC) of brand JK Cement (43grade) confirming to IS 8112-1989[24] was used throughout the investigation. Fine aggregates used throughout the investigation contained of clean river sand with maximum size of 4.75mm. Hence, the locally obtainable river sand is used as fine aggregates in the present experimental work. After that the cleaned fine aggregates is chosen and tested for numerous properties such as specific gravity, fineness modulus, bulk modulus etc. in accordance with IS:2386-1963[6]

C. Waste glass:

Waste glass was collected from the locally available waste in shops and disposals of reconstruction building at Jammu, J&K, consisting of waste window glass. Then the same standard procedure was then applied to conduct another sieve analysis representative sample of waste glass and according to the IS specifications, the samples were grouped under coarse aggregates. The sieve analysis revealed that most of the coarse waste glass was within the range between 4.75 mm to 12.5 mm with in particle size diameter. The specific gravity of waste glass was found to be 1.96 - 2.41. Chemical composition of glass is presented in TABLE 1. Fig.1 shows unsieved waste glass and Fig.2 shows manual mixing of waste glass with sand.

IV. EXPERIMENTAL METHODOLOGY

A. Introduction:

In this, various series of different test were accomplished on the waste glass used as partially replacement with coarse aggregate, concrete cubes & cylinders to get strength characteristics of the use of waste glass for probably using it in normal strength concrete practice. The several such as compressive, tensile and workability are relatively important mechanical properties of any hardened concrete including use waste glass in concrete. The use of waste glass in concrete must embrace the same conventional concreting practices to guarantee the hardened concrete properties. This section will discuss on the results that are attained from the testing and compare it from the testing and compare it with the standards accordingly. The results are such as water absorption test, slump tests, compression cube test, and the splitting strength test.

B. Mixing of Concrete:

The mixing process is carried out in electrically operated mixer. The ingredients are laid in uniform layers, one by one in the order – coarse aggregate, fine aggregates and then cementitious materials. Dry mixing is done to obtain a uniform colour. After dry mixing, water is added to prepare concrete. Afterwards that workability test are done instantly after the proper mixing of concrete and the test are done.

C. Mix Proportion:

The concrete mix proportions ordinary grade concrete and standard grade concrete are designed using IS:10262-1982[7]. The mix we use in our experimental work is the nominal mix which is M20 with the generally used mix proportion of 1:1.5:3 and with the water cement ratio of 0.5. Therefore, the mixture proportions used in experimental laboratory for tests is M20 as per Indian standard.

D. Mixing and Casting of concrete Specimens:

The objective of mixing is to get a homogenous and consistency of cement, water, sand, aggregate and if any used admixtures in the concrete and also the mainly to meet the all requirement of the standard. There are 30 cubes and 30 cylinders in 5 different batches of M20 mix design mixed and it was moulded in accordance with IS:10262-1982[7].

Specimen casting-

M20:

WG 00% 6 cubes and 6 cylinders (FULL NA)
WG 10% 6 cubes and 6 cylinders (NA 90%)
WG 20% 6 cubes and 6 cylinders (NA 80%)
WG 30% 6 cubes and 6 cylinders (NA 70%)
WG 40% 6 cubes and 6 cylinders (NA 60%)

30 Cubes	**30 cylinder**
15 for 03 days.	15 for 03 days.
15 for 28 days.	15 for 28 days.

E. Test on Fresh Concrete:

Slump cone Test Slump test is used to determine the workability of fresh concrete. The slump test utilizing a metallic slump mould. The change in level between the height of mould and that of uppermost point of the decreased concrete was measured and described as slump. The slump tests were completed according to IS 1199-1959[25].

F. Tests on hardened concrete:

From each concrete mixture, cubes of size 150mm X 150mm X 150mm and 150mm X 300mm cylinders have been casted for the determination of compressive strength and splitting tensile strength respectively. Each concrete specimen was under curing in normal conditions as per IS 516-1959[8] and each were tested respectively at 3days and 28days for determining compressive strength as per IS 516-1959[8] and splitting tensile strength as per IS 5816-1999[26].

G. Water absorption test:

The average dry weight of all the different cube samples after eliminating from the moulds it was measured and then the average weight of cube samples afterward submerging in the water for curing was measured at partial percentage 10%,20%,30%,40% then the water absorption was measured. The ratio of water absorption was measured for all the concrete samples and it give indirect measure of durability.

V. RESULTS AND DISCUSSION

A. Fresh concrete tests:

The slump values of all the different mixed samples are characterized in TABLE 2. The slump will increase with the increase in waste glass content. The Waste glass content absorbed low water as related to the sand and thus increasing the workability of concrete mix. Slump was maximum for the concrete mixture comprising of 40% waste glass by partially replacing with coarse aggregates. The difference in slump with waste glass content is shown in the Graph. 1.

Table 1 – Chemical Composition of Glass

Oxides	SiO^2	Al^2O^3	Fe^2O^3	MgO	Na^2O	K^2O
Percentage	70.4	1.9	1.2	10.3	10.3	0.4

B. Hardened concrete:

The Compressive strength tests and the Split tensile strength tests are depicted in Table 4. Compressive strength tests and split tensile strength tests were carried out at 3days and for 28 days respectively. An increase in compressive strength was detected up to 10% replacement of coarse aggregates by waste glass and there after declining. Therefore the maximum compressive strength measured was 7% more than that of the reference mix at 28 days corresponding to the concrete mix having 10% waste glass in place of coarse aggregates. Compressive strength for concrete mix with 20% waste glass content was found to be lesser than that of reference mix. Splitting tensile strength reduced with increasing the waste glass content. Graph. 2 shows the compressive strength of all mixes at 3 and 28 days respectively. Graph 3 shows the splitting tensile strength of all mixtures at 3 days and 28 days respectively.

C. Water absorption:

The Water absorption test was done for all different mixtures and the percentage of the water absorption was recorded. The percentage of the water absorption were reduced with rise in waste glass content. The lowermost value of the water absorption test was found for concrete mix with the 40% waste glass content. Therefore, the average permissible water absorption of aggregate should not be greater than 2%. The normal weight aggregates of the higher absorption value are acceptable depends on local performance. As far as about this test work, the water absorption of waste glass does not exceed the permissible value but it partially decreases with increase in the waste glass content. Table 3 and Graph 4 shows the different percentage of water absorption for all mixtures.

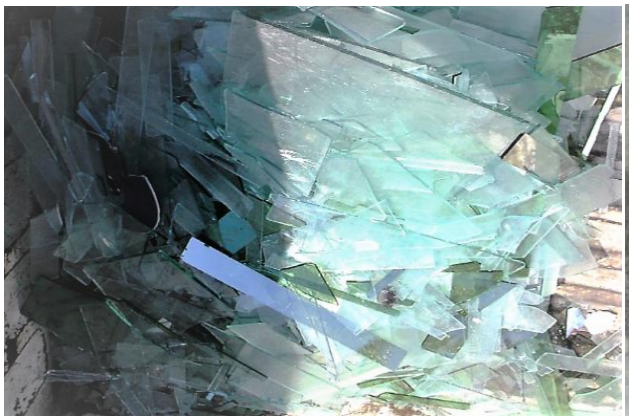


Figure.1 – Shows waste glass to be used.

Figure.2- Waste glass being mixed with sand.

Table 2-Shows slump test values

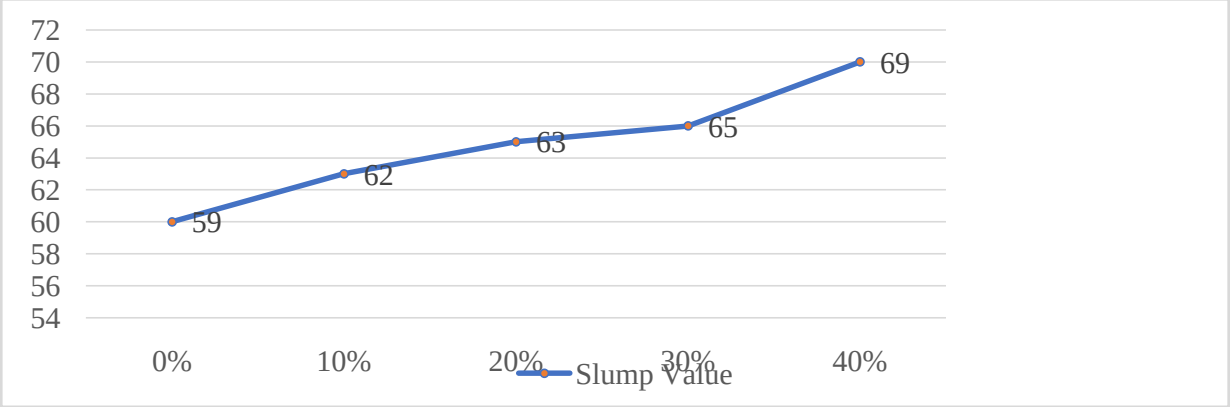
Waste Glass (%)	Slump Value (mm)
0%	59
10%	62
20%	63
30%	65
40%	69

Table 3- Water absorption test results.

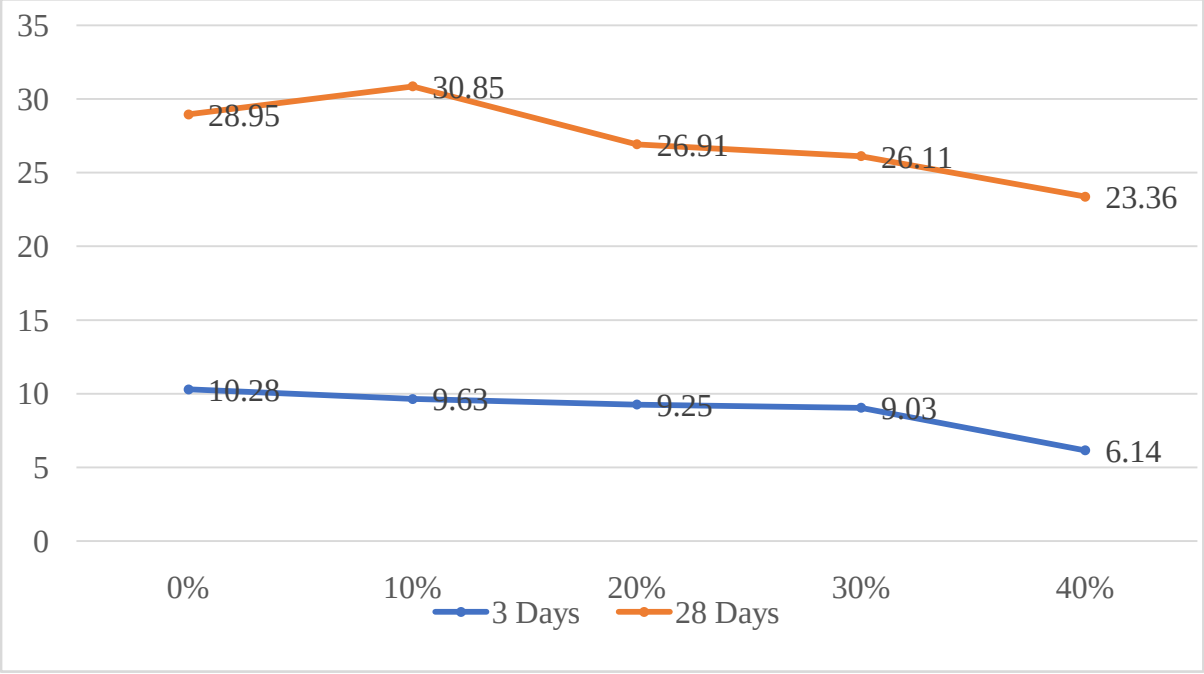
S.No.	Glass percentage (%)	Avg. Dry wt. of Cube (gm)	Avg. wet wt. of Cube(gm)	Water absorbed	Percentage Water absorbed
1.	0%	8390	8480	90	1.07
2.	10%	8330	8410	80	.96
3.	20%	8220	8290	70	.85
4.	30%	8125	8181	56	.69
5.	40%	7946	7990	44	.55

Table 4- Compression strength and splitting tensile strength test results.

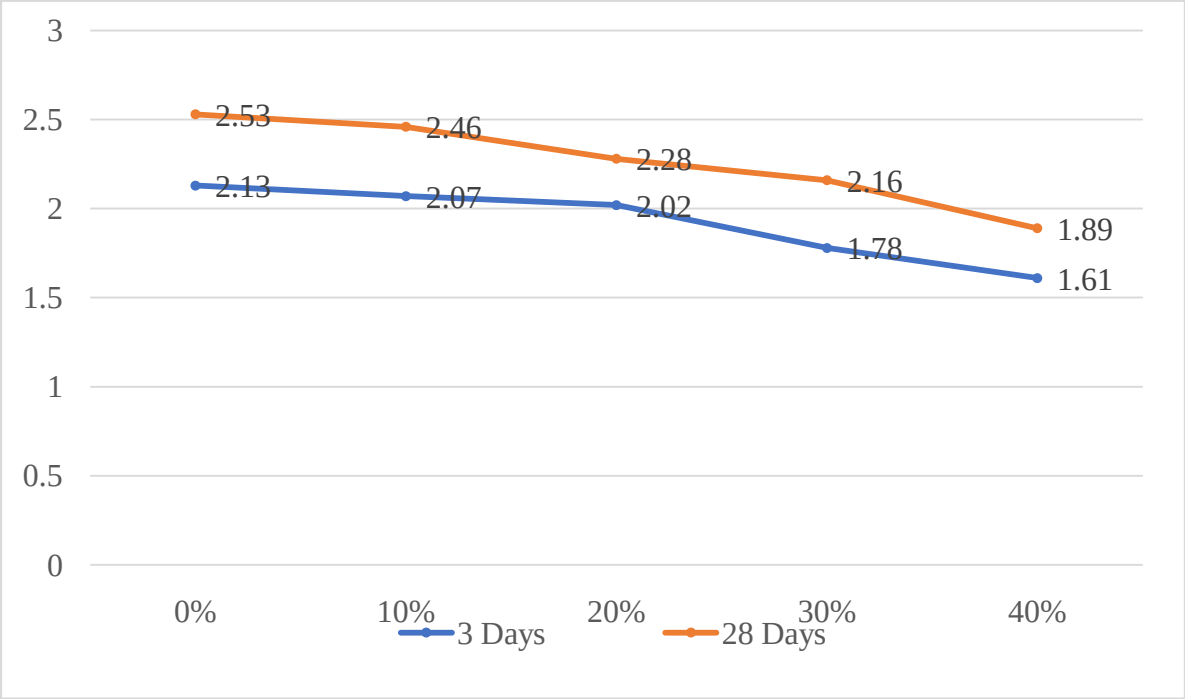
Batch	3days compressive strength	28days compressive strength	Batch	3 days splitting strength (N/mm^2)	28days splitting strength(N/mm^2)
0%	10.28Mpa	28.95Mpa	0%	2.13	2.53
10%	9.63Mpa	30.85Mpa	10%	2.07	2.46
20%	9.25Mpa	26.91Mpa	20%	2.02	2.28
30%	9.03Mpa	26.11Mpa	30%	1.78	2.16
40%	6.14Mpa	23.36Mpa	40%	1.61	1.89



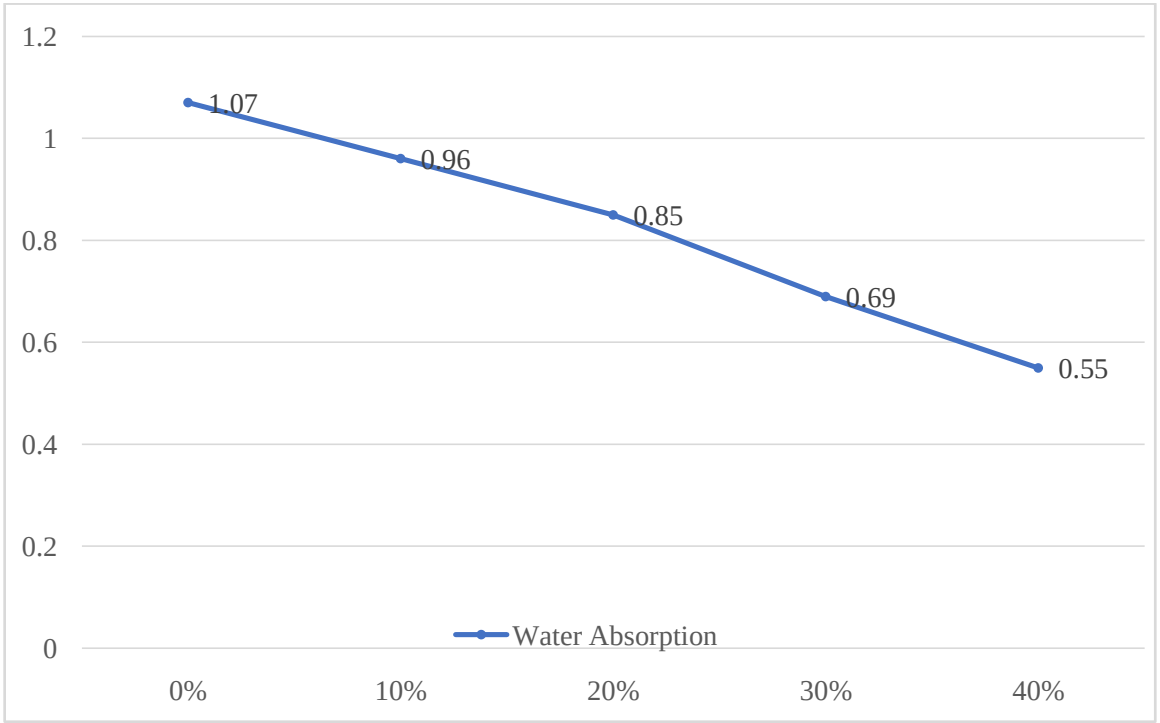
Graph 1 : - Slump value observation.



Graph 2 : - Compressive Strength of Cubes at 3 and 28 Days.



Graph 3 -Split Tensile Strength of Cylinders at 3 and 28 Days.



Graph 4 - Shows the Water absorption result for the cube specimens of size 150mm x 150mm x 150mm.

D. Summary:

The prime objective of this research was to study the effect of waste glass content on the properties of concrete mixes when added as a partial replacement with coarse aggregate. This main objectives was accomplished through the following:

- Detecting the effects on the properties with the addition of waste glass on the fresh properties of concrete mixes.
- To Study the impact of waste glass on the hardened concrete properties.
- Determining the optimum actual waste glass content to be added within the concrete mix as a partial exchange with coarse aggregate.
- Focusing on the concrete mixes with ideal waste glass contents by testing their compressive strength, splitting strength, and the slump test.

These targets were reached by conducting a standard series of: slump cone test, compressive strength test, water absorption test and splitting tensile test. Study is needed to determine the contribution of waste glass to the performance of hardened mortar The output results obtained from this laboratory program showed reliable data points and promising further research prospects for the future aspects.

E. Advantages:

A large amount of useless glass residue, by-products, and waste materials are produced by different industries on regular basis. The residual and unused wastes are disposed into environment as burden without any commercial return. Consequently, huge money is being spent for their disposal reasons as well as environmental pollution occurs. It is well known that addition of these wastes in concrete as a supplement of cement generally reduces the construction cost and more or less maintains the properties of concrete. Therefore, waste glass can be used as partial replacement for coarse aggregate in concrete for various applications:

- The possibility of waste glass recycling and using into concrete production. The use of recycled glass as aggregate can also greatly enhance the aesthetic appeal of the concrete.
- The Glass is a single inert material that might be recycled many times without lack or change in its chemical properties.
- The major aim of environmental authorities is to reduce, as far as possible, the disposal of postconsumer glass in landfill and diversion to economically viable glass product streams.
- Increase in the waste glass amount, the percentage of water absorption decreases. Hence, that make it light weight concrete practically.
- The large use of waste glass in concrete can be economical as it is non-useful waste and is free of cost. Hence reduces the overall cost.
- Constant use and practice of waste glass in concrete industry will help in preserving natural resources specially obtained from river and thus make construction industry sustainable.
- Use of waste glass have great potential in concrete. According to EECO (environmental council of concrete organization), and can be used in support layers, sub-bases and such as permeable base and unsterilized bases.
- With successful use their will, be less demand for natural and crushed aggregates.
- Produce job opportunities in the local area & around and also a financial benefit for business like, local council engineers, concrete subcontractors, specialist of civil works, demolition contractors, recycling material plants etc

So, while use of waste glass in concrete as coarse aggregate is still relatively new and its use have not been fully developed, it is becoming a popular choice for contractors and landscapers. Its durability &lightweight design enables it to be used in many different situations. Thus, it shows that the use of waste glass as coarse aggregate in concrete provides environmental as well as financial benefits.

F. Disadvantages:

The major concern is the variation in concrete strength with use of waste glass. In such projects, the only disadvantage is bulk mass of the waste glass obtained from waste site. And to use successfully it will took special skilled manpower with safety and precautionary measures. Although the mix can be easily dropped apart if not correctly applied or poured. The use of excess amount of waste glass will also lead to failure of any concrete structure and will prevail concrete cracks in structure. It means it is unpredictable & it is recommended to use as per recommendations of concerned authorities. There is no ductility. Ductility is a solid material's ability to deform under stress and its maintenance can be highly challenging. When the it is used in any construction then it is may become difficult to recycle it again. Structures made with these materials have comparatively less life as conventional concrete.

VI. CONCLUSIONS AND FUTURE SCOPE

A. Conclusion:

The paper presents the necessity of sustainable construction in present world and the possibility of waste glass recycling and using into concrete production. According to According to the test which has been carried out in the laboratory, results shown by testing the multiple samples that good quality concrete could be produced with use of waste glass in concrete. The use of waste glass should be further promoted. Based on the experimental investigation reported in the work, the following conclusions are drawn:.

- Marginal decrease in strength is observed at 30% to 40%. Replacement level of waste glass with coarse aggregate.
- The waste glass can be efficiently used as coarse aggregate by partial replacement.
- The most ideal replacement level of waste glass as coarse aggregate is to be 20%.
- With the increase in waste glass content, percentage water absorption decrease.
- With rise in waste glass quantity, the average weight decreases with waste glass content thus create the waste glass concrete light weight.
- It is determined that the workability of concrete mix rise with rise in waste glass content.
- The use of waste glass in concrete can prove to be economical as it is non-use full waste and free of cost.
- The main use of waste glass in construction industry will eliminate the dumping and landfilling problem of waste glass and it will prove to be environmental friendly thus makes road map and planning way for greener concrete.
- The use of waste glass in concrete will not disturbed the natural resources particularly river gravels and thus making concrete construction industry sustainable.
- The results show the splitting tensile strength decreases with increase in waste glass content.
- It has been observed that the workability of concrete decreases with the addition of waste glass. But this difficulty can be overcome by using plasticizers or super-plasticizers.

Hence, the use of waste glass in concrete has been proved to perform adequately and in a manner as good as concrete containing natural aggregates. It is likely that this study may lead to a greater use of waste glass in concrete and its diversion from waste.

B. Future Study:

It is suggested for the upcoming studies for extending this research to provide a wider perspective in order to be fully able to consider further parameters and different combinations of parameters governing the effect on the behaviour and engineering properties of fresh and hardened concrete containing different types and sizes of waste glass materials. This new research project is aiming to examine the results of this study, considering this phase as a threshold for exploring the facts in a more powerful and accurate manner. This project also lays emphasis on drawing attention of the various construction agencies and other interested agencies to use of waste glass as coarse aggregate replacing crushed aggregates and river bed gravels which have very adverse effect on environment leading to scouring of piers foundations which ultimately leads to failure of bridges. Moreover the problem of alkali silica reaction due to alkalis in cement and silica in glass aggregate are also mitigated due to use of suppressant of alkalis silica reaction in the form of barium hydroxide[12]. Not only barium hydroxide but lithium salts and naturally occurring metakaolin, pulverized fuel ash etc.

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