International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 06 Issue: 10 | Oct 2019 www.irjet.net p-ISSN: 2395-0072

STUDY ON EFFECT OF WASTE GLASS AS PARTIAL REPLACEMENT FOR COARSE AGGREGATE IN CONCRETE

Purnima Biranagi[1], Sagar Raj Urs KP[2], Shridhar k[3], Sunitha H K[4], Vinoda M N[5]

[1]Assitant Professor, Department of Civil Engineering, Dr. Ambedkar Institute of Technology, Bengaluru, India
[2345]B E Students, Department of Civil Engineering, Dr. Ambedkar Institute of Technology, Bengaluru, India

---

ABSTARACT:- Concrete is made up of cement, fine aggregates, coarse aggregate, water and admixtures if necessary.

Laboratory experiments were conducted on strength characteristics of concrete made with utilizing broken waste glass as 5%, 10%, 15% and 20% by weight of coarse aggregates for M-20 mix. These mixes were prepared following a specific W/C ratio of 0.5. 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.

INTRODUCTION

Concrete is a composite material composed of coarse aggregate bonded together with a fluid cement which hardens over time. Most concretes used are lime-based concretes such as Portland cement concrete or concretes made with other hydraulic cements. However, road surfaces are also a type of concrete, asphalt concrete, where the cement material is bitumen, and polymer concretes are sometimes used where the cementing material is a polymer.

In Portland cement concrete (and other hydraulic cement concretes), when the aggregate is mixed together with the dry cement and water, they form a fluid mass that is easily molded into shape. The cement reacts chemically with the water and other ingredients to form a hard matrix which binds all the materials together into a durable stone-like material that has many uses. Often, additives are included in the mixture to improve the physical properties of the wet mix or the finished material. Most concrete is poured with reinforcing materials (such as rebar) embedded to provide tensile strength, yielding reinforced concrete.

After the Roman Empire collapsed, use of concrete became rare until the technology was redeveloped in the mid-18th century. Today, concrete is the most widely used man-made material (measured by tonnage).

Concrete is world's most widely used construction material. The utilization of concrete is increasing at a higher rate due to development in infrastructure and construction activities all around the world.

GLASS: The amount of waste glass has gradually increased over the recent years due to urbanization and industrialization where most of the waste glass end up in landfill while only small fraction can be recycled because of the high cost of cleaning and colour sorting . Since glass is not biodegradable, landfill is not an environmentally friendly solution. Recent studies have shown that the waste glass can be effectively used in concrete either as aggregate (fine or coarse aggregate) or as cement replacement. Being amorphous and containing relatively large quantities of silicon and calcium , glass is in theory pozzolanic or even cementitious in nature when the particle size is less than 75 micron. Finely ground glass as oppose to coarse waste glass does not contribute to alkali-silica reaction.

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. 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.

LITERATURE REVIEW

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.

Meyer et al[1]: 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[2]: investigated the properties of concretes containing waste glass as fine aggregate. The strength properties and the alkali silica reaction (ASR) expansion were analyzed 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.[3] 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 analyzed. 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.

Kou and Poon.[4] 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.

Caijun & Keren[5]: 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.

Wang[6]: 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.

SCOPE OF THE WORK

The aim of this project is to determine the strength and durability characteristics of concrete by using waste glass pieces.

OBJECTIVES

It would be a milestone achievement for the local construction industries. Therefore, the main objective of this research is to determine and prove the feasibility of concrete using wate glass.

- To determine the compressive strength of concrete.
- To compare the value, Obtained by addition of waste glass pieces with different percentage.
- To check the obtained results by addition of glass with 5% &10% will satisfy the results of Zainab and Enas

MATERIALS REQUIRED

The constituent materials used in this investigation were procured from local sources. These materials are required by conducting various tests. Due to these results we were define what type of materials are used. The materials are listed below:

- Cement
- Fine Aggregate
- Coarse Aggregate
- Waste glass
- Water

CEMENT:

In the most general sense of the word, cement is a binder, a substance which sets and hardens independently, and can bind other materials together. The word "cement" traces to the roman's, who used the term "opuscaementicium" to describe masonry which resembled concrete and was made from crushed rock with burnt lime as binder. The volcanic ash and pulverized brick additives which were added to the burnt lime to obtain a hydraulic binder. Cement used in construction are characterized as hydraulic or non-hydraulic. The most important use of cement is the production of mortar and concrete the bonding of natural use of aggregates to from a strong building material which is the face of normal environmental effects.

ORDINARY PORTLAND CEMENT:

Is the most common type of cement in general use around the world, because it is a basic ingredient of concrete, mortar, stucco and most non-specialty grout. It is a fine powder produced by grinding Portland cement clinker (more than 90%), a limited amount of calcium sulphate which controls the set time, and up to 55 minor constituents (as allowed by various standards).

- The cement used for our experimental work is OPC 53-Grade. Conformed to the quality provisions of Indian standard specification. Tests conducted on cement are specific gravity, standard consistency, fineness of cement, initial setting time.
- The specific gravity of the cement was 3.10

FINE AGGREGATE:

Well graded river sand passing through 4.75 mm was used as fine aggregate. The sand was air-dried and sieved to remove any foreign particles prior to mixing. We are conducting tests on fine aggregate are Specific Gravity, Bulking, sieve analysis, water content of fine aggregate.

COARSE AGGREGATE:

Coarse aggregates up to 16mm was used as coarse aggregate. We are conducting tests on coarse aggregate are fineness, specific gravity, water absorption, impact test.

WATER: This is the least expensive but most important ingredient of concrete. Water, which is used for making concrete, should be clean and free from harmful impurities such as oil, alkali, acid, etc. In general, water which is fit for drinking should be used for making concrete and shall conform to the requirements of IS: 456-1978. Water-cement ratio was taken as 0.45

WASTE GLASS:

PROPERTIES OF GLASS:

MECHANICAL PROPERTIES OF GLASS:

***Density: 2500 Kg/m^3**

A 4mm thick pane of glass weighs 10Kg/m^2.

***Hardness: 470 HK**

The hardness of float glass is established according to knoop. The basis is the test

***Compression resistance: 800-1000MPa**

The compression strength defines the ability of a material to resist a load applied vertically to its surface.

***Modulus of elasticity: 70000 MPa**

The modulus of elasticity is either determined from the elastic elongation of a thin bar, or from bending a bar with a round or rectangular cross section.

***Bending strength: 45 MPa**

The bending strength of a material is a measure of its resistance during deflection.

The main characteristics of glass are transparency, heat resistance, pressure and breakage resistance and chemical resistance.

THERMAL PROPERTIES OF GLASS:

*** Transformation range: 520-550̊ C**

*** Temperature and softening temperature: Approx.600̊ C**

Contrary to solid bodies of crystalline structure, glass has no defined melting point. It continuously transforms from the solid state to the viscous state. The transition range is called the transformation range and according to DIN 52324(ISO 7884), it lies between 520̊C and 550̊C. Tempering and bending requires a temperature of a further 100̊C.

***Specific heat:0.8J/g/K**

The specific heat (In Joules) defines the amount of heat required to rise the temperature of 1g of float glass by 1K.The specific heat of glass increases slightly the temperature is increased up to transformation range.

***Thermal exopansion: 9.10-6 K-1**

The temperature coefficient of expansion for float glass is given according to DIN 52328 and ISO 7991.The main characteristic of glass are transparency, heat resistance, pressure and breakage resistance and chemical resistanc

OPTICAL PROPERTIES OF GLASS:

Glass has several strong points concerning optical properties

-It can be produced large and homogeneous panes.

-Its optical properties are not affected by ageing.

-It is produced with perfectly flat and parallel surfaces.

-Float glasses has the refractive index (n) of

-The main characteristic of glass are transparency, heat resistance, pressure and breakage resistance and chemical resistance.

TECHNICAL PROPERTIES:

The surface of glass is affected if it is exposed for a long time to alkalies (and ammonia gases in damp air) in conjunction with high temperatures. Float glasses will also react to compounds that contain hydrofluoric acid under normal condition. These are used for treating glass surfaces.

Figure.1 – Shows waste glass to be used.

Figure.2- Waste glass being mixed with sand.

MIX DESIGN

The process of selecting suitable ingredients of concrete and determining their relative amounts with the objective of producing a concrete of the required, strength, durability, and workability as economically as possible, is termed the concrete mix design. The proportioning of ingredient of concrete is governed by the required performance of concrete in 2 states, namely the plastic and the hardened states. If the plastic concrete is not workable, it cannot be properly placed and compacted. The property of workability, therefore, becomes of vital importance. The compressive strength of hardened concrete which is generally considered to be an index of its other properties, depends upon many factors, e.g. quality and quantity of cement, water and aggregates; batching and mixing; placing, compaction and curing. The cost of concrete is made up of the cost of materials, plant and labour. The variations in the cost of materials arise from the fact that the cement is several times costly than the aggregate, thus the aim is to produce as lean a mix as possible.

REQUIREMENTS OF CONCRETE MIX DESIGN

The requirements which form the basis of selection and proportioning of mix ingredients are:

- The minimum compressive strength required from structural consideration
- The adequate workability necessary for full compaction with the compacting equipment available.
- Maximum water-cement ratio and/or maximum cement content to give adequate durability for the particular site conditions. Maximum cement content to avoid shrinkage cracking due to temperature cycle in mass Concrete.

COMPRESSIVE STRENGTH

It is one of the most important properties of concrete and influences many other describable properties of the hardened concrete. The mean compressive strength required at a specific age, usually 28 days, determines the nominal water-cement ratio of the mix.

WORKABILITY

The degree of workability required depends on three factors. These are the size of the section to be concreted, the amount of reinforcement, and the method of compaction to be used. For the narrow and complicated section with numerous corners or inaccessible parts, the concrete must have a high workability so that full compaction can be achieved with a reasonable amount of effort. This also applies to the embedded steel sections. The desired workability depends on the compacting equipment available at the site.

DURABILITY

The durability of concrete is its resistance to the aggressive environmental conditions. High strength concrete is generally more durable than low strength concrete. In the situations when the high strength is not necessary but the conditions of exposure are such that high durability is vital, the durability requirement will determine the water-cement ratio to be used.

MAXIMUM NOMINAL SIZE OF AGGREGATE

In general, larger the maximum size of aggregate, smaller is the cement requirement for a particular water-cement ratio, because the workability of concrete increases with increase in maximum size of the aggregate.

GRADING AND TYPE OF AGGREGATE

The grading of aggregate influences the mix proportions for a specified workability and w/c ratio. Coarser the grading leaner will be mix which can be used. Very lean mix is not desirable since it does not contain enough finer material to make the concrete cohesive. The type of aggregate influences strongly the aggregate-cement ratio for the desired workability and stipulated water cement ratio.

MIXED DESIGN CALCULATION FOR M20 GRADE (1:1.5:3)

Volume of mould=0.15*0.15*0.15=0.003375m^3

For 36 blocks =0.003375*36

=0.1215m^3

Dry volume = wet volume*1.57

=0.1215*1.57

=0.190m^3

FOR 0%REPLACEMENT OF COARSE AGGREGATE WITH GLASS PIECE:

CEMENT=1.4KG

FINE AGGREGATE=2.1KG

COARSE AGGREGATE=4.2KG

GLASS PIECE=0

WATER=0.7L

FOR 5% REPLACEMENT OF COARSE AGGREGATE WITH GLASS PIECE:

CEMENT=1.4KG

FINE AGGREGATE=2.1KG

COARSE AGGREGATE=3.99KG

GLASS PIECE=210gms

WATER=0.7L

FOR 10% REPLACEMENT OF COARSE AGGREGATES WITH `GLASS PIECE:

CEMENT=1.4KG

FINE AGGREGATE=2.1KG

COARSE AGGREGATE=3.78KG

GLASS PIECE=420gms

WATER=0.7L

FOR 15% REPLACEMENT OF COARSE AGGREGATES WITH GLASS PIECE:

CEMENT=1.4KG

FINE AGGREGATE=2.1KG

COARSE AGGREGATE=3.57KG

GLASS PIECE=630gms

WATER=0.7L

FOR 20% REPLACEMANT OF COARSE AGGREGATES WITH GLASS PICE:

CEMENT=1.4KG

FINE AGGREGATE=2.1KG

COARSE AGGREGATE=3.36KG

GLASS PIECE=840gms

WATER=0.7L

TOTAL ESTIMATED QUANTITY FOR 7^{TH} & 28^{TH} DAYS OF BLOCKS:

CEMENT: 42KG

FINE AGGREGATES: 63KG

COARSE AGGREGATES: 99.45KG

GLASS PIECE: 12.6 KG

PREPARATION OF MOULDS: (AS PER IS: 516-1959)

CUBE MOULDS

The mould shall be of metal, preferably steel or cast iron, and stout enough to prevent distortion. It shall be constructed in such a manner as to facilitate the removal of the moulded specimen without damage, and shall be so machined that, when it is assembled ready for use, the dimensions and

CASTING OF TEST SPECIMENS :(AS PER IS: 516-1959)

PREPARATION OF MATERIALS:

All materials shall be brought to room temperature, preferably 27o± 30 c before commencing the experiments. The cement samples, on arrival at the laboratory, shall be thoroughly mixed dry either by hand or in a suitable mixer in such a manner as to ensure the greatest possible blending and uniformity in the material, care is being taken to avoid the intrusion of foreign matter. The cement shall taken be stored in a dry place, preferably in air tight metal containers

PROPORTIONING

The proportions of the materials, including water, in Concrete mixes for determining the suitability of the materials available, shall be similar in all respects to those to be employed in the work. Where the proportions of the ingredients of the mortar as used on the site are to be specified by volume, they shall be calculated from the proportions by weight used in the test cubes and the unit weights of the materials.

WEIGHING

The quantities of cement, each size of aggregate, some %age of coconut shell and water for each batch shall be determined by weight, to an accuracy of 0.1 percent of the total weight of the batch.

MIXING CONCRETE

The concrete shall be mixed by hand or preferably in a laboratory batch mixer, in such a manner as to avoid loss of water or other materials. Each batch of concrete shall be of such a size as to leave about 10 percent excess after moldings the desired number of test specimens.

HAND MIXING

The concrete batch shall be mixed on a water-tight, non absorbent platform with a shovel, trowel or similar suitable implement, using the fallowing procedure:

a) The cement and fine aggregate and coarse aggregate shall be mixed dry until the mixture is thoroughly blended and is uniform in colour.

b) The aggregates shall then be added and mixed with the cement until it is uniformly distributed throughout the batch.

c) The water shall then be added and the entire batch mixed added to the coconut shell until the concrete appears to be homogenous and has the desired consistency. If repeated mixing is necessary, because of the addition of water increments while adjusting the consistency, the batch shall be discarded and a fresh batch made without interrupting the mixing to make trial consistency tests.

COMPACTION

COMPACTION BY HAND

When compacting by hand, the standard tamping bar shall be used and the strokes of the bar shall be distributed in a uniform manner over the cross section of the mould. The number of strokes per layer required is 12. The strokes shall

penetrate into the underlying layer and the bottom layer shall be tamped throughout its depth. Where voids are left by tamping bar, the sides of the mould shall be tapped to close the voids. After the top layer has been compacted, the surface of the concrete shall be finished level with the top of the mould, using a trowel, and covered with a glass or metal plate to prevent evaporation.

WORKABILITY OF CONCRETE

Workability is defined as the amount of useful internal work necessary to achieve full compaction. It is also defined as the ease with which concrete can be placed and degree to which it resist segregation. It is also given new definition which includes all the essential properties of concrete in plastic condition i.e. mixing ability, transportability, modeliability and ease compaction.

CURING OF TEST SPECIMENS: (AS PER IS: 516-1959):

The test specimens shall be stored on the site at a place free from vibration, under damp matting, sacks or other similar material for 24 hours +1/2 hour from the time of adding the water to the other ingredients. The temperature of the place of storage shall be within the range of 220 to 320C. After period of 24 hours, they shall be marked for later identification, removed from the moulds and, unless required for testing within 24 hours, stored in clean water at a temperature of 240 to 300C until they are transported to the testing laboratory. They shall be sent to the testing laboratory well packed in damp sand, damp sacks, or other suitable material so as to arrive there in a damp condition not less than 24 hours before the time of test. On arrival at the testing laboratory, the specimens shall be stored in water at a temperature of 270 + 20C until the time of test. Records of the daily maximum and minimum temperature shall be kept both during the period of the specimens remain on the site and in the laboratory.

COMPRESSIVE STRENGTH DETERMINATION:

GENERAL:

Compressive strength test is carried out as per Indian Standard code IS 516: 1959 on plain concrete and concrete with waste glass and results are tabulated and conclusions are drawn.

SPECIMEN PREPARATION:

Fresh concrete is made by mixing the proper amounts of cement, water and aggregate as indicated by the mix design calculations, which is then placed in moulds. TS 500 and DIN designate 15x15x15 cm cubic moulds. Three specimens should be prepared. Cubes are filled in two equal portions. All possible measures should be taken during placing so that the specimen is prepared in a similar way to the actual placing condition in the site. The specimens are left in moulds for two days and then cured in a moist environment such as curing room, water or a wet blanked. At the end of 7and 28 days, the cubic specimens are ready for the compression test. Cubes provide this with us capping.

WEIGHING OF MATERIALS:

Concrete is prepared for M20mix, designed for plain concrete and concrete with waste glass. Materials such as cement, fine aggregate, coarse aggregate and waste glass pieces are weighed to accuracy.

MIXING OF MATERIALS:

Concrete is mixed in a non absorbent clean platform i.e., in a mixing tray with a trowel. Initially coarse aggregate is put into the platform following fine aggregates and cement for plain concrete. For concrete with waste glass pieces, initially coarse aggregate is put into the mixing tray followed by mixture of fine aggregates and Polypropylene fibers and mixed properly. Now cement is poured to the tray and mixed properly in the dry state. At last required quantity of water as per water-cement ratio is added and mixed well within 2 minutes.

MOULD PREPARATION:

Mould is cleaned properly and greased with mould oil. Concrete is placed in the mould of dimension 150mm x 150mm x 150mm in 3 layers each layer of height approximately 50mm. after the placement of first layer of concrete it is compacted by a tamping rod of 16mm diameter, 0.6m long and bullet pointed at the lower end. The strokes of the bar are uniformly distributed over the cross section of the mould. Each layer is compacted with 25 strokes and coconut shells are sprinkled uniformly on each layer, next scoop of concrete is placed followed by same manner of compaction and top layer is finished.

CURING OF SPECIMENS:

The test specimens are stored in place free from vibration, in moist air of at least 90% relative humidity and at a temperature of 27o+ 2o C for 24 hours from the time of addition of water to the dry ingredients. After this period, the specimens are marked and removed from the moulds and immediately submerged in clean fresh water and kept there until taken out just prior to test. The water in which the specimens are submerged, are renewed every seven days and maintained at a temperature of 27o+ 2o C. The specimens are not allowed to become dry at any time until they have been tested.

6.1.7 METHOD OF TESTING IN CTM:

Specimens are tested at the ages of 7,14,28days. The specimens to be tested are taken out from water and wiped to remove excess water and grit present on the surface. 3 specimens are tested for each type of mix at specific age. Dimensions of the specimens are measured with an accuracy of 0.1mm and tabulated. Cubes are placed on the compression testing machine of 100 tons capacity such that the marked face faces the observer and load is applied on the specimen and increased at the rate of 140kg/sq cm/min until the resistance of the specimen to the increasing load breaks down and no greater load can be sustained. Maximum load applied to the specimen was recorded and compressive strength of the concrete is found out using the relation,

Compressive strength =P/(B*D) N/mm^2

P=load in N.

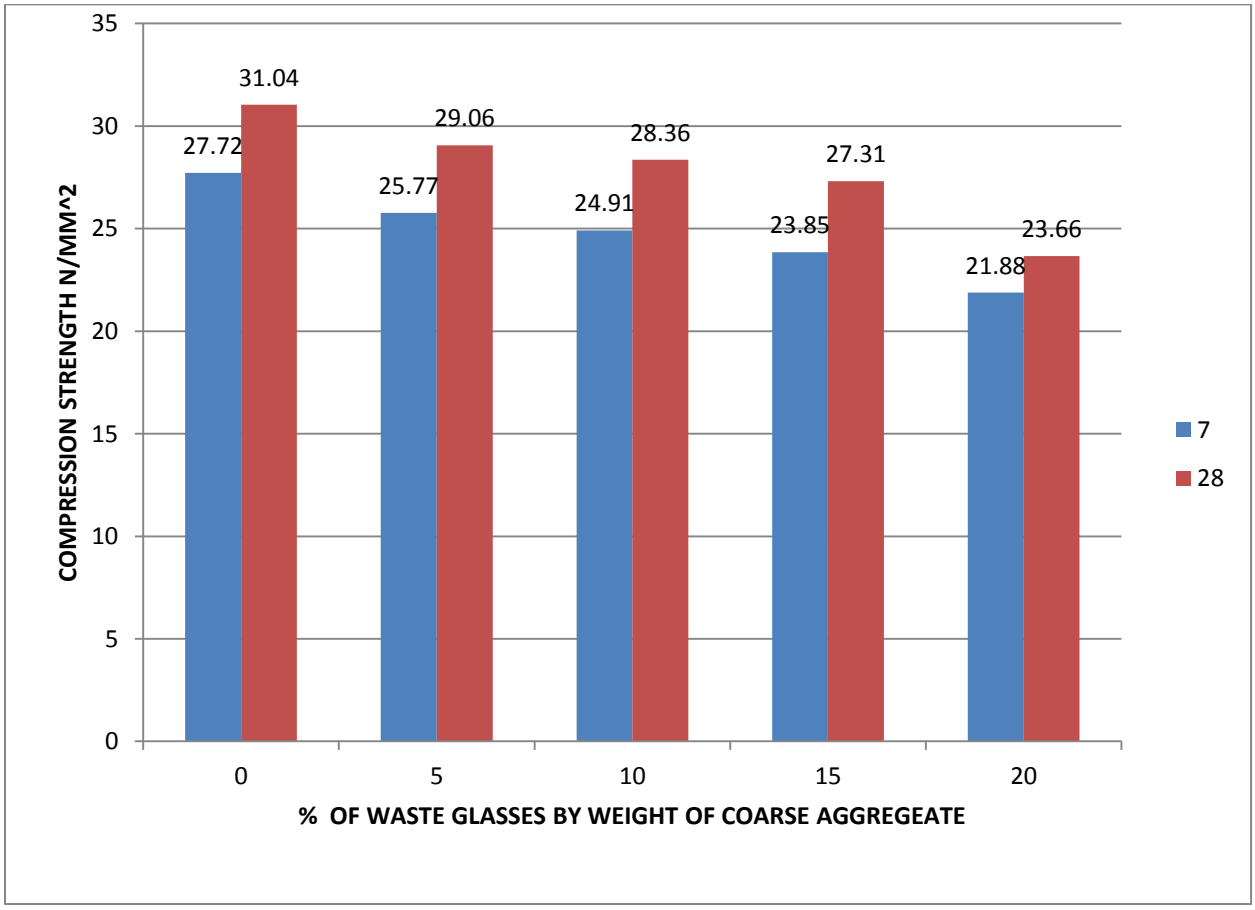
B=breadth of cube in mm.

D=depth of cube in mm.

COMPRESSION TEST RESULTS

COMPARISON OF COMPRESSION STRENGTH OF 7 DAYS AND 28 DAYS CURING:

Type of Mix	M1	M2	M3	M4	M5
7 Days compressive strength(N/mm²)	27.72	25.77	24.91	23.85	21.88
28 Days compressive strength(N/mm²)S	31.04	29.06	28.36	27.31	23.66



CONCLUSIONS AND FUTURE SCOPE

Conclusions:

- Marginal decrease in strength is observed at 15% to 20%. 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 10%.
- 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 land filling 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.

- 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.

REFERENCES

1. C Meyer, N Egosi , C Andela - Concrete with Waste Glass as Aggregate, Recycling and Re-use of Glass Cullet", Dhir, Dyer and Limbachiya, editors, Proceedings of the International Symposium Concrete Technology Unit of ASCE and University of Dundee, March 19-20, 2001

2. Zainab Z. Ismail, Enas A. AL-Hashmi,(2009), Recycling of waste glass as a partial replacement for fine aggregate in concrete Waste management, 29(2), pp 655-659.

3. B. Topcu and M. Canbaz, "Properties of Concrete containing waste glass", Cement and Concrete Research, vol. 34, pp. 267-274, Feb. 2004

4. Kou, S. and Poon, C., "Properties of self-compacting concrete prepared with recycled glass aggregate", Cement and Concrete Composites Journal, Vol. 31, pp. 107 – 113, 2009.

5. Caijun & Keren International science index Vol:8, No: 10, 2014 waset.org/publication /9999599

6. Her-Yung Wang, "A study on the effects of LCD glass sand on the properties of concrete", Waste Management, Vol. 29, pp. 335–341, May 2008.\