Study on Evaluation of Waste Glass Powder as a Partial Replacement of Cement Concrete-Review

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Abstract— Cement manufacturing industry is one of the carbon-dioxide emitting sources besides deforestation and burning of fossil fuels. The global warming is caused by the emission of green-house gases, such as CO2, to the atmosphere. Among the greenhouse gases, CO2 contributes about 65% of global warming. The global cement industry contributes about 7% of greenhouse gas emission to the earth's atmosphere. In order to address environmental effects associated with cement manufacturing, there is a need to develop alternative binders to make concrete. Consequently extensive research is on going into the use of cement replacements, using many waste materials and industrial by products. Efforts have been made in the concrete industry to use waste glass as partial replacement of coarse or fine aggregates and cement. In this study, finely powdered waste glasses will be used as a partial replacement of cement in concrete and compared it with conventional concrete. This work examines the possibility of using Glass powder as a partial replacement of cement for new concrete. Glass powder will be partially replaced as 5%,10%, 20%, 30% and 40% and tested for its compressive, Tensile and flexural strength up to 28 days of age and will be compared with those of conventional concrete. Glass powder will be used as cement replacement material up to particle size less than 75µm to prevent alkali silica reaction. For study of size effect of glass powder the powder is divided into two grades one is glass powder having size less than 75 micron and another is glass powder having particle size ranges from 75 micron to 150 micron.

Keywords: Waste Glass Powder, Cement Concrete

I. Introduction

The interest of the construction community in using waste or recycled materials in concrete is increasing because of the emphasis placed on sustainable construction, the waste glass from in and around the small shops is packed as a waste and disposed as landfill. Glass is an inert material which could be recycled and used many times without changing its chemical property. Glass is amorphous material with high silica content, thus making it potentially pozzolanic when particle size is less than 75µm. Studies have shown that finely ground glass does not contribute to alkali – silica reaction. In the recent, various attempts and research have been made to use ground glass as a replacement in conventional ingredients in concrete production as a part of greenhouse management. A major concern regarding the use of glass in concrete is the chemical reaction that takes place between the silica – rich glass particle and the alkali in pore solution of concrete, which is called Alkali – Silicate reaction can be very detrimental to the stability of concrete, unless appropriate precautions are taken to minimize its effects. ASR can be prevented or reduced by adding mineral admixtures in the concrete mixture, common mineral admixtures used to minimize ASR are pulverized fuel ash (PFA), silica fume. A number of studies have proven the suppressing ability of these materials on ASR. The fact that glass has high silica content has led to laboratory studies on its feasibility as a raw material in cement manufacture.

The use of finely divided glass powder as a cement replacement material has yielded positive results. Partial replacement of cement with milled waste glass benefits the microstructure and stability of cementitious materials. A denser and more homogeneous structure is produced when milled waste glass is used as partial replacement for cement, which benefits the resistance to moisture sorption and thus the long-term durability of cementitious materials. Waste glass, when milled to about the particle size of cement and used in concrete as replacement for about 20% of cement, improves the moisture barrier qualities, durability, and mechanical performance of concrete. These improvements result from the beneficial chemical reactions of milled waste glass with cement hydrates, which yield chemically stable products capable of refining the pore system in concrete.
Replacing cement by pozzolanic material like waste glass powder in concrete, not only increases the strength and introduces economy but also enhances the durability of concrete.

A. General Pozzolana Information

The pozzolanic materials are essential a siliceous or aluminous material which itself possessing no cementitious properties, which will in finely divided form and in the presence of water, react with calcium hydroxide [$Ca(OH)_2$] liberated in the hydration process to form compounds possessing cementitious properties. The pozzolans can be used as partial replacement of cement. The pozzolanic materials when used as partial replacement of cement are generally substituted for 10 to 35 percent. This substitution produces concrete that is more permeable but much more resistant to the action of salt, sulphate, or acid water. Strength gain is usually slower than for the normal concrete. Pozzolans when added to concrete mixes, rather than substituted for a part of the cement, improve workability, impermeability and resistance to chemical attack. The overall effect depends on the aggregates used in concrete. The aggregate deficient in fine material give the best result. For a pozzolan to work to remediate ASR, it must be quite effective in powdered form (minus 325 mesh), and it must not bring unacceptable chemical constituents to the reaction. Deleterious chemical constituents include sulfides (turn concrete green), sulfates (can cause delayed expansion), and alkalis (which add more alkali to concrete which creates higher risk of ASR over the life of the concrete). A pozzolan can be thought of as a sacrificial anode, as it de-polymerizes at the 13.5 pH environment of freshly poured concrete to go into solution to ultimately react with the lime in solution to form additional CSH binder. The widely dispersed presence of the pozzolan will consume (sequester) the alkalis in concrete such that the reactive aggregate remains untouched because of its larger particle size and the sacrificial characteristics of the pozzolan. A good pozzolan functions both to mitigate ASR and to consume the lime to greatly reduce efflorescence .This brings up the issue of pozzolan chemistries and sources. There are large amounts of mineral processing slags , coal fly ashes, recycled glasses, and other amorphous materials that all undergo with varying effectiveness the pozzolanic reaction to react with the lime in concrete. The problem is their level of effectiveness and the chemical constituents they introduce to the mix. For instance, most slags contain sulfides and have widely varying reactivity's, and each must be individually tested to determine whether the side effects are acceptable. Similarly, fly ashes vary widely in composition and fineness and many contain carbon, sulfates or lime, which may create undesirable effects in concrete. Silica fume and metakaolin are widely used, but they have high water demands and greatly affect concrete workability and placement rheologies.

B. Recycled Glass as a Pozzolana

The issue of recycled glass is quite complicated from a chemistry point of view. Years ago, the reinforcement fiberglass manufacturers saw a large market potential in using glass reinforcements as reinforcing fiber in concrete. Early tests soon indicated that normal chemistry reinforcement fiberglass almost totally dissolved in the concrete environment, as the extremely low alkali content of the fiber glass, about 1%, caused it to be highly susceptible to alkalis in concrete environments. The fiberglass manufacturers were able to address the problem by adding 16% zirconia to the glass chemistry to make it alkali resistant (so called AR glass). Borosilicate (Pyrex) type glasses are so expansive that they were selected to be the ASTM C441 (standard test method for effectiveness of pozzolans) test aggregate that severely tests the ASR mitigation capability of various pozzolans. Under no circumstances should borosilicate glass be added to concrete. Soda lime plate and bottle glass are reactive aggregates and must be mitigated with pozzolans and/or lithium compounds. Understanding the need for a pozzolan to be sacrificial, the phenomena of the quick reaction(in alkaline environments like concrete) of fiberglass led to the development of pozzolan powder derived from this same reinforcement fiberglass, called VCAS White Pozzolan.

VCAS, a patented product, has been shown to be very effective, is as white as white cement, and has a very low water demand. VCAS has an optimum ratio of Ca, Si and Al ions to react with lime to form CSH and CASH. Further, there is no chemical baggage associated with VCAS in the form of sulfides, sulfates, carbon, heavy metals, or high alkali content. It reacts quickly and can be used at a 20% cement replacement level to completely mitigate ASR reaction, even in cements with 1% or higher alkali contents. As the VCAS reacts with lime, the product, CSH, precipitates within the pore and void structure of the concrete structure, densifying the concrete and mitigating secondary efflorescence (a process that starts occurring several days after placement).Over the years, it naturally occurred too many to grind up bottle or plate glass to minus 325 mesh for use as a pozzolan. However, an incomplete understanding of the chemistry, especially the delaying effect of high alkali reactions taking place, caused several problems. First, it takes much higher loadings and longer time frames for a pozzolan made from bottle glass to offer sufficient ASR mitigation. Perhaps the more serious problem, longer term, is that bottle glass powder does eventually react, releasing high quantities of alkali into the concrete matrix to further aggravate ASR conditions with reactive aggregates. Why would cement manufacturers work so hard to make low alkali cements less than 0.6% alkali, then see a bottle glass pozzolan containing up to 15% alkali (25x that of cement) replace some of the cement? Chemically speaking, high alkali pozzolans create a long running battle to fix problems created by themselves. The more a bottle glass sacrifices itself, the more problems it causes. The key role of a pozzolan is to chemically tie up (sequester) alkalis (Na_2O and K_2O) to keep them from reacting with susceptible aggregates. In doing so, they also react with lime. Since bottle glass used as a pozzolan is already loaded up with alkalis, its capacity to tie up more alkalis is limited compared to very low alkali pozzolans like metakaolin, silica fume and VCAS made from reinforcement fiberglass. Therefore, it takes much more bottle glass powder as a cement replacement to mitigate ASR. Adding all the extra bottle glass pozzolan required creates another set of problems. First, the more pozzolan that is added retards strength development in the concrete to an unacceptably low rate. Secondly, as the bottle glass powders do react, they add more alkalis in the form of sodium silicate (aka water glass) to the concrete, which are highly soluble and can migrate to the surface in the form of sodium efflorescence.

II. LITERATURE REVIEW

A. Slump Test

Jangid Jitendra B. and Saoji A.C. [2012] resulted that the workability decreases as the percentage glass powder in the mix increases.

Khatib J.M et. al [2012] in his study showed that there was a systematic increase in the slump as the glass powder content in the mix increases.

Chikhalikar S.M. and Tande S.N. [2012] studied the properties of SFRC (Steel Fibre Reinforced Concrete) containing waste glass as pozzolon and concluded that the 20% replacement of cement by waste glass powder gives better workability.

Vasudevan Gunalaan and Kanapathy pillay Seri Ganis [2013] studied slump property in his research and resulted that compared to control mix, by using waste glass powder will give another benefit which is the workability of concrete which is much higher.

R .Vandhiyan et. al [2013] investigated that the workability was reduced due to the replacement and it reduced with increase in replacement, this is due to the increase in the surface area of the glass powder and also the angular shape of the glass particles.

Kumarappan N. [2013] presented that there is a systematic increases in the slump as the glass powder in the mix increases. The slump ranged from around 40mm for the reference mix (i.e. 0% glass powder) to 160mm at 40% glass powder.

Saoji A.C. [2012] concluded that the upto 40% replacement of cement, compressive strength increase upto 20% and cement replaced beyond which decreases compressive strength. Chikhalikar S.M. and Tande S.N. [2012] investigated on the characteristics properties of fibre reinforced concrete containing waste glass as pozzolona and showed that the compressive strength increase is achieved upto 30% as compared to control mix, but the peak % increase is at 20% replacement.

Dali J.S. and Tande S.N. [2012] studied the properties of concrete containing mineral admixtures, when it is subjected to alternative wetting and drying and high temperature and resulted that the compressive strength increment is upto 25% replacement of cement by waste glass powder, but the peak % increment is at 20% replacement in both the cases, i.e. concrete without subjecting to alternate wetting and drying, and concrete subjected to alternate wetting and drying.

Patel Dhirendra et. al [2012] investigated the strength characteristics of pre cast blocks incorporating waste glass powder and studied that the moderate level decrease in the compressive strength at 28 days occurs. Many works have been done to explore the benefits of using waste glass powder in making and enhancing the properties of concrete.

Vasudevan Gunalaan and Kanapathy pillay Seri Ganis [2013] investigated the test results at 7, 14, 28 days of curing of specimens containing waste glass powder as partial replacement of cement and his results showed that the 20% glass powder mix amount shows a positive value of compressive strength at 28 days compare to other ratio which 10% and 15% is not achievable even though have slight increment from 14 days results.

Nwaubani Sunny O. and Poutos Konstantinos I. [2013] concluded that increasing the amount of glass in mortar causes a general decrease of compressive strength, but the decrease becomes less evident with prolonged curing time. The particle size distribution of waste glass used was the key factor influencing the strength developmentJangid Jitendra.

B. Compressive Strength

Oliveira L.A Pereira de et. al [2010] study focused on the assessment of the pozzolanic activity of green, amber and flint color waste glass of different particle sizes(75µm – 150µm,45µm – 75µm and < 4µm) as a component of cementitious materials used as filler or binder in mortar and concrete. He concluded that 30% of 45-75 µm ground waste glasses size range could be incorporated as cement replacement in mortar or concrete without any detrimental effects caused by the expansivity provoked by the alkali silica reaction.

Bajad M.N. et. al [2011] studied the strength properties containing glass when subjected to sulphate attack and showed that the peak compressive strength is achieved at 20% replacement of cement by waste glass powder both when concrete is not subjected to sulphate attack and when concrete subjected to sulphate attack and the increment continues upto 25% replacement beyond which it decreases.

C. Flexural Strength

Bajad M.N. et. al [2011] experimentally showed that 20% replacement by waste glass powder is optimal both in the case of concrete subjected to sulphate attack and when not subjected to sulphate attack.

Chikhalikar S.M. and.Tande S.N. [2012] tested flexural strength parameter in his study and resulted that 20% dosage of waste glass powder is optimal for replacing cement .

Dali J.S. and Tande S.N. [2012] studied the properties of concrete containing mineral admixtures, when it is subjected to alternative wetting and drying and high temperatures and showed that 20% replacement gives higher strength in both the cases when concrete not subjected to alternative wetting and drying, and when concrete subjected to alternative wetting and drying.

Jangid Jitendra B. and Saoji A.C. [2012] in their work proposed that flexural strength increases upto 35% replacement of cement by waste glass powder as compared to control mix and the peak % increment is at 20%, beyond which it decreases.

Vandhiyan R. et. al [2013] 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.

Vijayakumar. G et. al [2013] showed that flexural strength increment is achieved upto 40% replacement of cement by waste glass powder

D. Split Tensile Strength

Chikhalikar S.M. and Tande S.N. [2012] in their study on Steel Fibre Reinforced Concrete (SFRC) presented that the tensile strength attains a peak value at 20% replacement of cement by waste glass powder

Dali J.S. and Tande S.N. [2012] performed tests on concrete containing mineral admixtures at high temperatures and concluded that 20% replacement level is optimal when concrete is not subjected to alternative wetting and drying and also when concrete subjected to alternative wetting and drying

Vijayakumar G. et. al [2013] studied that the glass powder concrete increases the tensile strength effectively when compared with conventional concrete.

Vandhiyan R. et. al [2013] showed that there was a marginal improvement in the tensile strength..
Many works have been done to explore the benefits of using waste glass powder in making and enhancing the properties of concrete.

Dr. G.Vijayakumar, Ms. Vishaliny, Dr. D. Govindarajulu investigated the test results at 28 days of curing of specimens containing waste glass powder as partial replacement of cement and his results showed that Conventional concrete shows at 28 days compressive strength as 31.1 N/mm2, split tensile strength of 2.27N/mm2 and flexural strength of 3.25N/mm2

1) Replacement of glass powder in cement by 20%, 30% and 40% increases the compressive strength by 19.6%, 25.3% and 33.7% respectively.
2) Replacement of glass powder in cement by 40% increases the split tensile strength by 4.4% respectively
3) Replacement of glass powder in cement by 20%, 30% and 40% increases the flexural strength by 83.07%, 99.07% and 100% respectively.
4) Glass powder concrete increases the compressive, tensile and flexural strength effectively, when compared with conventional concrete.
5) Very finely ground glass has been shown to be excellent filler and may have sufficient pozzolanic properties to serve as partial cement replacement, the effect of ASR appear to be reduced with finer glass particles, with replacement level.

Dhanaraj Mohan Patil, Dr. Keshav K. Sangle investigated the test results at 28 days curing of specimen containing waste glass powder as partial replacement of cement and his results showed that on addition of GLP initial the rate of gain of strength is low but at 28th day it meets required design strength.

– Addition of GLP increases the strength of concrete.
– At the level of 20% replacement of cement by glass powder meets maximum strength as compare to that of normal concrete and other percentage of replacement of cement.
– As the size of GLP particle decreases in concrete the strength of concrete increases. From results it is conclude that particle size less than 90 micron get higher strength than that of particle size ranges from 90 to 150 micron.

III. Objectives

The objective of the research is to study the effect of the use of Glass Powder as a partial replacement of cement to assess the pozzolanic nature of fine glass powder when mixed in concrete and to know the extent to which glass powder can replace cement. In this study, finely powdered waste glasses will be used as a partial replacement of cement in concrete and compared it with conventional concrete. This work examines the possibility of using Glass powder as a partial replacement of cement for new concrete. Glass powder will be partially replaced as 5%,10%,15%,20%,25% 30% and tested for its compressive, Tensile and flexural strength up to 28 days of age and will be compared with those of conventional concrete.

– The primary objective of this study is to investigate the practicality, versatility and feasibility of utilizing recycled glass as a partial replacement to cement.
– To evaluate the recyclability of powdered waste glass as a pozzolana as partial replacement of cement in the concrete.
– To Study the influence of waste glass on hardened properties of concrete mixes such as: compressive strength, flexural and splitting resistance.
– Determine the optimum waste glass powder to be added as a partial replacement of cement.

IV. Scope

Cement manufacturing industry is one of the carbon dioxide emitting sources besides deforestation and burning of fossil fuels. The global warming is caused by the emission of green house gases, such as CO2, to the atmosphere. Among the greenhouse gases, CO2 contributes about 65% of global warming. The global cement industry contributes about 7% of greenhouse gas emission to the earth's atmosphere. In order to address environmental effects associated with cement manufacturing, there is a need to develop alternative binders to make concrete.

– Due to cement replacement by glass powder the cement use in construction will be lesser, thereby effecting the production of cement which in turn will affect the generation of green house gases positively.
– Many researchers have revealed that by replacing cement with waste glass powder upto 40%, an increase in compressive strength of about 34% occurs,hence it can be used where high strength concrete is required.

V. Requirements for this project

A. Materials

1) 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 nallah sind. Two sizes of coarse aggregate is used; one 10 mm and other 20mm in the ratio of 70:30.

2) 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.

– Glass is an amorphous (non-crystalline) that in essence, a super cooled liquid and not a solid.
– Glass can be made with excellent homogeneity in a variety of forms and sizes from small fibres to meter-sizes pieces.
– Primarily glass is made up of sand, soda ash, limestone and other additives (Iron, Chromium, Alumina, Lead and Cobalt).
– Glass has been used as aggregates in construction of road, building and masonry materials.

3) Source of Glass:

– Sand is filtered through three different size screens having three different sizes.
– The finest sand makes the finest glass the largest sand makes the strongest glass.

- Sand is melted in crucible to make glass.
- Source of Waste Glass:
- Glass food and beverages container.
- Window repair shops.
- Glass decorative items.
- Old tube lights, electric bulbs.
- Glass polishing and glass window and door manufacturing shop.
- Casting of Specimen :
- Seven types of mix will considered; of which One control mixture S-1 (without glass powder) will designed according to Indian Standard Specification IS: 10262(1999) .
- The other six concrete mixes will be made by replacing the cement with 5%, 10%, 15%, 20%,25%, 30% of glass powder weight.

B. 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 and glass powder .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.

VI. PREPARATION OF MATERIALS

All materials shall be brought to room temperature, preferably 270 + 30̊ C before start the results. The cement samples, on arrival at the laboratory, shall be carefully mixed dry either by hand or in a appropriate mixer in such a manner as to ensure the maximum possible blending and uniformity in the material, care is being taken. The cement shall then be stored in a dry place, preferably in air-tight metal containers. Samples of aggregates for each batch of concrete shall be of the desired grading and shall be in an air-dried condition. In general, the aggregate shall be separated into fine and coarse portion and recombined for each concrete batch in such a way as to produce the desired grading. IS sieve 480 shall be normally used for separating the fine and coarse fractions, but where special grading are being investigated, both fine and coarse aggregate shall be separated into different sizes.

1) Proportioning

The proportions of the materials, including water, in concrete mixes used 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 concrete 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.

2) Weighing

Weigh batching is the correct method of measuring the materials. For important concrete, invariably weigh batching should be adopted. Use of weight system in batching, facilitates accuracy, flexibility and simplicity.

3) Mixing Concrete

Thorough mixing of the materials is essential for the production of uniform concrete. The mixing should ensure that the mass become homogeneous, uniform in colour and consistency. There are two methods adopting for mixing concrete one is hand mixing and other is machine mixing.

4) Compaction of Test Specimens: (As Per is: 516-1959)

Compaction of concrete is the process adopted for expelling the entrapped air from the concrete. In the process of mixing, transporting and placing of concrete air is likely to get entrapped in the concrete. The lower the workability, higher is the amount of air entrapped. In other words, stiff concrete mix has high percentage of entrapped air and, therefore, would need higher compacting efforts than high workable mixes. Therefore, it is imperative that 100% compacting of concrete is one of the most important aim to be kept in mind in good concrete making practices.

5) Compaction by Vibration

When compacting by vibration, each layer shall be vibrated by means of an electric or vibrator or by means of a suitable vibrating table until the specified condition is attained.

6) Placing Moulds on the Vibrating Table

This is the special case of formwork vibrator, where the vibrator is clamped to the table or table is mounted on springs which are vibrated transferring the vibration to the table. They are commonly used for vibrating concrete cubes. Any specimen kept on the table gets vibrated. This id adopted mostly in laboratory and in the making small but precise prefabricated R.C.C members.

Fig. 5.1: Vibrating table

7) 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 + ½ 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 320̊ C. After the period of 24 hours, they shall be marked for later classification, removed from the moulds and, unless required for testing within 24 hours, stored in clean water at a temperature of 240 to 300̊ C 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 + 20̊ C until the time of test.

Fig. 5.2: Curing of test specimens.

The experimental work was carried out in our college concrete technology laboratory. In this study, total of seven groups of concrete mixes were prepared in laboratory. First group was normal cement concrete mix. Second, third, fourth, fifth, sixth, and seventh group was cement replacement by fine glass powder (GLP) particle size less than 75 micron with replacement from 5%, 10%, 15%,20%,25% and 30% respectively.

B. Compressive 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 0, 5, 10, 15, 20, 25 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 both conventional and glass 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.

Fig 7.3: compression test

C. Split Tensile Strength of Concrete

Seven different mixes (Mix1, Mix2, Mix3, Mix4, Mix5, Mix6, Mix7) were prepared using cement replaced by glass powder at varying percentage of 0, 5, 10, 15, 20, 25 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

Fig. 7.4: split tensile test

VII. CONCLUSION

- On addition of GLP initial rate of gain of strength is low but at 28th day strength is more than the design strength.
- Addition of GLP increases the strength of concrete.
- At the level of 20% replacement of cement by glass powder, strength is higher as compare to that of normal concrete and other percentage of replacement of cement on 28^{th} day.

- The compressive strength of glass powder concrete shows an increment of about 18% at the age of 28th days at optimum point.
- The flexural strength of glass powder concrete shows an increment of about 27% at the age of 28th days at optimum point.
- The split tensile strength of glass powder concrete shows an increment of about 29% at the age of 28th days at optimum point.
- Workability of concrete decreases with increase in percentage replacement of cement with glass powder.

VIII. FUTURE WORK

The project work was emphasized on use of glass materials as partially replacement of cement. Further one can extend this work as follows.

- The effect of glass materials on compressive strength of concrete as partially replacement of coarse aggregates and fine aggregates can be analysed and studied.
- The effect of pulverised glass materials on ductility at beam column joint, durability ,fire resistant properties etc. can be analysed and studied
- The glass powder and silica fume are the pozzolanic materials. Therefore compressive strength can be studied by using this materials same as partially replacement of cement in concrete. And also can be determined its optimum dosage range when concrete riches maximum strength.

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