Strength Assessment and Feasibility Study on Waste Glass Powder as Partial Replacement of Cement in Concrete Production

Ankit Jena[1], Manasmita Paikaray [2]
[1] *Assistant Professor, GIFT*
[2] *Assistant Professor, SMEC*

***Abstract*- Concrete is one of the most widely used construction materials in the world. However, the production of Portland cement, an essential constituent of concrete, leads to the release of significant amount of CO2, a greenhouse gas. One ton of Portland cement clinker production is said to create approximately one ton of CO2 and other greenhouse gases (GHGs). Environmental issues are playing an important role in the sustainable development of the cement and concrete industry. In order to address environmental effects associated with cement manufacturing, there is a need to develop alternative binders to make concrete. Storage and safe disposal of waste & crushed glass is a huge problem for our urban & rural areas in India. Everywhere reuse of waste glass eliminates this problem. In this experimental work, the effect of partially replacing of glass powder in concrete is studied. The cement in concrete is replaced by waste glass powder (WGP) in steps of 0%,5% ,10% &15% respectively by volume of cement and its effects on compressive strength, split tensile strength, workability and flexural strength are determined at 7th, 28th and 45th days. It is found that the compressive, flexural and split tensile strengths of concrete increase initially as the replacement percentage of cement by glass powder increases and becomes maximum at about 10% and later decreases. The workability of concrete reduces monotonically as the replacement percentage of cement by glass powder increases. The replacement of cement up to about 10% by glass powder can be done without sacrificing the compressive strength.**

Index Terms- Concrete, Cement Replacement, Waste Glass Powder, workability, Pozzolanic.

1. INTRODUCTION

Concrete is a blend of cement, sand, coarse aggregate and water. The key factor that adds value to concrete is that it can be designed to withstand harshest environments significant role. Today global warming and environmental devastation have become manifest harms in recent years, concern about environmental issues, and a changeover from the mass-waste, mass-consumption, mass-production society of the past to a zero-emanation society is now viewed as significant. Normally glass does not harm the environment in any way because it does not give off pollutants, but it can harm humans as well as animals, if not dealt carefully and it is less friendly to environment because it is non-biodegradable. Thus, the development of new technologies has been required .The term glass contains several chemical diversities including soda-lime silicate glass, alkali-silicate glass and boro-silicate glass. To date, glass powder of these types glasses have been widely used in cement and aggregate mixture as pozzolana for civil works. The introduction of waste glass in cement will increase the alkali content in the cement. It also help in bricks and ceramic manufacture and it preserves raw materials, decreases energy consumption and volume of waste sent to landfill. As useful recycled materials, glasses and glass powder are mainly used in fields related to civil engineering, for example, in Cement, as pozzolana (supplementary cementitious materials),and coarse aggregate. Their recycling ratio is close to 100%, and it is also used in concrete without adverse effects in concrete durability. Therefore, it is considered ideal for recycling.

Recently, Glasses and its powder has been used as a construction material to decrease environmental problems. The coarse and fine glass aggregates could cause ASR (alkali-silica reaction) in concrete, but the glass powder could suppress their ASR tendency, an effect similar to supplementary cementations materials (SCMs). Therefore, glass is used as a

replacement of supplementary cementitious materials.

2. SIGNIFICANCE OF THE WORK

The use of recycled glass as partial replacement of cement in concrete paves the way for a great positive environmental impact. Recent research findings have shown that concrete made with waste glass powder have shown better long term strength. When tested for various physical properties of concrete like compressive strength, flexural strength and split-tensile strength the concrete mixtures with 5% and 10% WGP (75µm – 150 µm particle size) as partial replacement of cement yielded values greater than that of the value of conventional concrete. It has been concluded that 10% glass powder could be incorporated as cement replacement in concrete without any long-term detrimental effects. Up to 10% of WGP could be replaced in concrete of 35 MPa strength grade with acceptable strength development properties. It was observed that with a progressive increase in partial replacement of cement by WGP till 15%, the slump value, gradually reduced. Glass was ground to a particle size of 150 µm or smaller to reduce the alkali reaction (ASR) induced expansion. In fact, data reported in the literature show that if the waste glass is finely ground, under 75 µm this effect does not occur and mortar durability is increased (Mageswari.L.M and B.Vidivelli,2010). The tensile and flexural strength also showed signs of increase affected by the addition. At a replacement level of 10 %, the tensile strength increased by 3%, in comparison to the control conventional concrete whereas the flexural strength increased by 2.5% (Seung Bum Park and Bong-Chum Lee,2004).

3. EXPERIMENTAL INVESTIGATION

A. Material used

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 53 grade conforming to IS 8112 was used throughout the work. The fine aggregate used in this investigation was clean river sand, whose maximum size is 4.75 mm, conforming to grading zone I. Machine crushed blue granite stone angular in shape was used as coarse aggregate. Two size of coarse is used; one 16 mm passing through 12.5 mm retained and other 25 mm passing through 20mm retained. As per IS: 2386 – 1963 recommendations the various properties of coarse aggregates were determined.

2. Glass powder: Waste glass available locally in Bhubaneswar was collected and made into glass powder. Glass waste is very hard material. Before adding glass powder in the concrete it has to be powdered to desired size. In this studies glass powder ground in ball pulverizer for a period of 30 to 6o minutes resulted in particle sizes less than size 150 µm and sieved in 75 µm. The physical, chemical properties and chemical composition are presented in the table 1 & 2.

TABLE 1:Physical properties of glass powder

S.No	Physical Properties of Glass Powder	
1	Specific gravity	2.6
2	Fineness Passing 150µm	99.5
3	Fineness Passing 75µm	98

TABLE 2:Chemical composition of glass powder

Composition (% by mass)/ property	Glass powder
Silica (SiO_2)	72.5
Alumina (Al_2O_3)	0.4
Iron oxide (Fe_2O_3)	0.2
Calcium oxide (CaO)	9.7
Magnesium oxide (MgO)	3.3
Sodium oxide (Na_2O)	13.7
Potassium oxide (K_2O)	0.1

B. Mix proportion and of testing specimens

1. Mix Design: A concrete mixture of M35 was designed as per standard specification IS: 10262-1982 to achieve target mean strength 43.25 MPa. The other three concrete mixtures were made by replacing 5%, 10% and 15% of cement with waste glass powder (WGP) by mass to improve the strength performance of concrete. In this study, total four mixes are prepared M1 indicate concrete mix with 0% WGP, M2 indicate concrete mix 5% WGP, M3 indicate concrete mix with 10% WGP and M4 indicate concrete mix with 15% WGP. The detail mix proportion along with their identification is designated according to their replacement as given in table 3.

TABLE 3: Mix Proportion

Concrete Mix Proportion	W/C Ratio	Mix Identity
Concrete mix with 100% cement + 0% WGP	0.43	M1
Concrete mix with 95% cement + 5% WGP	0.43	M2
Concrete mix with 90% cement + 10% WGP	0.43	M3
Concrete mix with 85% cement + 15% WGP	0.43	M4

2. Strength Test: The concrete prepared with various percentage replacement of the cement such as 5%,10% and 15% was cured under normal condition as per IS recommendation and were tested at 7 days, 28 days and 45 days for determining the slump, compressive , tensile and flexural strength and also compared with the test results of conventional concrete Fig.1,2,3&4.

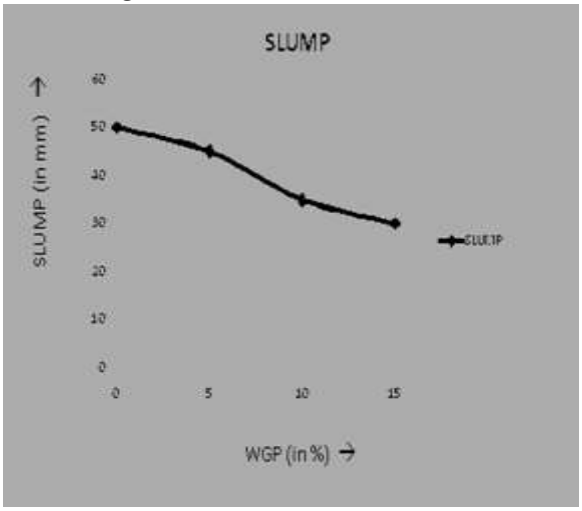

Fig. 1: Comparative slump values

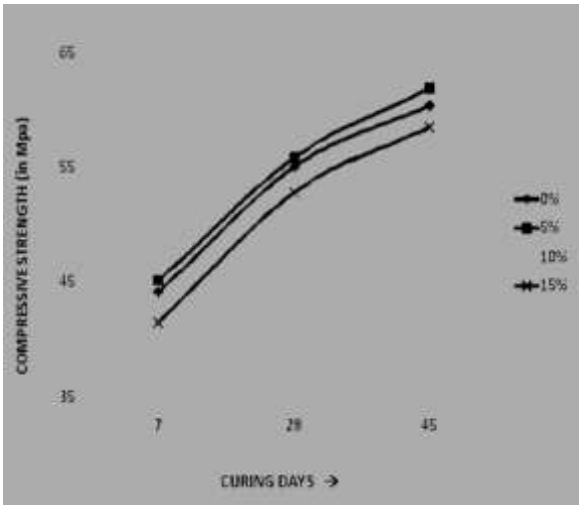

Fig 2: Comparative compressive strengths

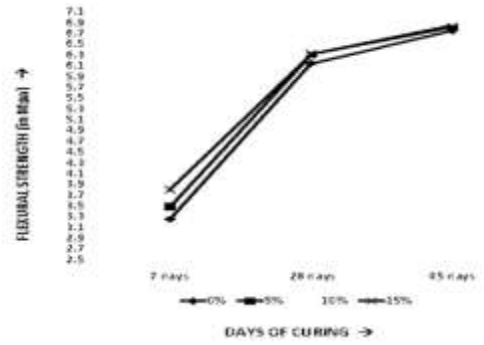

Fig 3: Comparative flexural strengths

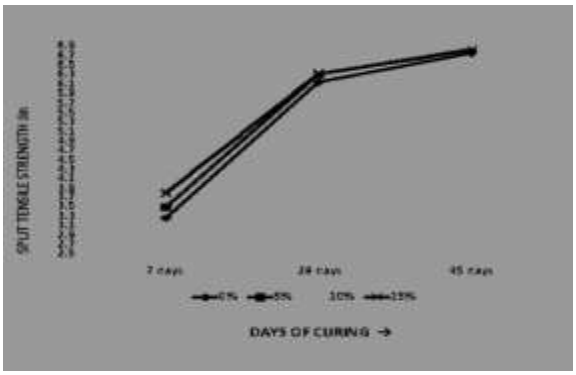

Fig 4: Comparative split tensile strengths

4. RESULTS AND DISCUSSION

Workability decreases as the glass content increased (i.e. cement content decreased) due to reduction of fineness modulus of cementious material, less quantity of cement paste is available for providing lubricating effect per unit surface area of aggregate, and hence mobility of aggregate is restrained. An increasing trend in strength was observed with increasing replacement of cement with glass powder up to 10%. When the cement replacement level was increased beyond 10%, the compressive, flexural and split tensile strength decreased. The increase in strength up to 10% replacement of cement by glass powder may be due to the pozzolanic reaction of glass powder. Waste glass when ground to a very fine powder, SiO2 react chemically with alkalis in cement and form cementitious product that help contribute to the strength development. Also it may be due to the glass powder effectively filling the voids and giving rise to a dense concrete microstructure as a result waste glass powder offers resistance against expansive forces caused by sulphates and penetration of sulphates ion into the concrete mass. However, beyond 10%, the dilution effect takes over and the

strength starts to drop. Thus it can be concluded that 10% was the optimum level for replacement of cement with glass powder. The strength improvement at early curing ages was slow due to pore filling effect.Waste glass powder(WGP) initially acts like a pore filler and only later, after 7-10 days, its hydration liberates sufficient amount of lime for starting the secondary pozzolanic reaction.This reaction leads to more quantity of C-S-H gel getting formed.

5. CONCLUSIONS

In the present experimental investigation, the strength enhancement results of concrete mixtures using WGP are presented. Four concrete mixtures are used in three different series and evaluated the effect of WGP on strength of concrete.Based on the above results the following conclusions may be drawn:

- In general WGP was found to be a good partial replacement of cement in concrete production from strength and workability point of view and according to recycle of waste material.
- The glass satisfies the basic chemical requirements for a pozzolana. However, it does not comply with the additional requirement for the alkali content because of the high percentage of Na2O in glass. Despite this situation, finely ground glass powders exhibited very high pozzolanic activity.
- The general strength of 5% and 10% WGP concrete samples produced high strength concrete with compressive strength reaching up to 45.15Mpa, 55.68Mpa and 61.92Mpa for 7, 28 and 45 days respectively for 5% partial replacement of cement and 46.46Mpa, 57.33Mpa and 63.45Mpa for 7, 28 and 45 days respectively for 10% partial replacement of cement.
- Concrete with 15% WGP had least compressive strength, which indicates that the the dilution effect takes over at 15% replacement and the strength starts to drop. However, even though the strength of the samples have been dependant on those two variables, i.e. amount of WGP and curing period, the least desirable structural requirement for high strength concrete was achieved for this replacement value.
- Very finely ground glass has been shown to be excellent filler and may have sufficient pozzolonic properties to serve as partial cement replacement, the effect of ASR appear to be reduced with finer glass particles, with replacement level.
- The fresh concrete results of this research indicate the workability decreases as the % of WGP increases.
- As age of curing increases, the strength, of concrete increases.
- From the result its concluded that 5% and 10% WGP samples could be considered for production of high strength concrete.
- Finally, 10% WGP is the ideal percentage of WGP which is in the boundary limit of the production of high strength concrete.

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