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Factors Affecting the Properties of Conglasscrete

M.N.Bajad [1] ,C.D.Modhera [2] and A.K.Desai [3]
[1] (*Research Scholar,Department of Applied Mechanics, S.V. N.I.T, Surat, Gujarat ,India*)
[2] (*Professor & Head , Department of Applied Mechanics, S.V. N.I.T, Surat, Gujarat ,India)*
[3] (*Professor, Department of Applied Mechanics, S.V. N.I.T, Surat, Gujarat ,India)*

Abstract: *Chloride attack is one of the most important aspects for consideration when we deal with the durability of concrete. Chloride attack is particularly important because it primarily causes corrosion of reinforcement. Statistics have indicated that over 40% of failure of structures is due to corrosion of reinforcement. This paper deals with an experimental study on the mechanism of chloride attack. Cement replacement by glass powder in the range of 5% to 40% in increments of 5% and EPCO KP-200 used in concrete as a corrosion inhibitor with 2% by weight of cement has been studied. Concrete produced by replacing 20% of cement by glass powder and the addition of 2% EPCO KP-200 by weight of cement not only increased strength but also reduced the ingress of chloride ion in concrete mass.*
Keywords: *Chloride attack, corrosion, durability, strength*

I Introduction

It has been estimated that several million tons of waste glasses are generated annually worldwide due to the rapid growth of population, improvement in the standard of living, industrialization and urbanization [1]. Hence utilization of waste glass has become a critical issue worldwide. The key sources of waste glasses are glass containers, window glasses, windscreen, medicinal bottles, liquor bottles, tube lights, bulbs, electronic equipment, etc.

Recycling, disposal and decomposing of waste glass possesses major problems for municipalities everywhere, and this problem can be greatly eliminated by re-using waste glass as a cement replacement in concrete. Moreover, there is a limit on the availability of natural aggregate and minerals used for making cement, and it is necessary to reduce energy consumption and emission of carbon dioxide resulting from construction processes, the solution of this problem is sought thought usages of waste glass as partial replacement of portland cement [2].

Recycling of waste glass may affect the respiratory system if breath in pollutants. Case-local residents at Mercedes Arumbula claimed that the neighborhood and kids have developed asthma once the plant was built in their community [3].

Glass is used in many forms in day to day life. It has a limited life span and after use it is either stock piled or sends to landfills. Glass is non-biodegradable (remains in our environment) and do not decompose easily by itself therefore do not have significant environmental and social impact could result in a serious impact after disposal [4].

Disposal of waste glass degrade communities living condition and harmful to human health because lactate and gas releases from the landfill site [5].

Deterioration of reinforced concrete structures arises due to corrosion of steel present in concrete which leads to structural failure [6]. The corrosion of reinforcing steel embedded in concrete is considered as a major worldwide problem. This problem takes place because of the effect of the chloride [7].

Chloride deposited in the concrete that tend to make the concrete more porous [8].Therefore the action of chloride in concrete containing waste glass powder (WGP) by using corrosion inhibitor needs to be investigated.

This research focuses on studying the effects of chloride attack by using corrosion inhibitor on the properties of concrete produced by replacing the cement with WGP [Conglasscrete] in various percentages.

Within the scope of this study, the main goals were to investigate the possibility

- To improve the compressive strength,
- To increase resistance to chloride attack,
- To reduce amount of chemical ion over a range of WGP and corrosion inhibitor percentages,
- To reduce the environmental and health problems related to the disposal of waste glass and the scarcity of land area needed for disposal and

The aim of this research was achieved through the following objectives:

- To design concrete mix containing WGP in different percentage for M2O grade of concrete mix.

- Study the influence of WGP on hardened properties of concrete (with and without subjecting to chloride attack) mixes such as: compressive strength and chloride content .
- To decide suitability of dosage of corrosion inhibitor to prevent effect of chloride.

II. Research Significance

Waste glass contains about 72.5%, SiO_2 (Silica). When it is ground to fineness of around 600 µm (0.023 in.), SiO_2 reacts with alkalis in cement (pozzolanic reaction) to form cementitious product [9].Such product help contribute to the strength development and durability.

When concrete contains WGP , gives a higher percentage of Di-Calcium Silicate (C_2S) , Low Tri-Calcium Aluminate (C_3A), Tetra-Calcium Aluminate Ferrite (C_4AF) and C_3S/C_2S content [10]which result in producing less heat of hydration and offers greater resistance to the chemical attack .

Specific gravity of WGP is lower than the specific gravity of cement [11] thus it helps reduces the unit weight.

WGP being an inexpensive material, not only saves money by replacing cement,but also reduces the amount of disposable wastes [12].

The use of inhibitors in concrete is an alternative option for preventing the concrete deterioration in the presence of chloride ion [13].

The use of WGP as partial replacement for cement in concrete is a viable strategy for reducing the use of portland cement and thus reducing the environmental impact by saving more landfills because filled lands may unfit for agricultural activities and for any structure to be built on it and reducing energy impact of concrete production because production of cement is an energy-intensive and highly polluting process [14].

Therefore an experimental investigation in developing concrete containing WGP by using corrosion inhibitor is very important.

III The Methodology And Investigations

The purpose of this investigation was to evaluate the effect of partial replacement of cement by WGP on durability of concrete specimens subjected to chloride attack.

3.1 Procuring ingredients:

3.1.1 Cement

Ordinary portland cement (OPC) 43 confirming to IS [15].

3.1.2 Aggregate

The locally available sand of zone II had the specific gravity of 2.62. The specific gravity of the locally available coarse aggregate was 2.93. The coarse aggregate used were about 20 mm (0.7874 in.) and down size. Aggregates, used for experimental investigation, confirmed to the provisions of Indian standard specification [16].

3.1.3 Water

Water confirming to IS [17].

3.1.4 Admixture:

To impart workability to the mix, superplasticiser- Sulphonated Naphthalene Formaldehyde (SNF) was used to the dosage of 2% by weight of cement.

3.1.5 Supplementary Materials

3.1.5.1 Waste glass:

The waste glass materials used this study were gathered from the disposals of reconstruction, building demolishing projects, mirror cutting, polishing industry etc. The whole quantity was cleaned out of the dirt materials and impurities and then the WGP were obtained by crushing waste glass pieces in a cone crusher mill. Chemical composition of cementing materials as shown in figure 1& 2.

3.1.5.2 Corrosion inhibitor

To impart protection of concrete against chlorides, EPCO KP-200 was used to the dosage of 2% by weight of cement.

3.2 Fixing the desired mix proportion and casting of specimens

Mix design carried out to form M20 grade of concrete by using IS[18] yielded a mix proportion of 1:2.35:4.47 with a W/C ratio of 0.45.

135 numbers of cube specimens of dimensions 150 x 150 x 150 mm were cast according to the mix proportion and by using corrosion inhibitor with a WGP as a cement replacement in different proportion.

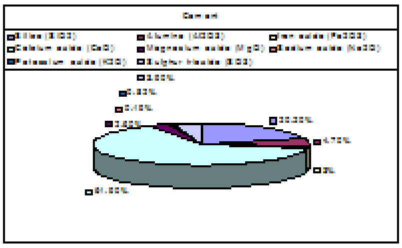

Figure 1: Chemical composition of cement

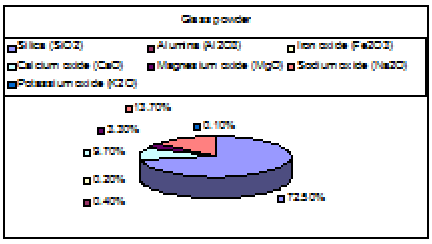

Figure 1: Chemical composition of WGP

3.3 Curing of specimens

To find out the strength of control concrete, the 27 numbers of a cube specimen of each were immersed in a 100% H_2O solution for 7 days, 28 days, and 90 days.

Generally sea water content 3.5% of salt .In order that to find out the effect of chloride attack for worst condition, 108 numbers of cube specimens were immersed in a 5% sodium chloride (NaCl) solution for 7 days, 28 days, and 90 days.

3.4 Testing of strength

To find out the strength, the specimens were tested in accordance with the provisions of the Indian standard specification [19] Fig. 3 shows experimental set up for measuring strength of specimens and for chemical analysis

3.5 Sampling

A drill machine was used for securing cylindrical core specimens. The diameter of the core was 2.5 times more than the maximum size of the aggregate and the length of the core was 95% of core diameter. Samples more than 25 mm in maximum dimension was reduced in size by use of jaw crusher. Particles were too crushed to less than 25 mm in maximum dimensions using a rotating puck grinding apparatus. Crushed samples were sieved through 600 µm IS sieve thoroughly blended the material by transferring it from one glazed paper to another at least 10 times for homogenizing the powder for obtaining a representative sample.

3.6 Storing

The powder samples were collected in clean, chemically resistant glass bottles and kept ready in a dry place for the determination of chemical content.

3.7 Chloride Content (Cl_2)

To find out Cl_2, the powder samples were tested using Argentometric method in accordance with the provisions of the Indian standard specification [20].

Figure. 3: Experimental set up for measuring strength of specimens and for chemical analysis

IV. Test Results And Discussion

Test results are presented in tabular forms and have been discussed under different categories.

Strength

Table 1 shows overall results of various strength of concrete at different age with cement replacement by WGP.

. Compressive strength of concrete with 20% cement replacement by WGP showed a higher value by 30%, 24% and 24 % than reference mix for 7 days, 28 days and 90 days respectively.

An increasing trend in strength was observed with increasing replacement of cement with WGP up to 20%. It is due to the pozzolanic reaction of WGP. WGP particle smaller than 45 µm particle size, SiO_2 reacts chemically with alkalis in cement and form cementitious products (by producing C-S-H gel) with improved binding capabilities and chemical stability that help contribute to the strength development and durability . Also unreacted WGP particles act as micro aggregates filling up voids, rendering the packing effect. This gives rise to a dense concrete microstructure. As a result, WGP particles offers resistance against expansive forces caused by chemicals and penetration of chemical ion into the concrete mass. In addition, a high SiO_2 content in WGP prolongs the setting time and gives more strength. Additionally, use of WGP prevents Ca $(OH)_2$ leaching. A pozzolana material, WGP particle reacts with $Ca(OH)_2$ (liberated in the hydration process at ordinary temperature) to form compounds processing cementitious properties.

Table 1 : Overall results of various strength of concrete for different age with cement replacement by WGP

Mix	WGP (%)	7 days			28 days			90 days		
		fc [MPa]	fcc [MPa]	fccci [MPa]	fc [MPa]	fcc [MPa]	Fccci [MPa]	fc [MPa]	fcc [MPa]	fccci [MPa]
Reference	00	21.05	20.41	23.36	27.05	24.71	29.15	27.33	22.25	25.81
WGP-5	05	22.28	21.38	25.55	28.58	26.93	30.70	28.87	23.95	27.90
WGP-10	10	23.27	22.57	25.95	29.77	27.85	32.72	30.08	25.05	28.93
WGP-15	15	24.86	23.61	27.74	31.56	29.33	33.54	31.85	26.52	31.02
WGP-20	20	27.3	25.93	29.94	33.50	31.10	36.38	33.86	28.20	32.43
WGP-25	25	23.72	22.77	26.64	30.52	27.40	31.51	30.82	25.70	30.19
WGP-30	30	17.62	16.73	19.07	24.22	23.10	26.91	24.44	20.81	23.93
WGP-35	35	16.04	15.39	17.92	22.44	21.03	24.28	22.72	18.81	22.19
WGP-40	40	12.93	12.54	14.54	19.03	18.10	20.99	19.25	16.30	18.66

Table 2 : Overall results of chemical contents in concrete for different age with cement replacement by WGP

Mix	WGP (%)	7 days		28 days		90 days	
		Cl_2 [Mg/lit.]	Cl_2^1 [Mg/lit.]	Cl_2 [Mg/lit.]	Cl_2^1 [Mg/lit.]	Cl_2 [Mg/lit.]	Cl_2^1 [Mg/lit.]
Reference	0	109.97	90.97	131.97	109.97	139.96	115.97
WGP-5	05	80.98	67.98	84.98	75.98	100.97	83.98
WGP-10	10	44.98	39.99	56.98	47.98	81.98	68.98
WGP-15	15	36.99	30.99	40.99	33.99	68.98	54.98
WGP-20	20	31.99	24.99	39.99	31.99	58.98	52.98
WGP-25	25	69.98	58.98	86.98	70.98	108.97	87.98
WGP-30	30	96.97	78.98	102.97	87.98	119.97	101.97
WGP-35	35	106.97	89.97	114.97	92.97	126.97	103.97
WGP-40	40	101.97	90.97	124.97	104.97	128.97	108.97

A decreasing trend in strength was observed with increasing replacement of cement with WGP beyond 20%, because the dilution effect takes over and the strength starts to drop. Furthermore, reduction of cement content causes fewer amounts of C-S-H gel and ever decreasing strength.

The strength improvement at early curing ages was slow due to pore filling effect of glass. Initially WGP acts like pore filler material but after 7-10 days, when the secondary pozzolanic reaction takes place, does it start to hydrate. This reaction increases the C-S-H gel formation. The strength improvement therefore at early ages is slow when only pore filling
effect exists and improves at later ages when the secondary pozzolanic reaction starts.

After 28 days, strength continues indefinitely at a constant rate because in about a month's time, 85 to 100 % of cement hydrates. The 28 days strength of concrete is assumed as full strength of concrete.

Durability

Effect of exposure conditions

Table 1 also demonstrates overall results of strength of concrete subjected to chloride at different age with cement replacement by WGP.

It was observed that chloride attack lowered the compressive strength of control concrete by 3 % at 7 days, 9 % at 28 days and 19 % at 90 days.Compressive strength of concrete with 20% cement replacement by the WGP in the chloride attack experiment showed a higher value by 23%, at 7 days, 15% at 28 days and 3% at 90 days than control concrete. Compressive strength of concrete by using 2% EPCO KP-200 subjected to chloride attack with 20% cement replacement by WGP showed a higher value by 42 % at 7 days, 34 % at 28 days and 19 % at 90 days than control concrete.

It is observed that there was a reduction in strength of concrete produced by replacing cement by WGP when such concretes were subjected to chloride attack. This is due to the chloride deposited in the pores of the concrete .

After 28 days, strength continues indefinitely at a decreasing rate when concrete subjected to chloride attack. Since more age of attack, increases amount of chemical ion in concrete mass.

At the early age of attack, the addition of 2% EPCO KP-200 not only compensated the loss of strength (due to the chloride attack) but also increased the strength tremendously as a result of filling concrete pores and blocking the porosity of concrete by the formation of complex compounds that is by geometric pore blocking effects.

Whereas after 28 days age of attack , the addition of 2% EPCO KP-200 only partly compensated the loss of strength (due to the chloride attack) because after 28 days age of attack, strength continues indefinitely at a decreasing rate.

Cl_2 contents

Table 2 shows overall results of chemical contents in concrete for different age with cement replacement by WGP.

It was observed that Cl_2 in concrete subjected to chloride attack with 20% cement replacement by WGP showed a lower value by 71% at 7 days, 70% at 28 days, and 58% at 90 days with respect to reference mix.Cl_2 in concrete by using 2% EPCO KP-200 subjected to chloride attack with 20% cement replacement by WGP showed a lower value by 77 % at 7 days, 76% at 28 days and 62% at 90 days than concrete subjected to chloride attack.

With the increasing percentage of WGP in concrete, the Cl_2 content was observed to be decreasing. It reached a minimum when the cement replacement level was 20%. The control specimen with no cement replacement had the highest Cl_2 content. It is due to WGP offering a barrier against penetration of chemicals by producing a dense C-S-H gel.

The gel fills up the capillary pore space giving impermeability and ever increasing strength. Moreover, WGP's pozzolanic reaction blocks the pores reducing the porosity of the binder and hindering the chemical ion transport. Furthermore, additional C-S-H gel is formed when SiO_2 reacts with Ca $(OH)_2$.This formation increases resistance to chemical ion. Besides, the use of WGP has been found to be useful in resisting the ingress of chemical ions into concrete because of the micro structural densification imparted by the pozzolanic reaction or secondary hydration of WGP. As well, addition of WGP refines the matrix of hydrated portland cement due to its reaction with free lime formed during cement hydration, thereby improving the penetration resistance against aggressive agents such as chloride and sulphate. Also using WGP in concrete reduces heat of hydration, refinement of pore structure, permeability and increase the resistance to chemical attack. Hence it is concluded that the concrete produced by replacing 20% of cement by a WGP was more effective in blocking the penetration of Cl_2 ions in the concrete mass.

Beyond 20%, the Cl_2 content started to increase again, because in term of oxide composition low calcium oxide content (9.7 %) in WGP does not help the binding effect, rather results in weakening the cement paste.

The Cl_2 content at early curing ages (0 to 7 days) was less, after it was more and then continues indefinitely at an increasing rate. It is because of more age of attack, decreases the resistance of concrete against penetration because the rate of gain of strength a faster to start and the rate get reduced with age as at later stages the hydration process becomes slower.

The EPCO KP-200 reduced the ingress of chloride ion because a common mechanism for inhibiting deterioration involves the formation of a thin protective coating which prevents access of chloride.

Optimum WGP content

Highest strength and lowest Cl_2 content was achieved with 20 % replacement of cement by WGP. It is due to healthier grouping of 20% of WGP and 80% of OPC for producing right amount of hydration products [greatest C-S-H gel and smallest $Ca(OH)_2$] and improving the packing density of the paste because the use of blending pozzolana materials
such as WGP reduces the amount of $Ca(OH)_2$ in concrete and to overcome its bad effect by converting it into a cementitious product is an innovation in research work. Control concrete constitutes 30% $Ca(OH)_2$ and 70% C-S-H gel of the volume of solids in a completely hydrated cement paste. The lack of strength and durability of concrete is on account of the presence of $Ca(OH)_2$.The only advantage is that a $Ca(OH)_2$, being alkaline in nature maintains pH value around 13 in the concrete which resist the corrosion of reinforcement.

Thus it is concluded that 20% was the optimum level for replacement of cement with WGP.

V. Conclusions

Based on the results of this experimental investigation, the following conclusions are drawn

- Higher strength series 17% to 30% was achieved when 20 % cement was replaced by the WGP in concrete.
- Concrete produced by replacing 20% of cement by WGP showed greater strength in the range of 3% to 23% when concrete subjected to chloride attack .
- Concrete produced by replacing 20% of cement by WGP and EPCO KP-200 admixed at 2% addition level by weight of cement showed a maximum strength in the range of 19 % to 42 %.
- Chloride attack lowered the compressive strength ranges between 3 % and 19 %.
- Concrete produced by replacing 20 % of cement by WGP showed less amount of chloride ranges from 58% to 71% .Concrete produced by replacing 20% of cement by WGP and EPCO KP-200 admixed at 2% addition level by weight of cement showed less amount of chloride ranges between 62 % and 77%
- The addition of EPCO KP-200 not only increased strength of concrete but also improved the resistance of concrete against penetration of chloride ion.

Hence it is recommended that the utilization of the 20 % WGP in concrete as cement replacement along with 2 % corrosion inhibitor is beneficial.

Notation

Cl_2 is chloride content in concrete subjected to chloride attack
Cl_2^1 is chloride content in concrete with EPCO KP-200 subjected to chloride attack
f_c is compressive strength of concrete without subjecting to attack
f_{cc} is compressive strength of concrete subjected to chloride attack
f_{ccci} is compressive strength of concrete with EPCO KP-200 subjected to chloride attack

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