ISSN 0974-5904, Volume 10, No. 04

DOI:10.21276/ijee.2017.10.0418

International Journal of Earth Sciences and Engineering

www.cafetinnova.org

August 2017, P.P. 854-862

Blending of Mineral Additions in Concrete

MOHANKUMAR NAMDEORAO BAJAD

Department of Civil Engineering, Sinhgad College of Engineering, Pune, INDIA

Email: *mnbajad@rediffmail.com*

Abstract*: Cement concrete is one of the versatile construction materials. The growing demand for tall, lean yet strong structures has led to advancement in concrete technology. Deterioration of concrete structures arises due to chloride and sulphate present in concrete as a result of aggressive environments. Numerous million tons of waste products are generated yearly universal. Hence utilization of waste products becomes a serious problem. Additions of waste products help in improving the properties of concrete either fresh state or mechanical properties or both. However, each of waste products has some critical issues either by physical or physico – chemical properties. Blending helps in improving the limitation of a particular addition with the help of other material. According there can be binary, ternary and quaternary blends. Powder of waste glass act as a pozzolanic and inert material. Research has suggested that blending of powder additions can make concrete an affordable alternative. In this paper, an attempt has been made to find out the effect of chloride and sulphate attack on the properties of concrete containing waste glass powder (GP) [conglasscrete] as pozzolana and inert. Experimental work has been carried out with cement replacement by the GP in the range of 5% to 40% in increments of 5% by weight of cement and EPCO KP-200 used in concrete as a corrosion inhibitor with 2% by weight of cement. Replacement of 20% cement by GP and the addition of 2% EPCO KP-200 by weight of cement not only increased strength and durability but also reduced the unit weight of concrete subjected to chloride or sulphate attack*

Keywords: *Chloride Attack, Deterioration, Durability, Glass Powder, Pozzolanic, Sulphate Attack and Strength*

1. Introduction

It has been estimated that several million tons of waste products 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 products has become a critical issue worldwide. Recycling, disposal, and decomposing of waste products possesses is a major problem for municipalities everywhere, and this problem can be greatly eliminated by re-using waste products 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 the energy consumption and emission of carbon dioxide resulting from construction processes, and the solution of this problem is sought thought the usages of waste products as partial replacement of Portland cement [2]. The recycling of waste products may affect the respiratory system if we breathe in pollutants. Case-local residents at Mercedes Arumbula claimed that the neighborhood and kids had developed asthma once, when the plant was built in their community. Some of the waste products are non-biodegradable (remains in our environment) and does not decompose easily by itself, therefore does not have a significant environmental and social impact, which could result in a serious impact after disposal [3].

The disposal of waste products degrades the communities living conditions and is harmful to human health because lactate and gas is released from the landfill site [4]. Additions of waste products help in improving the properties of concrete either fresh state or mechanical properties or both. However, each of waste products has some critical issues either by physical or physico – chemical properties [5]. Deterioration of reinforced concrete structures arises due to the 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]. Sulphate reacts with a product of hydration that causes expansion. Chloride is deposited in the concrete that tends to make the concrete more porous [8]. Therefore, the action of chloride and sulphates in concrete containing waste products by using a corrosion inhibitor needs to be investigated.

2. Type of mineral additions or supplementary cementitious materials or powders

Powdered materials apart from ordinary Portland cement added in concrete mixs to improve the fresh as well as hardened state properties of concrete are termed as mineral additions or supplementary cementitious materials as shown in figure 1. Cementitious materials can also be defined as all materials that contribute to the strength of concrete either by chemical or physical action [9]. The mineral additions can be classified into three main categories [10].

a) Type 1 addition: Inert or inactive (Limestone powder)

b) Type 2 addition: Pozzolanic or reactive (Fly ash, silica fume, metakaolin, blast furnace slag)
c) Type 3 addition: Industrial waste (granite fillers, marble dust, quarry dust, glass powder)

3. Role of mineral additions or supplementary cementitious materials in concrete

The basic objective of adding supplementary cementitious materials in any concrete mix is to improve its workability and strength economically. At microstructure level, mineral additions help in creating a dense, highly impermeable hydrated cement paste and a strong paste aggregate interface. The matrix densification ensures reduction in pores and improved impermeability. The additives to cement concrete can be classified as pozzolanic or inert based on their actions. Inert additions are chemically inert and do not take part in the cement hydration reactions. However, their physical properties have beneficial effects in form of improved workability and denser impermeable concrete. At microstructure level, the inert additions provide nucleation site to enhance hydration of Portland cement. Pozzolanic additions aid in gain of strength of concrete by a combination of physical and chemical processes. Calcium hydroxide, formed as a result of hydration of cement, has no cementing value. In the pozzolanic action, the siliceous compounds of the pozzolan react with calcium hydroxide to form compounds possessing cementitious properties.

The performance of the mineral additions depends on the physical and physico-chemical properties of the powder or addition, which in turn affect the fresh state properties of the concrete. These properties include particle shape, surface texture, and rate of superplasticizer adsorption, surface energy, finest fraction content, Blaine fineness and particle size distribution [11].

4. Research significance

By using waste products, changing the chemical composition of cement by varying the percentage of the four basic compounds. It is possible to obtain segregation and bleeding resistance. Blending will help in improving the limitation of a particular addition with the help of other material. Accordingly, there can be binary, ternary and quaternary blends [12]. A binary blend includes cement plus any one of the powder addition (inert or pozzolanic or waste). Ternary blend includes cement along with any two powder additions (cement + inert + pozzolanic or cement + pozzolanic + waste or cement + inert + waste). A quaternary blend is one with cement with all types of powder addition (cement + inert + pozzolanic + waste). A binary blend of cement and silica fume has high water demand and superplasticizer dosage requirement, with excessive shrinkage. This particular limitation can be overcome with ternary or quaternary blending [13]. The ternary and quaternary blends of mineral additions not only improve fresh state properties (like segregation resistance of the mix, reduce shrinkage), but also improve its mechanical properties and durability. Powder of glass act as a pozzolanic and inert material Waste glass contains about 72.5% SiO_2, when it is ground to a fineness of around 600 µm, SiO_2 reacts with alkalis in cement (pozzolanic reaction) to form a cementitious product [14] .Such a product helps contribute to the strength development, and durability. The specific gravity of waste glass is lower than the specific gravity of cement [15]. Thus, it helps reduce the unit weight. Waste glass being an inexpensive material, not only saves money by replacing cement, but also reduces the amount of disposable wastes [16].The use of inhibitors in concrete is an alternative option for preventing the concrete deterioration in the presence of a chloride ion [17].

Bagasse Ash *Fly Ash* *Limestone Powder* *Rice Husk Ash*

Silica Fume *Waste Glass Powder* *Quarry Dust Powder* *Blast Furnace Slag*

***Figure 1**: Mineral Additions*

The use of GP as a 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 be unfit for agricultural activities and for any structure to be built on it and reducing the energy impact of concrete production because the production of cement is an energy-intensive and a highly polluting process [18]. Therefore, an experimental investigation in developing concrete containing GP by using a corrosion inhibitor is very important. This research focuses on studying the effects of a chloride and sulphate attack by using a corrosion inhibitor on the properties of concrete produced by replacing the cement with GP [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 a chemical attack,
- To reduce the amount of chemical ion over a range of glass and corrosion inhibitor percentages,
- To reduce the unit weight of concrete,
- To reduce the environmental and health problems related to the disposal of waste glass and the scarcity of land area needed for disposal and
- To achieve economy by saving on cement consumption.

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

- To design a concrete mix containing GP in a different percentage for the M20 grade of concrete mix.
- To investigate the effect of replacing GP in the range of 5% to 40% (incrementing by 5%) by weight of cement on the properties of fresh concrete mixes such as workability by slump measures.
- To examine the influence of GP in the range of 5% to 40% (incrementing by 5%) on hardened properties of concrete (with, and without subjecting to a chloride or sulphate attack) mixes such as: density, compressive strength, flexural strength, and durability .
- To study the effect of a corrosion inhibitor in the range of 1% to 3% (incrementing by 1%) by weight of cement to prevent conglasscrete from a chloride attack.
- To compare cost analysis of normal concrete and concrete containing optimum GP.

5. Scope of studies

For several reasons, the effect of seawater on concrete deserves special attention. First, coastal and offshore sea structures are exposed to the simultaneous action of a number of physical and chemical deterioration processes, which provide an excellent opportunity to understand the complexity of concrete durability problems in practice [19](as shown in Figure 2 and 3). Second, oceans make up 80 percent of the surface of the earth; therefore, a large number of structures are exposed to seawater either directly or indirectly (e.g., winds can carry seawater spray up to a few miles inland from the coast). Concrete piers, decks, breakwater, and retaining walls are widely used in the construction of harbors and docks. To relieve land from the pressures of urban congestion and pollution, floating offshore platforms made of concrete are being considered for location of new airports, power plants, and waste disposal facilities. The use of concrete offshore drilling platforms and oil storage tanks is already on the increase. Most seawater is fairly uniform in chemical composition, which is characterized by the presence of about 3.5 percent soluble salts by weight. The ionic concentrations of Na+ and Cl− are the highest, typically 11,000 and 20,000 mg/liter, respectively. However, from the standpoint of aggressive action to cement hydration products, sufficient amounts of Mg_2+ and SO_2− 4 are present, typically 1400 and 2700 mg/liter, respectively. The pH of seawater varies between 7.5 and 8.4, and the average value in equilibrium with the atmospheric CO_2 being 8.2. Under exceptional conditions (that is., in sheltered bays and estuaries) pH values lower than 7.5 may be encountered; these are usually due to a higher concentration of dissolved CO_2, which would make the seawater more aggressive to Portland cement concrete. Besides physical and chemical reactions, the concrete in the marine structure in the tidal zone (located between the highest high tide and low tide) also faces mechanical forces and therefore deterioration is generally observed to be more severe. Moreover, the structure in the tidal zone faces alternate wetting and drying cycles, which accelerates the chemical action of salts and water on reinforced steel and the concrete around it. The structures in tidal and atmospheric zones are more vulnerable to the aggressive action of the sea than those, which are continuously fully submerged in water (Omer ozkand and Isa Yuksel, 2008) considering the deterioration of concrete in a marine environment, the conglasscrete with a corrosion inhibitor is recommended.

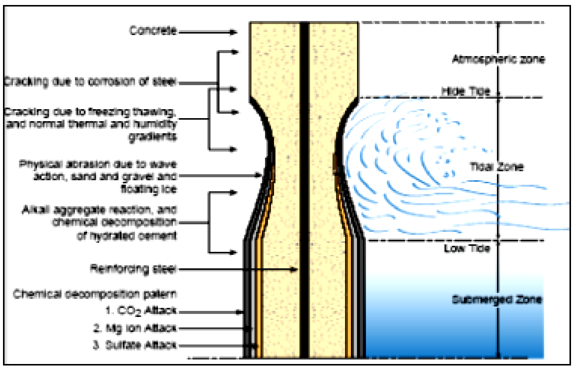

Figure 2: *Diagrammatic representation of deterioration of concrete exposed to sea water*

Figure 3: *Marine structures under chemical deterioration*

6. The methodology and investigations

6.1. Procuring ingredients

6.1.1. Cement

OPC 43 confirming to IS 8112 [20].

6.1.2. 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 and down size. An aggregate, used for experimental investigation, confirmed to the provisions of Indian standard specification IS 383[21].

6.1.3. Water

Water confirming to IS 456[22] and the pH value of water was 6.5.

6.1.4. Admixture

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

6.1.5. Supplementary materials

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 GP were obtained by crushing waste glass pieces in a cone crusher mill. The 600 µm passing fraction was used for the experiment. Silica (SiO_2), calcium oxide (CaO), fineness % passing (sieve size), unit weight (Kg/m^3), specific gravity were found to be 72.5%, 9.7%, 80(45 µm), 2579, 2.58 respectively.

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

6.2. Fixing the desired mix proportion and casting of specimens

Mix design carried out to form M 20 grade of concrete by using IS 10262 [23] yielded a mix proportion of 1:2.35:4.47 with a W/C ratio of 0.45. 162 numbers of cube specimens of dimensions 150 x 150 x 150 mm and 27 numbers of beam specimens of dimensions 150 x150x 700 mm were cast according to the mix proportion and by using corrosion inhibitor with a GP as a cement replacement in different proportion.

6.3. Curing of specimens

To find out the strength of control concrete, the 27 numbers of a cube and beam specimens 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% NaCl solution for 7 days, 28 days, and 90 days. To find out the effect of sulphate attack for worst condition, 27 numbers of cube specimens were immersed in a 5% $MgSO_4$ solution for 7 days, 28 days, and 90 days.

6.4. Testing of strength

To find out the strength, the specimens were tested in accordance with the provisions of the Indian standard specification IS 516[24]**.** Fig. 4 shows experimental set up for measuring strength of specimens and for chemical analysis

6.5. 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 .

6.6 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.

6.7. Chloride content (Cl_2)

To find out Cl_2, the powder samples were tested using Argento metric method in accordance with the provisions of the Indian standard specification IS14959[25].

6.8. Sulphate content (SO_4)

To find out SO_4, the powder samples were tested using Gravimetric method in accordance with the provisions of the British standard specification BS 1881[26].

7. Test results and discussions

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

7.1. Effects of GP on rheology property

Slump values were obtained as 100, 94, 91, 88, 82, 76, 73, 72 and 66mm for nine different mixes such as reference, GP-5, GP-10, GP-15, GP-20, GP-25, GP-30 and GP-40 respectively. It showed 34 % workability of concrete decreased as the 40% glass content increased. A decreasing trend in workability of concrete was observed with increasing replacement of cement with GP. It is due to reduction of fineness modulus of cementations material. In addition**,** in control concrete, at given water content, a considerable lowering of the cement content tends to produce harsh mixtures. Moreover for high aggregate cement ratio, less quantity of cement paste will be available for providing lubricating effect per unit surface area of the aggregate, and hence workability reduces. It is also observed that GP in concrete affects the performance of superplasticizer-SNF due to compatibility problems with a GP and cement.

7.2. Effects of GP on hardened properties

7.2.1. Density

Unit weight of concrete at 28 days were obtained as 2408, 2396, 2379, 2369, 2354, 2335, 2315, 2303 and 2283 kg/m^3 for nine different mixes such as reference,GP-5, GP-10, GP-15, GP-20, GP-25, GP-30 and GP-40 respectively. It showed 5.19 % unit weight of concrete decreased as the 40% glass content increased. A decreasing trend in density of concrete was observed with increasing replacement of cement with GP. It is due to reduction of specific gravity of cementations material. It was attributed to the fact that the specific gravity of waste glass (2.58) is lower than the specific gravity of cement (3.15).

7.2.2. Strength

Table 1 shows overall results of strength of concrete at different age with cement replacement by GP. Flexural strength of concrete with 20% cement replacement by GP showed a higher value by 22%, 20%, and 17% than reference mix for 7 days, 28 days and 90 days respectively. Compressive strength of concrete with 20% cement replacement by GP 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 GP up to 20%. It is due to the pozzolanic reaction of GP. Waste glass smaller than 45 µm particle size, SiO_2 reacts chemically with alkalis in cement and form cementations 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 glass particles act as micro aggregates filling up voids, rendering the packing effect. This gives rise to a dense concrete microstructure. As a result, waste glass 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 GP prolongs the setting time and gives more strength. Additionally, use of GP prevents $Ca(OH)_2$ leaching. A pozzolana material, waste glass reacts with $Ca(OH)_2$ (liberated in the hydration process at ordinary temperature) to form compounds processing cementitious properties. A decreasing trend in strength was observed with increasing replacement of cement with GP 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 waste GP 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.

Figure 4: *Experimental set up for measuring strength of specimens and for chemical analysis*

***Table 1:** Overall results of strength of concrete for different age with cement replacement by glass powder (GP)*

Mix	GP (%)	7 days fcr [MPa]	7 days fc [MPa]	7 days fcc [MPa]	7 days fccci, [MPa]	7 days fcs [MPa]	28 days fcr [MPa]	28 days fc [MPa]	28 days fcc [MPa]	28 days fccci [MPa]	28 days fcs [MPa]	90 days fcr [MPa]	90 days fc [MPa]	90 days fcc [MPa]	90 days fccci [MPa]	90 days fcs [MPa]
Reference	00	2.40	21.05	20.41	23.36	20.62	3.50	27.05	24.71	29.15	25.45	3.60	27.33	22.25	25.81	22.80
GP-5	05	2.45	22.28	21.38	25.55	21.83	3.62	28.58	26.93	30.70	27.15	3.64	28.87	23.95	27.90	24.22
GP-10	10	2.78	23.27	22.57	25.95	22.57	3.78	29.77	27.85	32.72	28.10	3.82	30.08	25.05	28.93	25.65
GP-15	15	2.85	24.86	23.61	27.74	24.36	3.95	31.56	29.33	33.54	30.00	4.00	31.85	26.52	31.02	27.18
GP-20	20	3.05	27.3	25.93	29.94	26.75	4.17	33.50	31.10	36.38	31.85	4.21	33.86	28.20	32.43	28.86
GP-25	25	2.90	23.72	22.77	26.64	23.00	4.00	30.52	27.40	31.51	29.01	4.05	30.82	25.70	30.19	26.30
GP-30	30	2.82	17.62	16.73	19.07	17.09	3.90	24.22	23.10	26.91	23.20	3.92	24.44	20.81	23.93	21.60
GP-35	35	2.42	16.04	15.39	17.92	15.71	3.57	22.44	21.03	24.28	21.55	3.60	22.72	18.81	22.19	19.70
GP-40	40	2.32	12.93	12.54	14.54	12.67	3.41	19.03	18.10	20.99	18.25	3.45	19.25	16.30	18.66	16.88

7.2.3. Durability

Effect of exposure conditions

Table 1 also demonstrates overall results of strength of concrete subjected to chloride and sulphate attack at different age with cement replacement by GP. It was observed that chloride attack lowered the compressive strength of control concrete by 3.04 % at 7 days, 8.65 % at 28 days and 18.58 % at 90 days. Compressive strength of concrete with 20% cement replacement by the GP in the chloride attack experiment showed a higher value by 23.18%, at 7 days, 14.97% at 28 days and 3.18 % 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 GP showed a higher value by 42.23 % at 7 days, 34.49 % at 28 days and 18.66 % at 90 days than control concrete. It was examined that sulphate attack lowered the compressive strength of control concrete by 2.04 % at 7 days, 5.91 % at 28 days and 16.57% at 90 days .Compressive strength of concrete with 20% cement replacement by the GP in the sulphate attack experiment showed a higher value by 27.07%, at 7 days, 17.74 % at 28 days and 5.98 % at 90 days than control concrete. It is observed that there was a reduction in strength of concrete produced by replacing cement by GP when such concretes were subjected to either chloride attack or sulphate attack. This is due to the chloride deposited in the pores of the concrete and reaction of sulphate with the product of hydration. After 28 days, strength continues indefinitely at a decreasing rate when concrete subjected to either chloride or sulphate attack. Since more age of attack, increases amount of chemical ion in concrete mass.

Cl_2 and SO_4 contents

Table 2 shows overall results of chemical contents in concrete for different age with cement replacement by glass powder (GP). It was observed that Cl_2 in concrete subjected to chloride attack with 20% cement replacement by GP showed a lower value by 70.91% at 7 days, 69.69% at 28 days, and 57.85% 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 GP showed a lower value by 77.27 % at 7 days, 75.75% at 28 days and 62.14% at 90 days than concrete subjected to chloride attack. SO_4 in concrete subjected to sulphate attack with 20 % cement replacement by GP showed a lower value by 72.72% at 7 days, 77.77% at 28 days, and 66.66% 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 GP showed a lower value by 77.27 % at 7 days, 75.75% at 28 days and 62.14% at 90 days than concrete subjected to chloride attack. SO_4 in concrete subjected to sulphate attack with 20 % cement replacement by GP showed a lower value by 72.72% at 7 days, 77.77% at 28 days, and 66.66% at 90 days with respect to reference mix.

***Table 2:** Overall results of chemical contents in concrete for different age with cement replacement by glass powder (GP)*

Mix	GP (%)	7 days Cl_2 [Mg/lit.]	7 days Cl_2^1 [Mg/lit.]	7 days SO_4 [Mg/lit.]	28 days Cl_2 [Mg/lit.]	28 days Cl_2^1 [Mg/lit.]	28 days SO_4 [Mg/lit.]	90 days Cl_2 [Mg/lit.]	90 days Cl_2^1 [Mg/lit.]	90 days SO_4 [Mg/lit.]
Reference	0	109.97	90.97	226.35	131.97	109.97	370.40	139.96	115.97	432.14
GP-5	05	80.98	67.98	185.20	84.98	75.98	205.781	100.97	83.98	288.09
GP-10	10	44.98	39.99	133.75	56.98	47.98	164.62	81.98	68.98	195.49
GP-15	15	36.99	30.99	92.60	40.99	33.99	102.89	68.98	54.98	154.33
GP-20	20	31.99	24.99	61.73	39.99	31.99	82.31	58.98	52.98	144.04
GP-25	25	69.98	58.98	154.33	86.98	70.98	246.93	108.97	87.98	308.67
GP-30	30	96.97	78.98	174.91	102.97	87.98	308.67	119.97	101.97	329.24
GP-35	35	106.97	89.97	185.20	114.97	92.97	339.53	126.97	103.97	390.98
GP-40	40	101.97	90.97	216.07	124.97	104.97	360.11	128.97	108.97	411.562

With the increasing percentage of glass in concrete, the Cl_2 or SO_4 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 or SO_4 content. It is due to waste GP 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, the glass powder'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 GP 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 GP. As well, addition of waste GP 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 waste GP 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 GP was more effective in blocking the penetration of Cl_2 or SO_4 ions in the concrete mass.

Beyond 20%, the Cl_2 or SO_4 content started to increase again, because in term of oxide composition low calcium oxide content (9.7 %) in GP does not help the binding effect, rather results in weakening the cement paste. The Cl_2 or SO_4 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.

7.3. Optimum GP content

Highest strength and lowest Cl_2 or SO_4 content was achieved with 20 % replacement of cement by GP. It is due to healthier grouping of 20% of GP 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 GP 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 GP.

8. Conclusions

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

- The workability reduced ranges from 3% to 6% as the every 5% GP addition.
- Blending of powder addition has a significant positive impact on hardened state properties (strength development, durability and engineering properties).
- Superplasticizer- SNF was not competent to compensate the loss of workability due to addition of GP.
- Use of compatible super plasticizer was found to be necessary to maintain workability with restricted (W/C) ratio.

Higher strength series 17% to 30% was achieved when 20 % cement was replaced by the GP in concrete.

- Concrete produced by replacing 20% of cement by GP showed greater strength in the range of 13.18% to 23.18% when concrete subjected to chloride attack and 12.04 % to 16.57%, when concrete subjected to sulphate attack.
- Concrete produced by replacing 20% of cement by GP and EPCO KP-200 admixed at 2% addition level by weight of cement showed a maximum strength in the range of 18.66 % to 42.33 %.
- Chloride attack lowered the compressive strength ranges between 3.04 % and 18.58 %.
- Sulphate attack lowered the compressive strength ranges between 12.04 % and 16.57 %.
- Concrete produced by replacing 20 % of cement by GP showed less amount of chloride ranges from 57.85% to 70.91% and sulphate ranges from 66.66% to 72.72%
- Concrete produced by replacing 20% of cement by GP and EPCO KP-200 admixed at 2% addition level by weight of cement showed less amount of chloride ranges between 62.14 % and 77.27%
- The addition of EPCO KP-200 not only increased strength of concrete but also improved the resistance of concrete against penetration of chloride ion.
- The density decreased up to 2% as the 20% GP increased
- Slightly reduced the cost of concrete produced by replacing cement by GP Hence it is recommended that the utilization of the 20 % waste GP in concrete as cement replacement along with 2 % corrosion inhibitor is beneficial.

Notation

Cl_2^-chloride content in concrete subjected to chloride attack Cl_2^{1-} chloride content in concrete with 2% EPC KP200 subjected to chloride attack

f_c -compressive strength of concrete without subjecting to attack
f_{cc} -compressive strength of concrete subjected to chloride attack
f_{ccci} - compressive strength of concrete with 2% EPCO KP-200 subjected to chloride attack
f_{cr} - flexural strength of concrete
f_{cs} - compressive strength of concrete subjected to sulphate attack
GP - glass powder
SO_4 - sulphate content

Acknowledgements

The author would like to thank the authorities of S. C. O. E. Pune for their kind support. The valuable suggestions, efforts and timely help extended by one and all in concrete discipline are gratefully acknowledged. Sincere gratitude is extended to all the authors whose publications provided directional information from time to time. The cooperation and help received from the scientific and technical staff of advanced materials laboratory in the preparation of this paper are gratefully acknowledged.

References

[1] Bashar Taha and Ghassan Nounu, "Properties of concrete contains mixed color waste recycled glass as sand and cement replacement", Construction and Building Materials, Vol.22, pp.731-720, 2008.
[2] Ilker Bekir Topcu and Mehmet Canbaz, "Properties of concrete containing waste glass", Cement and Concrete Research., Vol.34, pp.267-274, 2004.
[3] Baxer, S., Jin W and Meyer C., "Glasscrete-concrete with glass aggregate", ACI Materials Journal., Vol.97, pp.208-213, 2000.
[4] Suryavanshi, C.S., "Use of industrial and domestic waste in concrete", Civil Engineering and Construction Review, Vol.26, pp.26-31, 1999.
[5] Güneyisi E., Gesoðlu M. and Özbay E., "Strength and drying shrinkage properties of self-compacting concretes incorporating multi-system blended mineral admixtures", Construction and Building Materials.24: pp.1878–1887,2010.
[6] Ahmad Shayan, "Value added utilization of waste glass in concrete", IABSE symposium Melbourne, pp.1-11, 2002.
[7] Nepomuceno M., Oliveira L. and Lopes S.M.R.,"Methodology for mix design of the mortar phase of self-compacting concrete using different mineral additions in binary blends of powders", Construction and Building Materials., Vol.26,pp. 317–326, 2012.
[8] Jitendra A.Jain and Narayanan Neithalath , "Chloride transport in fly ash and GP modified concerts influence of test methods on microstructure", Cement and Concrete Composites, Vol.32,pp.148-156,2010.
[9] Neville A. M. and Brooks J. J., "Concrete Technology", Prentice Hall (Pearson), Essex: pp.408-410, 2008.
[10] Uysal M., Yilmaz K. and Ipek M., "The effect of mineral admixtures on mechanical properties, chloride ion permeability and impermeability of self-compacting concrete", Construction and Building Materials., Vol.27, pp.263–270, 2012.
[11] Felekoðlu B., Tosun K., Baradan B., Altun A. and Uyulgan B., "The effect of fly ash and limestone fillers on the viscosity and compressive strength of self-compacting repair mortars", Cement and Concrete Research. , Vol.36, pp.1719–1726, 2006.
[12] Nepomuceno M., Oliveira L. and Lopes S.M.R.,"Methodology for mix design of the mortar phase of self-compacting concrete using different mineral additions in binary blends of powders", Construction and Building Materials., Vol.26,pp. 317–326, 2012
[13] Omer Ozkand and Isa Yuksel, "Studies on mortars containing waste bottle glass and industrial by-products", Construction and Building Materials, Vol.22, pp.1288-1298, 2008.
[14] Caijun Shi, Yanzhhhong Wu, Chris Riefler and Hugh Wang, "Characteristics and pozzolana reactivity of glass powders (GP)", Cement and Concrete Research., Vol.35,pp.987-993, 2005.
[15] Yixin Shao, Thibaut Lefort, Shylesh Moras and Damian Rodriguez , "Studies on concrete containing ground waste glass", Cement and Concrete Research , Vol.30, pp.91-100,2000
[16] Federico, L.M. and Chidiac S.E., "Waste glass as supplementary cementitious material in concrete-Critical review of treatment methods", Cement and Concrete Composites, Vol.31, pp.606-610, 2009.
[17] Devi, M.and Kannan K., "Analysis of strength and corrosion resistance behavior of inhibitors in concrete containing quarry dust as fine aggregate",ARPN Journal of Engineering and Applied sciences, Vol.6,pp.124-134,2011.
[18] Her-Yung Wang and Wen-Liang Huang, "A study on the properties of fresh self-consolidating glass concrete (SCGC)", Construction and Building Materials, Vol.24, pp.619-624, 2010.
[19] Gambhir, M.L, "Concrete Technology", Tata McGraw-Hill Publishing Company Limited, New Delhi, 2006.
[20] IS 8112, "Specification for 43 grade ordinary Portland cement", Bureau of Indian Standards, New Delhi, 1989.
[21] IS 383, "Specification for coarse and fine aggregates from natural sources for concrete", Bureau of Indian Standards, New Delhi, 1970.
[22] IS 456, "Indian standard code of practice for plain and Reinforced Concrete", Bureau of Indian Standards, New Delhi, 2000.

[23] IS 10262(2009). “Recommended guidelines of concrete mix design”, Bureau of Indian Standards, New Delhi.
[24] IS 516, “Methods of tests for strength of concrete” Bureau of Indian Standards, New Delhi, 1959
[25] IS 14959: Part 2, “Determination of water soluble and acid soluble chlorides in concretes in concrete and mortar”, Bureau of Indian Standards, New Delhi, 2001.
[26] BS 1881: Part 124, “Methods for analysis of concrete (Cement content, sulphate content (SO_4) and alkali contents)”, Bureau of British Standards, 1988