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Development of sustainable High Performance green concrete utilizing fly ash and waste glass powder

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Abstract - *Nowadays recycling of waste industrial products are gaining popularity for making environment friendly concrete material. Thus the concrete can be called as Green Concrete. The concrete whose production is sustainable and has less carbon emission. Advancements in sustainable construction leads to green concrete approach. Nowadays, not only green concrete focusses on environment friendly approach but also sustainability and durability are prime factors to be studied. High performance concrete focusses on utilization of ordinary portend cement with other SCMs such as condensed silica, fly ash, GGBFS, alcofine, fibres in addition with requisite HRWRs. This mentioned present study highlights a critical review on development of High performance green concrete incorporating fly ash and condensed silica.*

Key Words: Green concrete, waste glass powder, fly ash, condensed silica,

1. INTRODUCTION

1.1 General

Development in concrete industry involves emergence of green concrete which involves sustainability and eco-friendly materials. Any construction activities require natural materials but use of waste materials in construction maybe a key point. It should also have high performance and life cycle sustainability. Waste glass bottles are used as replacement of fine aggregates and fly ash used as replacement of cement which are industrial waste products. These products are used to reduce CO_2 gas from environment. Normally river sand is used as fine aggregate which is passing through 4.75 mm sieve. Here, used glass bottles are collected and crushed glass passing through 4.75 mm sieve is used. Cementitious materials has been replaced here in different percentages and workability, durability & strength has been measured.

1.2 Material selection

- Easily available
- Reusable/ recyclable
- RE- manufactured
- Energy efficiency
- Water conservation

1.3 Experimental Methodology: Materials

- **Cement**

Use of cementitious materials as a partial replacement of cement in concrete:

(a) Class F fly ash
(b) waste glass powder (powdery amorphous)
(c) condensed silica

- **Aggregates**

Use of recycled materials as partial replacement of aggregate such as :

  - Recycled glass cullet
  - Plastic waste
  - Recycled concrete waste

- **Particle Size**

  - Fly ash – 10 - 100µm
  - Silica fume - 0.1 – 0.3µm
  - Recycled glass powder - 45 - 75µm
  - Recycled glass cullet - 100 - 500µm
  - Plastic waste - < 500µm

Table 1: Chemical and physical characteristics of Portland cement (PC), Fly ash (FA), Recycled glass powder (RGP) and Silica fume (SF)

Chemical composition, %	PC	FA	RGP	SF
SiO_2	19.5	57	74.8	85
Al_2O_3	5.1	21	2.0	1.12
Fe_2O_3	2.92	4.2	0.4	1.46
MgO	2.5	1.8	1.3	0.2 - 0.8
CaO	61.8	9.8	13.6	0.2 - 0.8
Na_2O	0.30	2.2	7.2	0.5-1.2
K_2O	1.11	1.5	0.6	-
Loss on ignition	2.5	1.3	0.5	<6.0
$SiO_2 + Al_2O_3 + Fe_2O_3$	27.52	82.2	76.5	87.58
Physical properties				
Specific gravity	3.1	2.6	2.5	2.2
Blaine fineness (m^2 /kg)	408	325	382	500 - 600

1.4 Advantages of green concrete

1. Green concrete is environment-friendly concrete.
2. Green concrete helps to reduce co_2 from the environment.
3. Compressive, split tensile strength, workability and durability is better to conventional concrete by using some industrial waste materials.
4. Reduces the consumption of cement, water overall.
5. Green concrete is economical compared to conventional concrete to use the waste materials.

2. HISTORY OF GREEN CONCRETE

The concrete which is made from concrete wastes and environment-friendly that are called as "Green concrete". Concrete which is produces less carbon dioxide than normal concrete is green concrete. The other name for green concrete is eco-friendly concrete.

"Green concrete" is a revolutionary topic in the history of concrete industry. This was first invented in Denmark in the year 1998 by Dr. WG.

3. LITERATURE REVIEW

Siad et. al.[1] used 2 cementitious materials 1st was high volume fly ash (HVFA) and 2nd was recycled glass powder (RGP). First cement was replaced by using HVFA and then HVFA was replaced by using RGP. The percentage they replaced 15%-60%. After using RGP the result they found compressive and flexural strengths improved and also improved the low tensile strength and Self healing properties also improved. As a result of using these materials multiple micro-cracking behavior with crack widths were less than 100 µm. Compressive strength of the concrete was measured at 120 days, by using these materials the rate of gain of strength and physical properties were improved.

Lu et. al.[2] noticed that large amount of waste glass generation (329 tonnes/daily in 2016) had a serious concern in Hong Kong due to lack of glass recycling industry. The Hong Kong Government took actions to expand the recycle waste glass. Jian-Xin Lu et al aim to designd an eco-friendly concrete paving block by using waste glass. Glass powder (GP) were used as partial binder and glass cullet (GC) as fine aggregates. Cathode ray tube glass was used as fine aggregate in the dry mixed concrete and prepared an eco-friendly concrete block with 50% GC and 50% recycled aggregates. The result showed that after using GC reduced water absorption inside the concrete blocks. They measured compressive strength of the concrete at 28 days. By using these materials the strength they got was constant despite increasing amount of glass cullet (GC) was used in the paving blocks at 28 days.

Aliabdo et. al.[3] aim was to use waste glass powder as replacement of cement. The glass powder contents was considered up to 25% by weight of cement. As the result it was found that the glass powder had pozzolanic characteristic and the use of glass powder had insignificant effect on setting time and cement expansion. Use of 10% glass powder as cement replacement enhanced the mortar compressive strength by about 9.0%. Finally 15% glass powder were used as cement addition increased concrete compressive strange by 16% in average and as a replacement for cement, it achieved better workability. This study did not address the alkali silica reaction, as the major criterion for glass powder in concrete. They did experiment in 3 phases. The first phase included the evaluation of the pozzolanic effect of glass powder using energy activity index while the second phase presented the use of glass powder in cement production to produce glass powder blended cement. This phase includes tests on powders, pastes and mortars. At this stage, glass powder was used as a substitute for cement. The mix proportions of this phase were considered as Egyptian standard specification of cements ESS 2421-1993 for cement paste and cement mortar. The Vicat test was used for standard cement paste and where the standard water content was used for cement mortar, cement sand ratio of 1:3 and a water cement ratio of 0.40 were used in the same specification. The effect of using glass powder in concrete production was presented in the third step. They measured compressive strenght of the concrete at 56 day.

Du et. al.[4] replaced cement by using waste glass powder (crushed waste bear bottle, soda lime glass etc) it also used as fine aggregates. Percentage of replacement was upto 60%. The microstructure of cement paste with various contents of

glass powder (GP) was investigated. The water to cement (w/c) ratio for the paste was taken 0.485 by weight.They tested it in this procedure 1st The rheological properties of cement paste containing GP were determined by a coaxial-cylinder viscometer named RotoVisco. After mixing the cement paste in the Hobart mixer, a small amount of sample was taken out and placed in the outer cylinder of the viscometer and immediately inserted into the inner cylinder. The sensor was rotated at different shear rates while recording the torque. Isothermal calorimetry was performed on triplicate paste samples by using an eight-channel microcalorimeter (TAM AIR). The result they got after 28 days cement replacement below 30% did not decrease compressive strength of concrete due to pozzolanic reaction between glass powder and cement hydration products. For this reason they measured compressive strength of the concrete at 7 days to 91 days.

Jiang et. al.[5] used glass powder and recycled glass cullet. Glass powder was used as replacement of cement and glass cullet as aggregate (fine/ coarse). They noticed that after using glass cullet as fine/ coarse aggregate in cement mortar concrete the workability, strength and destructive alkali-silica reaction (ASR) of concrete were expanded. Glass powder was used as a cementitious material. They found that Engineered cementitious composites (ECC) was a type of ultra-ductile fiber-reinforced cementitious composite, with high tensile ductility and ability to resist crack widths (< 100 μm). They replaced 20% cement measured compressive strength of the concrete at 7 days. Showed that compressive strength increased.

Shekhawat et. al.[6] waste glass powder was used as replacement of cement. They investigated that the workability was reduced due to the replacement and tested at 7, 14, 28 days of curing of specimens containing waste glass powder as partial replacement of cement. Cement was replaced at different percentages and as a result they got increased workability, strength parameters such as compressive strength, flexural strength and split tensile strength and also increased durability as measured by water absorption tests and absorption tests.

Xiao et. al.[7] utilized a growing number of industrial wastes and recycled materials. They investigated the use of waste glass powder-based geopolymer cement as a stabilizing agent in recycled waste glass aggregate (GA) bases. Two recycled materials, waste glass powder (GP) and class F fly ash (FF), here used as the raw materials. Here virgin aggregate replaced by the glass aggregate at 0% -50%. Here the drying shrinkage strains were recorded at 7days, 14 days, 21 days, 28 days and the results they found that GA reduced the drying shrinkage of the base samples after compromising the mechanical properties. During sample preparation, mechanical behavior was improved due to higher curing temperature and relative humidity, and the surface of GA could dissolve in alkaline solution and involve in the geopolymerization at 40°C.

Kou et. al.[8] reduced the cost of producing ultrahigh performance fibre reinforced concrete (UHPFRC). Reject fly ash (r-FA) and recycled glass powder was used in their research. At first cement was replaced by reject fly ash after that sand was replaced by recycled glass powder. These two mentioned cementitious products are used to prepare UHPFRC. In addition curing of UFPFRC's specimen was investigated at 25'c and 90'c for determination differences in mechanical properties. For that the result showed , using r-FA and GP reduced the ability of flow of fresh UHPFRC. The mechanical properties of the UHPFRC were increased by the used of GP. The test results show a significant improvement in the mechanical properties. And by the inclusion of r-FA as partial replacement of fine aggregate and can be effectively used in UHPFRC. The flow ability of the fresh concrete had a close relationship with the fineness of the cementitious materials and the aggregate was observed in the time of mixing and testing. Segregation of bleeding was not observed in the of mixing. However it shown that the specimens cured at 25'c gave lower compressive strength , flexural strength and fracture energy than it was cured at 90'c.

Islam et. al.[9] Used of milled waste glass in concrete as partial replacement of cement might be an important step towards to development of sustainable (environmentally friendly, energy-efficient and economical) infrastructure systems. When waste glass was milled down to the micro size of particles, this is expected that it goes to undergo pozzolanic reactions with cement hydrates and formed secondary calcium silicate hydrate (C-S-H). In the mentioned research chemical properties of clear and coloured glass were evaluated. Using X-ray fluorescence (XRF) chemical analysis of glass and cement samples was determined, and in result author found minor differences in composition between clear and colour glasses. By adding 0–25% ground glass flow and compressive strength tests on mortar and concrete were carried out in which the ratio of water to binder (cement +glass) kept the same for all replacement levels. Compared to control samples recycled glass mortar and concrete gave better strength. A 20% cement replacement with waste glass was found convincing considering with the cost and environment. At 7, 14, 28, 56, 90, 180 and 365 days Concrete samples were tested compressive strength and in result it increased. Each ton co2 emission from cement is reduced by using six ton glass powder concrete and by reducing green-house gas and particulate production save our environment.

Khan et. al.[10] as a partial precursor, waste glass powder (GP) was used fly ash (FA) and ground granulated blast furnace slag (GGBFS) based alkali activated mortars cured at ambient condition. Fly ash was replaced by 0%-40% glass powder alkali to activated FA and FA-GGBFS. At 7, 14, 28, 90

days compressive strength was tested and in the result they observed compressive strength increased and it also showed the use of glass powder was reduced the workability of both FA and FA-GGBFS Mortars. no strength was increase, porosity, sorptivity and chloride permeability was decreased. With the increase of GP content drying shrinkage of both FA and FA-GGBFS mortars was increased. In the result it shows that the microstructure of FA-GGBFS mortars was significantly improved by using of GP.

5. CONCLUSIONS

We came to know the above mention paper the researchers found chemical composition identical to SCMs (Supplementary Cementitious Materials) in the glass powder.

Green concrete can save natural materials by using waste industrial products like fly ash, waste glass, rice husk ash, micro silica, etc. Compressive, split tensile strength, workability and durability are increased by using these industrial waste materials.

CO_2 gas is also reduced by using these waste materials in the cement. Some studies have shown that glass powder have been used for improved self healing capacity of concrete.

In general researchers used as a replacement materials of cement and aggregate. Most of the time cement replaced by fly ash, silica fume, rice husk ash and aggregates replaced by glass cullet and plastic waste. Some time cement replaced by glass powder also.

But firstly cement can be replaced by fly ash then the used fly ash can be replaced by glass powder.

By using waste materials the cost will be reduced.

REFERENCES

1. Hocine Siad, Mohamed Lachemi, Mustafa Sahmaran, Habib A. Mesbah, Khandaker M. Anwar Hossain, "Use of recycled glass powder to improve the performance properties of high volume fly ash-engineered cementitious composites" published in Elsevier journal in December 2017

2. Jian-Xin Lu, Haibing Zheng, Shuqing Yang, Pingping He, Chi Sun Poon, " Co-utilization of waste glass cullet and glass powder in precast concrete products" published in Elsevier journal in june 2019

3. Ali A. Aliabdo, Abd Elmoaty M. Abd Elmoaty, Ahmed Y. Aboshama, " Utilization of waste glass powder in the production of cement and concrete" published in Elsevier journal in 5 August 2016

4. Hongjian Du and Kiang Hwee Tan, "Waste Glass Powder as Cement Replacement in concrete" published in Journal of Advanced Concrete Technology in November 2014

5. Yi Jianga, Tung-Chai Linga, Kim Hung Mob, Caijun Shia, "A critical review of waste glass powder – Multiple roles of utilization in cement-based materials and construction products" published in Elsevier journal in April 2019.

6. Bhupendra Singh Shekhawat, Dr. Vanita Aggarwal, "Utilisation of Waste Glass Powder in Concrete" published in GJESR Journal in July 2014.

7. Rui Xiao, Pawel Polaczyk, Miaomiao Zhang, Xi Jiang , Yiyuan Zhang , Baoshan Huang, and Wei Hu, "Evaluation of Glass Powder-Based Geopolymer Stabilized Road Bases Containing Recycled Waste Glass Aggregate" published in TRR Journal

8. Shi Cong Kou, and Feng Xing, "The Effect of Recycled Glass Powder and Reject Fly Ash on the Mechanical Properties of Fibre-Reinforced Ultrahigh Performance Concrete" published in Hindawi Publishing Corporation in December 2011.

9. G.M. Sadiqul Islam, M.H. Rahman, Nayem Kazi, "Waste glass powder as partial replacement of cement for 4 sustainable concrete practice" published in International Journal of Sustainable Built Environment in October 2016

10. Md. Nabi Newaz Khan , Jhutan Chandra Kuri, Prabir Kumar Sarker," Effect of waste glass powder as a partial precursor in ambient cured alkali activated fly ash and fly ash-GGBFS mortars" published in Elsevier journal in October 2020.

11. Irshad Ali, "Behavior of Concrete by using Waste Glass Powder and Fly Ash as a Partial Replacement of Cement" published in IJERT in May-2015.

12. Ernawati Sri Sunarsih, Galuh Widi Patanti, Rima Sri Agustin, Kundari Rahmawati," Utilization of Waste Glass and Fly Ash as a Replacement of Material Concrete" published in J. Phys.: Conf. Ser. in 2021.

13. Mustafa Tuncan, Bekir Karasu and Muhsin Yalcin " The Suitability for Using Glass and Fly Ash in Portland Cement Concrete" published in researchgate in January 2001.

14. K.I.M. Ibrahim," Recycled waste glass powder as a partial replacement of cement in concrete containing silica fume and fly ash" published in Elsevier in July 2021.