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Experimental Investigations on Green Concrete using Partial Replacement of Glass and Demolished Concrete Wastes

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Abstract

Green Concrete is a revolutionary topic in the history of concrete industry. This was first invented in Denmark in the year 1998. Green concrete has nothing to do with colour. It is a concept of thinking environment into concrete considering every aspect from raw materials manufacture over mixture design to structural design, construction, and service life. However, since the total amount of concrete produced is so vast the absolute figures for the environmental impact are quite significant, due to the large amounts of cement and concrete produced. Since concrete is the second most consumed entity after water it accounts for around 5% of the world's total co_2 emission. The solution to this environmental problem is not to substitute concrete for other materials but to reduce the environmental impact of concrete and cement. The potential environmental benefit to society of being able to build with green concrete is huge. It is realistic to assume that technology can be developed, which can halve the co_2 emission related to concrete production. During the last few decades society has become aware of the deposit problems connected with residual products, and demands, restricted and taxes had been imposed.

1. INTRODUCTION

Concrete which is made from concrete wastes that are eco-friendly are called as "Green concrete". Green concrete is the production of concrete using as many as recycled materials as possible and leaving the smallest carbon footprint as possible. The other name for green concrete is resource saving structures with reduced environmental impact for e.g. Energy saving, co_2 emissions, waste water. "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. Concrete wastes like slag, power plant wastes, recycled concrete, mining and quarrying wastes, waste glass, incinerator residue, red mud, burnt clay, sawdust, combustor ash and foundry sand. Green Concrete is a term given to a concrete that has had extra steps taken in the mix design and placement to insure a sustainable structure and a long-life cycle with a low maintenance surface e.g. Energy saving, CO_2 emissions, waste water. The goal of the Centre for Green Concrete is to reduce the environmental impact of concrete. To enable this, new technology is developed. The technology considers all phases of a concrete construction's life cycle, i.e.

structural design, specification, manufacturing and maintenance, and it includes all aspects of performance, i.e.,Mechanical properties (strength, shrinkage, creep, static behaviour etc.),

Fire resistance (spalling, heat transfer etc.),Workmanship (workability, strength development, curing etc.), Durability (corrosion protection, frost, new deterioration mechanisms etc.), Thermodynamic properties (input to the other properties) and Environmental aspects (CO_2-emission, energy, recycling etc.)

1.1 Some Benefits to using Green Concrete

- Lasts Longer,
- Uses Industrial Waste,
- Reduces Energy Consumption and
- Reduces CO_2 Emissions

2. MATERIALS

2.1 Fly ash

Fly ash is a fine powder which is a by-product from burning pulverized coal in electric generation power plants. Fly ash is a pozzolanic, a substance containing aluminous and siliceous material that forms cement in the presence of water. Fly ash can be an expensive replacement for Portland cement in concrete although using it improves strength, segregation, and ease of pumping concrete. The rate of substitution typically specified is 1 to 11/2 pounds of fly ash to 1 pound cement. Nonetheless, the amount of fine aggregate should be reduced to accommodate fly ash additional volume. Fly ash can be as prime material in blocks, paving or brick; however, one the most important applications is PCC pavement. PCC pavements use a large amount of concrete and substituting fly ash provides significant economic benefits. Fly ash has also been used for paving road and as embankment and mine fills, and its gaining acceptance by the federal government, specifically the Federal Highway Administration (FHA).

2.2 Glass Wastes

Glass in general is a highly transparent material formed by melting a mixture of materials such as silica, soda ash, and $CaCO_3$ at high temperatures followed by cooling during which solidification occurs without crystallization. Glass is widely used in our lives through manufactured products such as sheet glass, bottles, glassware, and vacuum tubing. Glass has been indispensable to man's life due to such properties as pliability to take any shape with ease, bright surface, resistance to abrasion, safety and durability. The utility ranges of the glass increase the amount of the waste glass (WG). The fluorescent lamp recycling facility crushes the fluorescent lamps, separates the metal caps, and recovers mercury. For 55,000 tubes recycled, approximately 30 m3 of waste glass will be generated. In the future, with the environmental law being strictly enforced and with the increasing use of

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fluorescent lighting systems for energy efficiency, it is expected that more non-recyclable waste glass will be accumulated from the fluorescent lamp recycling business. Foreign countries have long been taking much effort to recycle waste glass bottles. A bottle recovery system, through which empty bottles previously containing alcoholic beverages, refreshing beverages, condiments, milk, etc. are collected, washed, and reused, has already been established. In addition, broken bottles and bottles previously containing chemicals, cosmetics, etc. are melted down to be reused or crushed and turned into paving material, block material, glass marble, glass tile, glass fibre, lightweight blowing agents, etc. Use of recycled materials in construction is among the most attractive options because of the large quantity, low quality requirements and widespread sites of construction.

2.3 Demolished Concrete Waste (or) Recycled Concrete

Recycled concrete is a concrete aggregate manufactured using pre-existing concrete from demolished structures, sidewalks and roadways. Recycled aggregate is used as an alternative to sending used, non-biodegradable concrete to landfills. The most significant benefits of using recycled concrete are economic and environmental.When you use recycled concrete aggregate, you save the money it would have cost to secure, process and transport all-new material. These savings drastically increase if you use recycled concrete to rebuild or repair at the same location it was demolished. Because recycled concrete is more lightweight than virgin concrete, it has a higher yield, which results in less money spent on building costs and materials. When you choose recycled aggregate, you also save yourself the cost and potential headache of meeting proper concrete disposal regulations and locating a concrete disposal facility. On a larger scale, the process of recycling concrete can generate several new jobs, which puts money back into your local economy.

2.3.1 The Environmental Benefits of Recycled Concrete

When concrete is not recycled or reused, it is sent to a landfill. The Environmental Protection Agency (EPA) estimates that in 2017, 569 million tons of construction and demolition materials were generated in the U.S. alone. Since concrete is not biodegradable, it will not break down over time. The EPA cites reusing and recycling construction and demolition materials including concrete and asphalt concrete as one of the best practices to avoid overfilling landfills and wasting limited resources.Finally, the concrete recycling process can also incorporate and use other environmentally friendly practices and construction materials, including the use of old tires, scrap materials and organic waste as fuel for cement processing.

2.3.2 The Concrete Recycling Process

One might think that because recycled aggregate is so beneficial to builders, site managers and the environment, that it would be challenging to produce, but the concrete recycling process is relatively straightforward.

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Harvesting: First, concrete rubble is harvested from demolished buildings, sidewalks, curbs, gutters, roads, interstates, highways, airport runways, foundations and more. After the rubble is harvested, the rest of the process is either done on-site, off-site or at a concrete recycling facility.

Crushing: Once the concrete is harvested, it is crushed using one of several crushing methods. Popular methods for crushing include portable, mobile or stationary jaw crushers, impact crushers or cone crushers. Jaw crushers and impact crushers can both be used for initial crushing. Sometimes, a secondary crushing process usually done with a cone crusher is required to further size the rubble.

Screening: Because concrete aggregate is often mixed with other materials like clay, plastic, dirt, asphalt pavement, metal and wood chips it needs to be screened using scalping and deck screeners to be separated from those materials. Recycled concrete often goes through several screening processes, depending on the source of the concrete and how the end product will be used.

Cleaning: The final step in the concrete recycling process is cleaning. Before concrete can be recycled into new concrete, any remaining residue from removed materials must be cleaned away. This is done through hand-picking, magnetic separation or air or water separators.

3. EXPERIMENTAL TESTS

Cement Test:Ordinary Portland cement (53 grade) - Specification (IS12269-1987).

Finesses Test:The standard value of fineness of cement should have fineness less than 10 % orfineness should not be more than 10% as per IS Recommendations.

Standard Consistency Test:The standard consistency of cement paste generally varies between 25-35%. In our result is 27%.

Initial and Final Setting Time of Cement Test:Initial and final setting time is 30 and 600 mins.

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Figure 1Experimentation images

Soundness Test of Cement:The soundness calculated L1–L2 for the typesof cement ordinary or OPC, rapid, low heat, PPC, and high Alumina cement should not exceeds 10mm.

Heat of Hydration Test:it has been standardised that the low heat cement should not generate the heat of 65 calories per gram of cement in 7 days and 75 calories per gram for the duration of 28 days.

Specific Gravity Test on Test: The specific gravity of cement is 1440 kg/m^3.

Tensile Strength Test: The tensile strength of cement is between 3-5 MPa (i.e., 300-700 psi). In our result is 3.5 MPa.

Coarse Aggregates: Specific gravity test - 2.64%, water absorption test - 0.14%, flakiness index test- 5.76%, elongation index test- 14.26%, impact test - 24.10%, abrasion test- 27.48, sieve size (80,40,20,10, 4.75,2.36,1.18,0.6, 0.3 and 0.15mm) and fineness modulus test - 7.30.

Fine Aggregates: Sieve size (4.75, 2.36, 1.18,0.6,0.3 and 0.15 mm), fineness modulus test- 2.59, los angles abrasion test - max 40%, asphalt abrasion test -min 95%, water abrasion test - max 3%, bulk specific gravity test - min 2.5 gm/cm^3, apparent specific gravity test - min 2.5 gm/cm^3.

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Figure 2 Concrete cube preparation

4. MIX DESIGN (As per M25 - 1:1:2)

Table 1 MIX Design Details (As per M25 - 1:1:2)

Materials	Quantity	Ratio
Cement	435.45 kg/m^3	1
Fine Aggregates	676 kg/m^3	1.55
Coarse Aggregates	1067.69 kg/m^3	2.45
Water	191.5 Litres	0.44

5. RESULTS AND DISCUSSIONS

5.1 Compressive strength of the concrete when the cement is 15 % replaced by glass

Compressive strength of first cube at 14 days: 28.719 MPa, converting into 28 days: 28.719/0.90 = 31.91 MPa.Compressive strength of second cube at 14 days: 30.231 MPa, converting into 28 days: 30.231/0.90 = 33.59 MPa,compressive strength of third cube at 28 days: 37.33MPa and compressive strength of fourth cube at 28 days: 37.77 MPa.

5.2Compressive strength of the concrete when the cement is 30 % replaced by glass

Compressive strength of first cube at 14 days: 24.138 MPa, converting into 28 days: 24.138/0.90 = 26.82 MPa. Compressive strength of second cube at 14 days: 22.419 MPa, converting into 28 days: 22.419/0.90 = 24.91MPa,compressive strength of third cube at 28 days: 32.88 MPa andcompressive strength of fourth cube at 28 days: 34.67 MPa.

5.3 Compressive strength of the concrete when the cement is 45 % replaced by glass

Compressive strength of first cube at 14 days: 22.203 MPa, converting into 28 days: 22.203/0.90 = 24.67. Compressive strength of second cube at 14 days: 19.728 MPa, converting into 28 days: 19.728/0.90 = 21.92 MPa,compressive strength of thirdcube at 28 days: 26.87 MPa and compressive strength of fourthcube at 28 days: 28.23 MPa.

5.4 Compressive strength of the concrete when the cement is 15 % replaced by glass and fly ash

Compressive strength of first cube at 14 days:32.866 MPa, converting into 28 days: 32.866/0.90 = 36.54MPa. Compressive strength of second cube at 14 days:31.554 MPa, converting into 28 days: 31.554/0.90 = 35.06 MPa, compressive strength of third cube at 28 days: 38.24 MPa and compressive strength of fourth cube at 28 days: 37.92 MPa.

5.5 Compressive strength of the concrete when the cement is 30 % replaced by glass and fly ash

Compressive strength of first cube at 14 days:22.239 MPa, converting into 28 days: 22.239/0.90 = 24.71 MPa compressive strength of second cube at 14 days:24.444 MPa, converting into 28 days: 24.444/0.90 = 27.16 MPa,compressive strength of third cube at 28 days: 31.02 MPa and compressive strength of fourth cube at 28 days: 33.64 MPa.

5.6 Compressive strength of the concrete when the cement is 45 % replaced by glass and fly ash

Compressive strength of first cube at 14 days:20.304 MPa, converting into 28 days: 20.304/0.90 = 22.56 MPa. Compressive strength of second cube at 14 days:21.825 MPa, Converting into 28 days: 21.825/0.90 = 35.06 MPa,compressive strength of third cube at 28 days: 27.81 MPa and compressive strength of fourthcube at 28 days: 28.94 MPa.

Properties of Glass Powder

Table 2Compressive and tensile properties of glass powder

Glass Powder	Slump (mm)	Compressive strength (MPa)	Tensile strength (MPa)
0	120	36	2.76
10	90	39	2.91
20	75	40.89	2.95
30	70	56.46	3.95
40	65	47.33	2.93
50	50	42	2.89

Mix Design - M25 Grade Concrete

Table 328 Days compressive strength of Mix Design - M25 Grade Concrete

Mix.No.	Water	Cement	W/C Ratio	Slump (mm)	28 Days compressive

Peer Reviewed Journal
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					strength (MPa)
1	155.5	362	0.43	45	31.11
2	159	353	0.45	51	32.89
3	162	352	0.46	55	33.33

6. CONCLUSIONS

The tests were conducted and the observed values are concluded as follows: We can replace cement by glass safely up to 30%and little more but we cannot replace it by 45 % and more. We can replace cement by (glass + fly ash) up to 30% but we cannot replace it by 45 % and more. 28 days strength obtains from (glass + fly ash) is more than 28 days strength of glass replacement. On strength, criteria by glass + fly ash replacement are better than by only glass-replacement. It reduces the CO_2 emission up to 30%. At 15% replacement by glass powder strength came 24.2% more than normal concrete. At 30% replacement strength came 5.37% more than normal concrete. At 15 % replacement by (glass +fly ash) strength came 34 % more than normal concrete. At 30% replacement by glass + fly ash strength came 6.48% more than normal concrete.

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