A RESEARCH ON GREEN CONCRETE

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ABSTRACT
A 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 color. 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.

Green concrete is very often also cheap to produce because for example, waste products are used as a partial substitute for cement, charges for the disposal of waste are avoided, energy consumption in production is lower, and durability is greater. Green concrete is a type of concrete which resembles the conventional concrete but the production or usage of such concrete requires minimum amount of energy and causes least harm to the environment. The CO2 emission related to concrete production, is between 0.1 and 0.22 t per tonne of produced concrete.

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 CO2 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 CO2 emission related to concrete production. During the last few decades society has become aware of the deposit problems connected with residual products, and demands, restrictions and taxes have been imposed.

And as it is known that several residual products have properties suited for concrete production, there is a large potential in investigating the possible use of these for concrete production. Well-known residual products such as silica fume and fly ash may be mentioned. The concrete industry realized at an early stage that it is a good idea to be in front with regard to documenting the actual environmental aspects and working on improving the environment rather than being forced to deal with environmental aspects due to demands from authorities, customers and economic effects such as imposed taxes. Furthermore, some companies in concrete industry have recognized that reductions in production costs often go hand in hand with reductions in environmental impacts. Thus, environmental aspects are not only interesting from an ideological point of view, but also from an economic aspect. Green concrete has manifold advantages over the conventional concrete. Since it uses the recycled aggregates and materials, it reduces the extra load in landfills and mitigates the wastage of aggregates. Thus, the net CO2 emission are reduced. The reuse of materials also contributes intensively to economy. Green concrete can be considered elemental to sustainable development since it is eco-friendly itself. Green concrete is being widely used in green building practices.

***Keywords*: Green concrete, recycled, cement, coarse and fine aggregates**

1. INTRODUCTION

1.1 What is green concrete?

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, co2 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, CO2 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.

1) Mechanical properties (strength, shrinkage, creep, static behavior etc.)
2) Fire resistance (spalling, heat transfer etc.)
3) Workmanship (workability, strength development, curing etc.)

4) Durability (corrosion protection, frost, new deterioration mechanisms etc.)

5) Thermodynamic properties (input to the other properties)

6) Environmental aspects (CO2-emission, energy, recycling etc.)

1.2 SUITABILITY OF GREEN CONCRETE IN STRUCTURES

Several factors which enhances the suitability of green concrete in structures includes:

- Reduce the dead load of the structure and reduce the crane age load; allow handling, lifting flexibility with lighter weight.
- Reduction of emission of CO□ by 30%.
- Increased concrete industries use of waste products by 20%.
- Good thermal and fire resistance, sound insulation than the traditional concrete.
- Improve damping resistance of the building.
- Use of new types of residual products, previously land filled or disposed of in other ways.
- No environmental pollution and sustainable development.
- It requires less maintenance and repairs.
- Compressive strength behavior of the concrete with water cement ratio is more than that of conventional concrete.
- Flexural strength of the green concrete is almost same as conventional concrete.
- CO2-neutral, waste-derived fuels shall substitute fossil fuels in the cement production by atleast 10 %.
- Use of concrete industries own residual products.

1.3 Here is a list of 4 benefits to using green concrete.

1.3.1 Lasts Longer: Green concrete gains strength faster and has a lower rate of shrinkage than concrete made only from Portland cement. Structures built using green concrete have a better chance of surviving a fire (it can withstand temperatures of up to 2400 degrees on the Fahrenheit scale). It also has a greater resistance to corrosion which is important with the effect pollution has had on the environment (acid rain greatly reduces the longevity of traditional building materials). All of those factors add up to a building that will last much longer than one made with ordinary concrete. Similar concrete mixtures have been found in ancient Roman structures and this material was also used in the Ukraine in the 1950s and 1960s.

1.3.2 Uses Industrial Waste: Instead of a 100 percent Portland cement mixture, green concrete uses anywhere from 25 to 100 percent fly ash. Fly ash is a byproduct of coal combustion and is gathered from the chimneys of industrial plants (such as power plants) that use coal as a power source. There are copious amounts of this industrial waste product. Hundreds of thousands of acres of land are used to dispose of fly ash. A large increase in the use of green concrete in construction will provide a way to use up fly ash and hopefully free many acres of land.

1.3.3 Reduces Energy Consumption: If you use less Portland cement and more fly ash when mixing concrete, then you will use less energy. The materials that are used in Portland cement require huge amounts of coal or natural gas to heat it up to the appropriate temperature to turn them into Portland cement. Fly ash already exists as a byproduct of another industrial process so you are not expending much more energy to use it to create green concrete.

Another way that green concrete reduces energy consumption is that a building constructed from it is more resistant to temperature changes. An architect can use this and design a green concrete building to use energy for heating and cooling more efficiently.

1.3.4 Reduces CO2 Emissions: In order to make Portland cement–one of the main ingredients in ordinary cement–pulverized limestone, clay, and sand are heated to 1450 degrees C using natural gas or coal as a fuel. This process is responsible for 5 to 8 percent of all carbon dioxide (CO2) emissions worldwide. The manufacturing of green concrete releases has up to 80 percent fewer CO2 emissions. As a part of a global effort to reduce emissions, switching over completely to using green concrete for construction will help considerably

1.4. SCOPE IN INDIA

Green concrete is a revolutionary topic in the history of concrete industry. As green concrete is made with concrete wastes it does take more time to come in India because of industries having problem to dispose wastes and also, having reduced Environmental impact with reduction in CO2 emission. Use of green can help us reduce a lot of wastage of several products. Various non-biodegradable products can also be used and thus avoiding the issue of their disposal.

1.5 Types of wastes used in concrete

(Fig-1.1)

2. PROJECT OVERVIEW

2.1 Project Implementation

- NOMINAL CONCRETE
- CEMENT IS REPLACED BY GLASS
- CEMENT REPLACED BY GLASS AND FLYASH
- COMPARISON BETWEEN COMPRESSIVE STRENGTH OF NOMINAL CONCRETE AND REPLACED CEMENT CONCRETE

2.2 GLASS AS A CEMENTACEOUS MATERIAL

Million tons of waste glass is being generated annually all over the world. Once the glass becomes a waste it is disposed as landfills, which is unsustainable as this does not decompose in the environment. Glass is principally composed of silica. Use of milled (ground) waste glass in concrete as partial replacement of cement could be an important step toward development of sustainable (environmentally friendly, energy-efficient and economical) infrastructure systems. When waste glass is milled down to micro size particles, it is expected to undergo pozzolanic reactions with cement hydrates, forming secondary Calcium Silicate Hydrate (C–S–H). In this research chemical properties of both clear and colored glass were evaluated. Chemical analysis of glass and cement samples was determined using X- ray fluorescence (XRF) technique and found minor differences in composition between clear and colored glasses. Flow and compressive strength tests on mortar and concrete were carried out by adding 0–25% ground glass in which water to binder (cement + glass) ratio is kept the same for all replacement levels. With increase in glass addition mortar flow was slightly increased while a minor effect on concrete workability was noted. To evaluate the packing and pozzolanic effects, further tests were also conducted with same mix details and 1% super plasticizing admixture dose (by weight of cement) and generally found an increase in compressive strength of mortars with admixture. As with mortar, concrete cube samples were prepared and tested for strength (until 1 year curing). The compressive strength test results indicated that recycled glass mortar and concrete gave better strength compared to control samples. A 20% replacement of cement with waste glass was found convincing considering cost and the environment.

Specific gravity and fineness of clear and colored waste glass powders (prepared by ball mill) were 3.01 & 0.9% (#200 sieve) and 3.02 & 0.9% respectively as per ASTM standard mentioned above. Chemical composition of both glass powders were examined using a XRF-1800 Sequential X-ray fluorescence spectrometer. 20% binder was added to 80% glass powder to keep the material in position during test.

Then the whole mixture was pressed using 140 KN pressing force. The chemical composition of glass powder is compared with other pozzolanic materials in the discussion. As the results of fineness, specific gravity and chemical composition test of color and clear glass powder were found similar, further experimental work with mortar and concrete was conducted with clear glass power.

2.3 FLY ASH AS A CEMENTACEOUS MATERIAL

2.3.1 About Fly ash

Fly ash is a fine powder which is a byproduct from burning pulverized coal in electric generation power plants. Fly ash is a pozzolan, a substance containing aluminous and siliceous material that forms cement in the presence of water. When mixed with lime and water it forms a compound similar to Portland cement.

The fly ash produced by coal-fired power plants provide an excellent prime material used in blended cement, mosaic tiles, and hollow blocks among others.

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 1
½ pounds of fly ash to 1 pound of cement. Nonetheless, the amount of fine aggregate should be reduced to accommodate fly ash additional volume.

2.3.2 Fly Ash Applications

Fly ash can be used as prime material in blocks, paving or bricks; however, one the most important applications are 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 roads and as embankment

and mine fills, and its gaining acceptance by the Federal government, specifically the Federal Highway Administration.

2.3.3 Fly Ash Drawbacks

Smaller builders and housing contractors are not that familiar with fly ash products which could have different properties depending on where and how it was obtained.
For this reason, fly ash applications are encountering resistance from traditional builders due to its tendency to effloresce along with major concerns about freeze/thaw performance.
Other major concerns about using fly ash concrete include:

- Slower strength gain.
- Seasonal limitation.
- Increase in air entraining admixtures.
- An increase of salt scaling produced by higher fly ash.

2.3.4 Fly Ash Benefits

Fly ash can be a cost-effective substitute for Portland cement in some markets. In addition, fly ash could be recognized as an environmentally friendly product because it is a byproduct and has low embodied energy. It's also is available in two colors, and coloring agents can be added at the job site. In addition, fly ash also requires less water than Portland cement and it is easier to use in cold weather. Other benefits include:

- Cold weather resistance.
- Higher strength gains, depending on its use.
- Can be used as an admixture.
- Can substitute for Portland cement.
- Considered a non-shrink material.
- Produces denser concrete and a smoother surface with sharper detail.
- Great workability.
- Reduces crack problems, permeability and bleeding
- Reduces heat of hydration.

- Produces lower water/cement ratio for similar slumps when compared to no fly ash mixes.
- Reduces CO2 emissions.

2.3.5 Fly Ash Types

Currently, more than 50 percent of the concrete placed in the U.S. contains fly ash. Dosage rates vary depending on the type of fly ash and its reactivity level. Typically, Class F fly ash is used at dosages of 15 to 25 percent by mass of cementitious material, and Class C fly ash at 15 to 40 percent.

Class F fly ash, with particles covered in a kind of melted glass, greatly reduces the risk of expansion due to sulfate attack as may occur in fertilized soils or near coastal areas. Class F are generally low- calcium fly ashes with carbon contents less than 5 percent but sometimes as high as 10 percent. Class C fly ash is also resistant to expansion from chemical attack, has a higher percentage of calcium oxide, and is more commonly used for structural concrete. Class C fly ash is typically composed of high-calcium fly ashes with carbon content less than 2 percent.

2.4 Why glass was used

- Glass is a non-biodegradable material
- It is principle composed of silica
- When glass is milled down to micro size particle it is expected to undergo pozzolanic reaction with cement hydrate and form calcium silicate hydrate bond (C-S-H bond)
- It is easily available
- It's fineness should be 0.9% (#200 sieves)

2.5 Why fly ash was used

- Fly ash is a fine powder , a waste product originate from burning coal in electric generation power plant
- Fly ash is a pozzolanic substance containing aluminum and siliceous material that form cement in presence water and lime
- It has greater workability
- It reduce CO2 emission and heat of hydration
- It is of class C and class F type

3. PROJECT ANALYSIS

3.1 DATA INTERPRETITION

Grade of concrete, size of cube casting, different proportion of the materials like glass and fly ash etc Which replaces the cement etc are interpreted as:

Grade of concrete : M25

Nominal concrete : 4 cubes of 1:1:2 ratio

Cement replaced by glass in the concrete: 4 cubes with 15% replace cement

4 cubes with 30% replace cement

4 cubes with 45% replace cement

Cement replaced by glass and fly ash both in the concrete : 4 cubes with 15% replace cement

4 cubes with 30% replace cement

4 cubes with 45% replace cement (Glass: fly ash = 1:1)

3.2 CALCULATION

3.2.1 Calculation for nominal mix

Volume of cube : $0.15*0.15*0.15 = 3.375*10^{-3}$ m^3 (In wet condition)

(Take 1.52 times more volume in dry condition)

: $5.13*10^{-3}$ m^3

Volume of cement : $5.13*10^{-3}*0.25 = 1.2825*10^{-3}$ m^3
Unit weight of cement : 1440 Kg/m^3
Weight of cement for 1 cube : 1.846 Kg

Weight of cement for 4 cubes : 4*1.846 = 7.384 Kg (7.5 Kg approx.)

Unit weight of fine aggregate : 1600 Kg/m^3
Volume of fine aggregate : $5.13*10^{-3}*0.25 = 1.2825*10^{-3}$ m^3
Weight of fine aggregate for 1 cube : $1.2825*10^{-3}*1600 = 2.052$ Kg
Weight of fine aggregate for 4 cubes : 2.052*4 = 8.208 Kg (8.5 Kg approx.)

Unit weight of coarse aggregate : 1600 Kg/m^3

Volume of coarse aggregate : $5.13*10^{-3}*0.5 = 2.565*10^{-3}$ m^3
Weight of coarse aggregate for 1 cube : $2.565*10^{-3}*1600 = 4.140$ Kg
Weight of coarse aggregate for 4 cubes : 4.104*4 = 16.416 Kg (16.5 Kg approx.)

(Net amount of material is taken as 10% more in case of hand mixing)

3.2.2 Calculation for glass and fly ash mix

(For one cube calculation)

Weight of cement : 1.846 Kg

Weight of cement when 15% cement is replaced by glass : 1.846*0.85 = 1.569 Kg

Weight of cement when 30% cement is replaced by glass : 1.846*0.70 = 1.296 Kg

Weight of cement when 45% cement is replaced by glass : 1.846*0.55 = 1.016 Kg

Weight of glass when cement is replaced by 15% : 1.846*0.15 = 0.2769 Kg

Weight of glass when cement is replaced by 30% : 1.846*0.30 = 0.546 Kg

Weight of glass when cement is replaced by 45% : 1.846*0.45 = 0.830 Kg

Weight of cement when 15% cement is replaced by
Both glass and fly ash : 1.846*0.85 = 1.569 Kg

Weight of cement when 30% cement is replaced by

Both glass and fly ash : 1.846*0.70 = 1.296 Kg

Weight of cement when 45% cement is replaced by

Both glass and fly ash :1.846*0.55 = 1.016 Kg

Weight of glass when 15% cement is replaced by

Both glass and fly ash :1.846*0.15 = 0.138 Kg
Weight of glass when 30% cement is replaced by

Both glass and fly ash :1.846*0.30 = 0.275 Kg

Weight of glass when 45% cement is replaced by

Both glass and fly ash : 1.846*0.45 = 0.415 Kg

Weight of fly ash when 15% cement is replaced by

Both glass and fly ash : 1.846*015 = 0.138 Kg

Weight of fly ash when 30% cement is replaced by

Both glass and fly ash : 1.846*0.30 = 0.275 Kg

Weight of fly ash when 45% cement is replaced by

Both glass and fly ash : 1.846*0.45 = 0.415 Kg

The following table give you better information are as follow:

Table 3.1 weight of different material used in nominal concrete

NOMINAL CONCRETE			
Number of cubes	Weight of cement in 1 cube (in kg)	Weight of fine aggregate in 1 cube (in kg)	Weight of coarse aggregate in 1 cube (in kg)
4	1.846	2.052	4

Table 3.2 when cement is replaced by glass

Glass replaces cement		
Number of cubes used = 12		
% Replaces	Weight of cement (in kg)	Weight of glass (in kg)
15	1.565	0.2769
30	1.296	0.550
4	1.016	0.830

Table 3.3 when both glass and fly ash replaces cement

Glass and fly ash replaces cement			
Number of cubes used =12			
% Replaces	Weight of cement (in kg)	Weight of glass (in kg)	Weight of fly ash (in kg)
15	1.569	0.130	0.130
30	1.296	0.275	0.275
45	1.016	0.415	0.415

4. METHODOLOGY

4.1 Specifications

- M25 Grade concrete
- Water cement ratio = 0.45
- Coarse aggregate of 20mm size(1600kg/m3)
- Fine aggregate (Dry sand 1600kg/m3)
- Cement – OPC (Grade 45) (unit weight- 1440 kg/m3)
- Glass
- Fly ash (from NTPC power plant, Dadri)

4.2 Apparatus:

- Cube Mould (150x150x150 mm or 100x100x100 mm)
- Tamping bar (16 mm diameter and bull-nosed)
- Steel Float/Trowel.
- Compressive strength Testing machine
- Curing Tank
- Weighing machine
- Pan
- Hammer
- Cylindrical mould
- Sieving machine

4.3 Procedures of Making Concrete Cube:

1. Cleaning &fixing mould
2. Breaking of Glass
3. Mixing cement, glass and Fly ash.
4. Placing, Compacting & Finishing concrete
5. Curing

(Fig- 4.1)

4.3.1 Cleaning &fixing mould

- Clean the cube-mould properly and apply oil on inner surface of mould. But no oil should be visible on surface.
- Fix the cube mould with base plate tightly. No gap should be left in joints so that cement-slurry doesn't penetrate.

4.3.2 Breaking of Glass

- We bought the glass from nearby rag picker shop.
- The glass is the broken into very small pieces with the help of hammer.
- The grinded glass is then put in sieving machine.
- Sieving is done for 15 min.
- The last sieve used in sieving test is 1.41 mm sieve and glass passing through this sieve is used.

4.3.3 Mixing cement glass and Fly ash

- Amount of cement, glass and fly ash to be used is bought into a pan.
- The mixture formed is either mixed with the hands or with the help of trowel.
- The whole ingredients are mixed till the color of the mixture matches with the cement color.

- Proper precautions should be taken while mixing cement and glass as both these elements can cut skin.

4.3.4 Placing, Compacting & Finishing concrete.

- Take concrete from three or four random mixes.
- Place concrete into mould in three layers. Compact each layer by giving 35 blows of tamping bar.
- Remove excess concrete from the top of mould and finish concrete surface with trowel. Make the top surface of concrete cube even and smooth.
- Left the mould completely undisturbed for first four hours after casting.
- After ending undisturbed period, put down casting date and item name on the top of concrete specimen with permanent marker.

4.3.5 Curing

Curing is the maintaining of an adequate moisture content and temperature in concrete at early Ages so that it can develop properties the mixtures was designed to achieve. Curing begins Immediately after placement and finishing so that concrete may develop the desired strength and Durability.
Without an adequate supply of moisture content, the cementitious materials in concrete cannot

React to form a quality product. Drying may remove the water needed for this chemical reaction called hydration and the concrete will not achieve the potential properties.

Temperature is an important factor in proper curing, since the rate of hydration, and therefore, strength development, is faster at high temperature. Generally, concrete temperature should be maintained above 50F for an adequate rate of strength development. Further, a uniform temperature should be maintained through the concrete section it is gaining strength to avoid thermal cracking. For exposed concrete, relative humidity and wind condition are also important; they contribute to the rate of moisture loss from the concrete and could result in cracking, poor surface quality and durability. Protective measures to control evaporation of moisture from concrete surfaces before it sets are essential to prevent plastic shrinkage cracking.

Liquid after finishing. Do not apply to concrete that is still bleeding or has a visible water sheen on the surface. While a clear liquid may be used, a white pigment will provide reflective properties and allow for a visual inspection of coverage. A single coat may be adequate, but where possible a second coat, applied at right angles to the first, is desirable for even coverage. If the concrete membrane- forming curing compounds must con- formtoASTMC309.Applytotheconcretesurfaceabout one hour will be painted, or covered with vinyl or ceramictile, then a liquid compound that is non-reactive with the paint or adhesives must be used or use a compound that is easily brushed or washed off. On floors, the surface should be protected from the other trades with scuff-proof paper after the application of the curing compound

Plastic sheets - either clear, white (reflective) or pigmented. Plastic should conform to ASTM C 171, be at least 4 mils thick, and preferably reinforced with glass fibers. Dark colored sheets are recommended when ambient temperatures are below 60°F (15°C) and reflective sheets should be used when temperatures exceed 85°F (30°C). The plastic should be laid in direct contact with the concrete surface as soon as possible without marring the surface. The edges of the sheets should overlap and be fastened with waterproof tape and then weighted down to prevent the wind from getting under the plastic. Plastic can make dark streaks wherever a wrinkle touches the concrete, so plastic should not be used on concretes where appearance is important. Plastic is sometimes used over wet burlap to retain moisture Waterproof – used like plastic sheeting but does not mar the surface. This paper generally consists of two layer of craft paper cemented together and reinforced with fiber. The paper should conform to ASTM C 171.

- After 8 to 10 hours of casting, wrap the cube mould with wetted hessian cloth. Cover the mould's top portion with a polythene sheet so that water doesn't fall on concrete surface.
- Uncover and remove the cube specimens from mould after 24±½ hours of casting. For removing specimen from mould, first loosen all nut-bolts and carefully remove specimen because concrete is still weak and can be broken.
- Immediately after removing, put the specimen into a tank of clean water for curing. Make sure cube specimen is fully submerged in water.

4.4 PROCESS INVOLVED 4.4.1How fly ash and glass works with cement in concrete?

Ordinary Portland cement (OPC) is a product of four principal mineralogical phases. These phases are Tricalcium silicate- C_3S ($3CaO.SiO_2$), Dicalcium Silicate – C_2S ($2CaO.SiO_2$), Tricalcium Aluminate- C_3A ($3CaO.\ Al_2O_3$) and Tetracalcium alumino-ferrite – C_4AF ($4CaO.Al_2O_3\ Fe_2O_3$). The setting and hardening of the OPC takes place as a result of reaction between these principal compounds and water. The reaction between these compounds and water are shown as under:

$2C_3S$ + 6H = $C_3S_2H_3$ + 3CH

tricalcium silicate water C-S-H gel Calcium hydroxide $2C_2S$ + 4H $\rightarrow C_3S_2H_3$ + CH

The hydration products from C_3S and C_2S are similar but quantity of calcium hydroxide (lime) released higher in C_3S as compared to C_2S.

The reaction of C_3A with water takes place in presence of sulphate ions supplied by dissolution of gypsum present in OPC. This reaction is very fast and is shown as under:

C_3A + $3(CSH_2)$ +26H $C_3A(CS)_3H_{32}$

tricalcium allumінate +gypsum +water ettringite C_3A+ CSH_2 + 10H C_3ACSH_{12}

monosulphoaluminate hydrate

4.4.2 FLYASH FOR CEMENT CONCRETE

Tetracalciumalumino-ferrite forms hydration product similar to those of C_3A with iron substituting partially for alumina in the crystal of ettringite and monosulpho-aluminate hydrate.

Above reaction indicate that during the hydration process of cement, lime is released out and remains as surplus in the hydrated cement. This leached out surplus lime render deleterious effect to concrete such as make the concrete porous, give chance to the development of micro-cracks, weakening the bond with aggregates and thus affect the durability of concrete.

If fly ash is available in the mix, this surplus lime becomes the source for pozzolanic reaction with fly ash and forms additional C-S-H gel having similar binding properties in the concrete as those produced by hydration of cement paste. The reaction of fly ash with surplus lime continues as long as lime is present in the pores of liquid cement paste.

5. ACCEPTANCE CRITERIA FOR CONCRETE

As per 16.1(a) /IS 456/2000 (pg 30):-

 For all Concrete > M15 Grade and above

The average strength of four (4) non-overlapping consecutive test result shall not be less than –

For M15 or higher:

f average ≥ (fck + 0.825 Õ) N/mm2 or

f average ≥ (fck + 3) N/mm2

(Whichever is more)

 As per 16.1 (b)/IS456/2000 (pg 30)

Individual test result of any sample ITR ≥ (fck – 3) N/mm2

 As per 15.4 of IS456/2000 (pg 29)

The test result of the sample shall be average of the strength of three specimen and the individual variation shall not be more than that of the Average strength, if more the test result of the sample are Invalid.

6. COMPRESSIVE STRENGTH READING

6.1 Test result when cement is 15% replaced by glass

Compressive strength of 1st cube at 14 days : 28.719

Converting into 28 days : 28.719/0.90 = 31.91 Compressive strength of 2nd cube at 14 days : 30.231

Converting into 28 days : 30.231/0.90 = 33.59 Compressive strength of 3rd cube at 28 days : 37.33

Compressive strength of 4th cube at 28 days : 37.77

6.2 Test result when cement is 30% replaced by glass

Compressive strength of 1st cube at 14 days : 24.138

Converting into 28 days : 24.138/0.90 = 26.82 Compressive strength of 2nd cube at 14 days : 22.419

Converting into 28 days : 22.419/0.90 = 24.91 Compressive strength of 3rd cube at 28 days : 32.88

Compressive strength of 4th cube at 28 days : 34.67

6.3 Test result when cement is 45% replaced by glass

Compressive strength of 1st cube at 14 days : 22.203

Converting into 28 days : 22.203/0.90 = 24.67 Compressive strength of 2nd cube at 14 days : 19.728

Converting into 28 days : 19.728/0.90 = 21.92 Compressive strength of 3rd cube at 28 days : 26.87

Compressive strength of 4th cube at 28 days : 28.23

6.4 Test result when cement is 15% replaced by glass and fly ash

Compressive strength of 1st cube at 14 days : 32.866

Converting into 28 days : 32.866/0.90 = 36.54 Compressive strength of 2nd cube at 14 days
: 31.554
Converting into 28 days : 31.554/0.90 = 35.06 Compressive strength of 3rd cube at 28 days
: 38.24
Compressive strength of 4th cube at 28 days : 37.92

6.5 Test result when cement is 30% replaced by glass and fly ash

Compressive strength of 1st cube at 14 days : 22.239

Converting into 28 days : 22.239/0.90 = 24.71 Compressive strength of 2nd cube at 14 days
: 24.444
Converting into 28 days : 24.444/0.90 = 27.16 Compressive strength of 3rd cube at 28 days
: 31.02
Compressive strength of 4th cube at 28 days : 33.64

6.6 Test result when cement is 30% replaced by glass and fly ash

Compressive strength of 1st cube at 14 days : 20.304

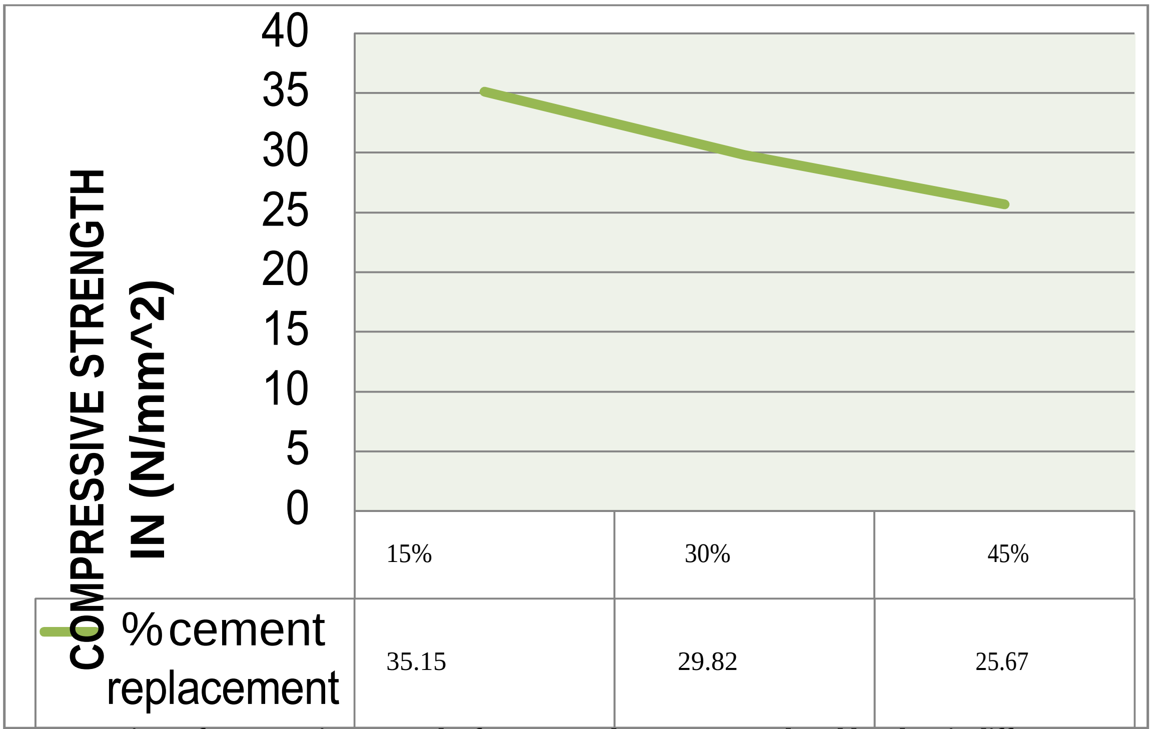
Converting into 28 days : 20.304/0.90 = 22.56 Compressive strength of 2nd cube at 14 days
: 21.825
Converting into 28 days : 21.825/0.90 = 35.06 Compressive strength of 3rd cube at 28 days
: 27.81
Compressive strength of 4th cube at 28 days : 28.94

7. RESULTS AND DISCUSSION

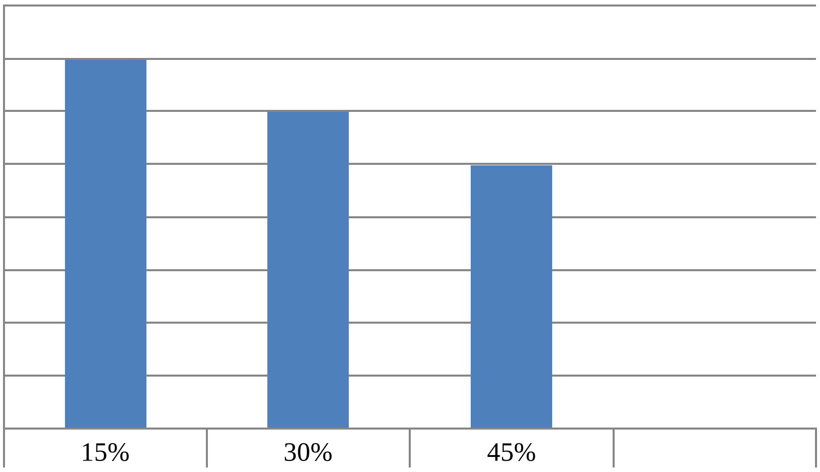
7.1 Compressive Strength test:

- When 28 days of curing was completed than (150 mm X 150mm) blocks were tested in CTM machine.
- Following results were obtained:

7.1.1 Comparison of compressive strength of concrete when replaced by glass indifferent proportion through line graph. (Fig. 7.1)



7.1.2 Comparison of compressive strength of concrete when cement replaced by glass in different proportion through bar graph. (fig. 7.2)



7.2 Table of compressive strength of concrete when cement replaced by glass in different proportion

7.2.1 Cement 15% replaced by glass (table 7.1)

Concrete	Test result(N/mm^2)	Average strength obtained(N/mm^2)	Average strength required(N/mm^2)	ITR value	Result
M25	31.91	35.15	28.3	>22 OKAY	PASS
	33.59				
	37.33				
	37.77				

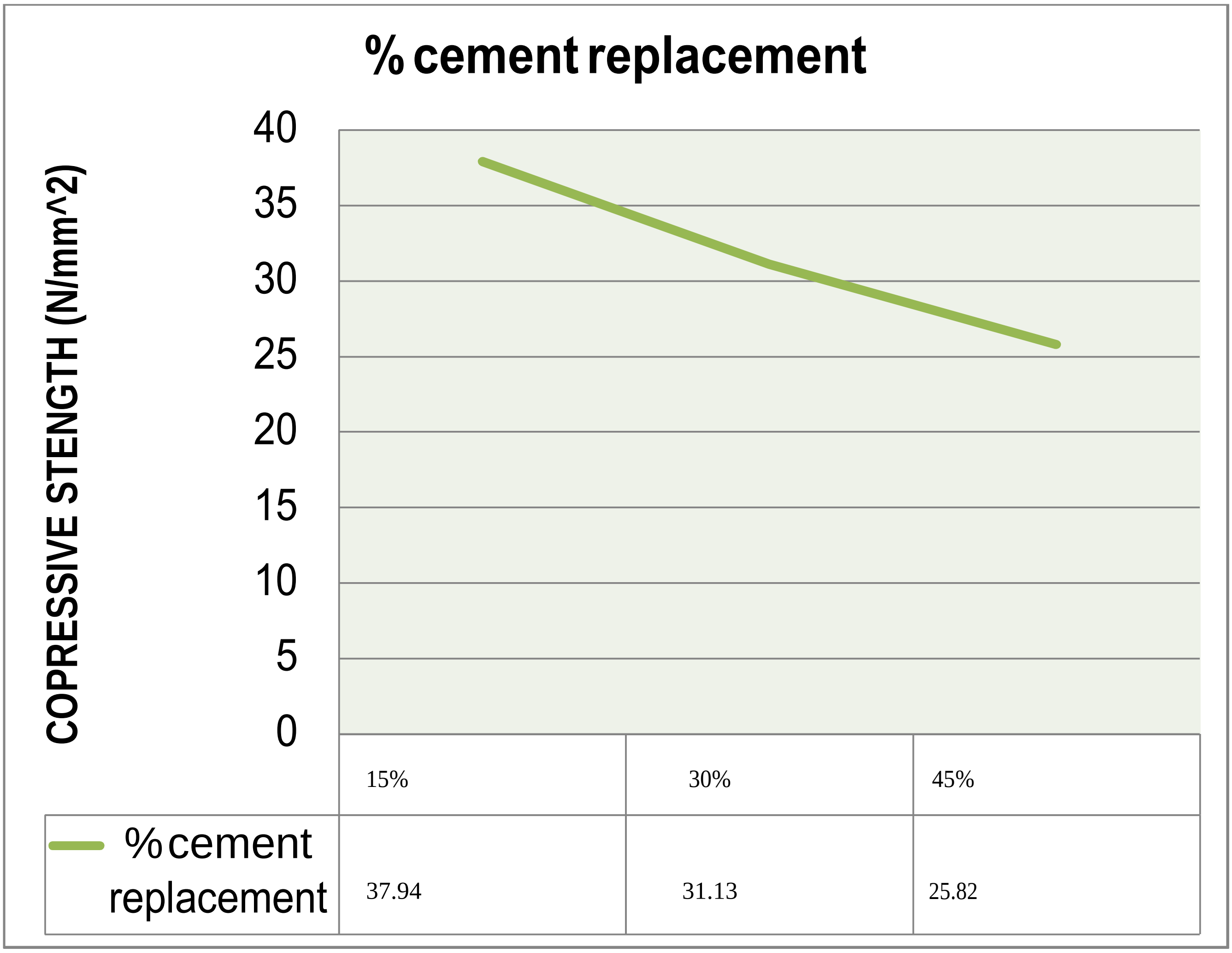
7.2.2 Cement when 30% replaced by glass (table 7.2)

Concrete	Test result(N/mm^2)	Average strength obtained(N/mm^2)	Average strength required(N/mm^2)	ITR value	Result
M25	26.82	29.82	28.3	>22 OKAY	PASS
	24.91				
	32.88				
	34.67				

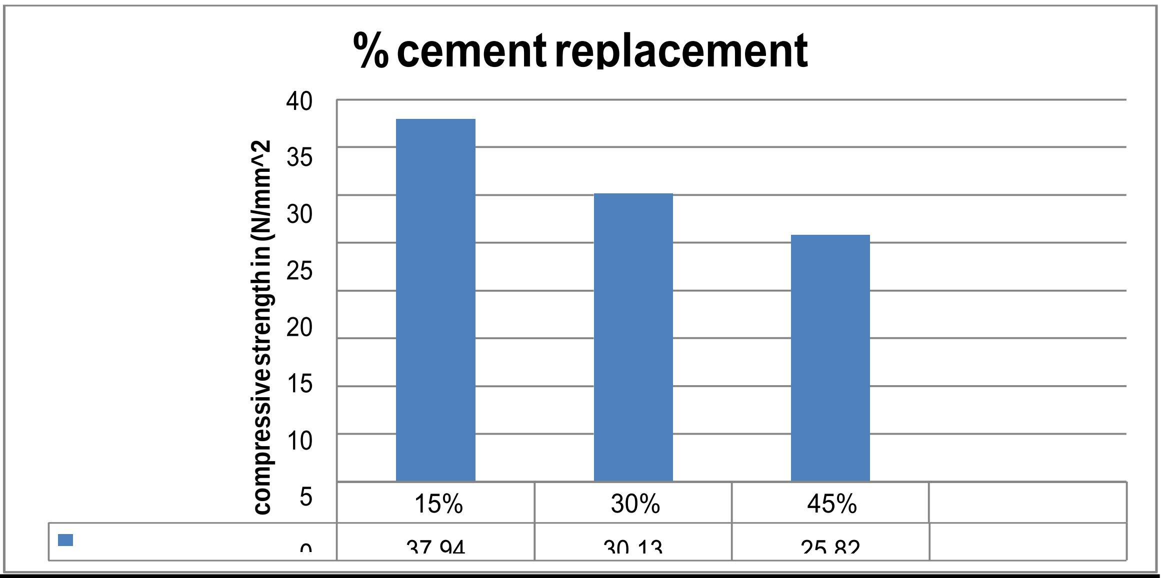
7.2.3 Cement when 45% replaced by glass (table 7.3)

Concrete	Test result(N/mm^2)	Average strength obtained(N/mm^2)	Average strength required(N/mm^2)	ITR value	Result
M25	24.67	25.67	28.3	<22 INVALID	FAIL
	21.92				
	26.87				
	28.23				

7.3 COMPARISON OF COMPRESSIVE STRENGTH OF CONCRETE WHEN REPLACED BY (GLASS+FLY ASH) IN DIFFERENT PROPORTION THROUGH LINE GRAPH (fig 7.3)



7.4 Comparison of compressive strength of concrete when cement is replaced by (glass + fly ash) in different proportion by bar graph. (Fig. 7.4)



7.5 Table of compressive strength of concrete when cement replaced by (glass+ fly ash) indifferent proportion

7.5.1 When cement is 15 % replaced by (glass+ fly ash) (table 7.4)

Concrete	Test result(N/mm^2)	Average strength obtained(N/mm^2)	Average strength required(N/mm^2)	ITR value	Result
M25	36.54	37.94	28.3	>22 OKAY	PASS
	35.06				
	38.24				
	37.92				

7.5.2 When cement is 30% replaced by (glass+ fly ash) (table 7.5)

Concrete	Test result(N/mm^2)	Average strength obtained(N/mm^2)	Average strength required(N/mm^2)	ITR value	Result
M25	24.71	30.13	28.3	>22 OKAY	PASS
	27.16				
	31.02				
	33.64				

7.5.3 When cement is 45% replaced by (glass+ fly ash) (table 7.6)

Concrete	Test result(N/mm^2)	Average strength obtained(N/mm^2)	Average strength required(N/mm^2)	ITR value	Result
M25	22.56	25.82	28.3	>22 OKAY	PASS
	24.25				
	27.87				
	28.94				

8. MERITS AND DEMERITS

8.1 Merits of fly ash replaced concrete

- It is economical
- It is Environmental friendly.
- Fly ash has very small particles which makes the concrete dense & reduces permeability ofconcrete. It can assess greater strength to building.
- It has Low heat of hydration which prevent thermal cracking.
- It gives better work ability & finishes

8.2 Demerits of fly ash replaced concrete

- Quality of fly ash can affect the quality & strength of concrete.
- Generally, as fly ash +cement content increases then compressive strength decreases.

8.3 Merits of glass replaced concrete

- It is economical
- It is Environmental friendly
- It is supposed to give the strength when its size is in powdered form
- It is non-biodegradable

8.4 Demerits of glass replaced concrete

- Glass powder size as decrease than strength of concrete increase but below 50-micron glass powder affect strength of concrete.
- To make the glass into powdered form is difficult task.
- it requires machinery and labor to convert glass into powdered form
- During conversion of glass into powdered form this can affect our eyes, hands and through respiration glass powder can reach to our respiration system.

9. Cost analysis

Prices

Price of cement per Kg= 6.50 Rs.

Price of waste glass powder per Kg= 5 Rs. Price of fly ash per Kg= 1.3Rs.

For normal concrete price of cement for one cube

Weight of cement = 1.846 Kg

Price of cement = 1.846 x 6.5= 11.99 Rs.

For glass replaced concrete price of cement for one cube

- **if 15 % replaced by glass** Weight of cement =1.569 Kg Weight of glass = 0.2769 Kg

Price of cement = 1.569 x 6.5=10.19 Rs. Price of glass =0.2769 x5=1.384 Rs.
Total price = 11.57 Rs

- **if 30 % replaced by glass** Weight of cement= 1.296 Kg Weight of glass = 0.55 Kg

Price of cement = 1.296 x 6.5= 8.424 Rs Price of glass = 0.55 x 5=2.75 Rs
Total price = 11.174 Rs.

For glass + fly ash replaced concrete price of cement for one cube

- **if 15 % replaced by glass + fly ash**

Weight of cement= 1.569 Kg Weight of glass = 0.138 Kg Weight of fly ash= 0.138 Kg

Price of cement = 1.569 x 6.5= 10.19Rs Price of glass = 0.138 x 5=0.69 Rs Price of fly ash=0.138 x 1.3= 0.179 Rs. Total price = 11.059 Rs.

- **if 30 % replaced by glass + fly ash**

Weight of cement= 1.296Kg Weight of glass = 0.275 Kg Weight of fly ash= 0.275 Kg
Price of cement = 1.296 x 6.5= 8.424Rs Price of glass = 0.275 x 5=1.375 Rs Price of fly ash=0.275 x 1.3= 0.3575 Rs. Total price = 10.156 Rs.

- **Reduction in price from normal concrete to 15 % glass replaced concrete for 1 cube= 11.99 – 11.57= 0.42 Rs**

- **Reduction in price from normal concrete to 30 % glass replaced concrete for one cube = 11.99-11.174= 0.816 Rs**
- **Reduction in price from normal concrete to 15 % glass + fly ash replaced concrete for one cube =11.99-11.059= 0.931 Rs**
- **Reduction in price from normal concrete to 30 % glass + fly ash replaced concrete for one cube =11.99-10.156= 1.834 Rs**

10. CONCLUSION

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 % & more.
- We can replace cement by (glass + fly ash) up to 30% but we cannot replace it by 45 % & more.
- 28 days strength obtain from (glass + fly ash) is more than 28 days strength of glass replacement.
- On strength, criteria by glass + fly ash replacement is 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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