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# "Comparative Evaluation of Strength Properties of Green Concrete and Conventional Concrete"

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***Abstract***
*The present study reports the mechanical properties of green concrete which contains recycled aggregates (RCA) sourced from local construction and demolition wastes and flyash sourced from industrial waste. For green concrete RCA was used as 50% replacement to natural coarsed aggregates (NCA) and flyash was used as 30% replacement to cement.*
*In this study, three series of concrete mixtures were prepared with water cement ratio (W/C) of 0.3, 0.4 and 0.5.Each series comprises of two concrete types named as conventional concrete mixture with 0% RCA and 0% flyash indicated by notation R0.And green concrete mixture with 50% RCA and flyash was incorporated as 30% replacement to cement indicated by notation R50F30.*
*The study shows that Green concrete compressive strength is 10 to 12% lesser than conventional concrete. Hence incorporation of 30% flyash does not made much difference in compression strength gain. However, the reduction in compressive strength can be compensated by a decreasing the W/C ratio.*
*The green concrete mixture and the results shows that split tensile strength of Green concrete [R50F30] decreased by 15 to 22% compared to conventional concrete [R0]. Hence the incorporation of flyash in green concrete [R50F30] decreased the tensile strength of concrete compared to conventional concrete [R0].*

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## I. Introduction

### 1.1 GENERAL

Green concrete is a concrete, partially or completely substituted for cement or fine aggregate or coarse aggregate. Alternative materials may be wastes of manufacturing processes. Another name for Green Concrete is a resource-saving structure that reduces environmental impact, carbon dioxide emissions, and waste water. "Green concrete" is a revolutionary topic in the history of concrete industry. This was first invented in 1998 by Dr.WG in Denmark.

Slag, fly ash, power plant waste, recycled concrete, mining waste, waste glass, incinerated slag, red mud, burning soil, sawdust, burning ash and foundry sand can be properly used in green concrete.

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 behaviour 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.)

There are a number of alternative environmental requirements with which green concrete structures must comply:

- CO2 emissions shall be reduced by at least 30 %.
- At least 20 % of the concrete shall be residual products used as aggregate.
- Use of concrete industries own residual products.
- Use of new types of residual products, previously land filled or disposed of in other ways.
- CO2-neutral, waste-derived fuels shall substitute fossil fuels in the cement production by at least 10 %.

## II. Suitability Of Green Concrete In Structures

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

1. Reduce the dead load of the structure and reduce the crane age load; allow handling, lifting flexibility with lighter weight.
2. Reduction of emission of $CO_2$ by 30%.
3. Increased concrete industries use of waste products by 20%.
4. Good thermal and fire resistance, sound insulation than the traditional concrete.
5. Improve damping resistance of the building.
6. No environmental pollution and sustainable development.
7. It requires less maintenance and repairs.
8. Compressive strength behaviour of the concrete with water cement ratio is more than that of conventional concrete.

## III. Objectives

The main objective of the project is comparative evaluation of strength properties of conventional concrete and green concrete incorporating recycled coarse aggregates and fly ash. Which includes-

1. To analyse workability of green concrete with conventional concrete.
2. To calculate compreesive strength of green concrete and conventional concrete.
3. To calculate tensile strength of green concrete and conventional concrete.
4. To analyse Economical Physibility.

## IV. Methodology

4.1 CONCRETE MIX DESIGN

"It can be defined as the process of selecting suitable ingredients of concrete and determining and their relative proportions with the object of concrete certain and minimum strength and durability as economically as possible."

For proportioning in connection with concrete mix four factors are important.

- Water cement ratio
- Cement content
- Gradation of aggregates
- Consistency

Methods of proportioning mix design:

Following are the methods, which are used for proportioning:

- Arbitrary proportions method
- Maximum density method
- Surface area method
- ACI committee method
- High strength concrete mix design
- Method based on flexural strength
- Indian Standard method
- Trial method

Objects of mix design:

- To achieve a specified compressive strength for a specified grade.
- For ensuring required workability.
- For achieving durability.
- To economics concrete production.
- For increasing yield per bag of cement without comparing strength.
- To avoid honey combing and bleeding.
- To comply with various standards.

Concrete Mix Design Procedure as per IS 10262 – 2009

## V. Procedure for concrete mix design requires following step by step process:

1. Calculation of target strength of concrete
2. Selection of water-cement ratio
3. Determination of aggregate air content
4. Selection of water content for concrete
5. Selection of cement content for concrete

6. Calculation of aggregate ratio
7. Calculation of aggregate content for concrete
8. Trial mixes for testing concrete mix design strength

Step 1: Calculation of Target Strength of Concrete

Target strength is denoted by ft which is obtained by characteristic compressive strength of concrete at 28 days (fck) and value of standard deviation (s)

$$ft = fck + 1.65\ s$$

Standard deviation can be taken from below table

| Grade of concrete | Standard deviation (N/mm2) |
|---|---|
| M10 | 3.5 |
| M15 | 3.5 |
| M20 | 4.0 |
| M25 | 4.0 |
| M30 | 5.0 |
| M35 | 5.0 |
| M40 | 5.0 |
| M45 | 5.0 |
| M50 | 5.0 |

Step 2: Selection of Water-Cement Ratio

Ratio of the weight of water to weight of cement in the concrete mix is water-cement ratio. It is the important consideration in concrete mix design to make the concrete workable. Water cement ratio is selected from the below curve for 28 days characteristic compressive strength of concrete.

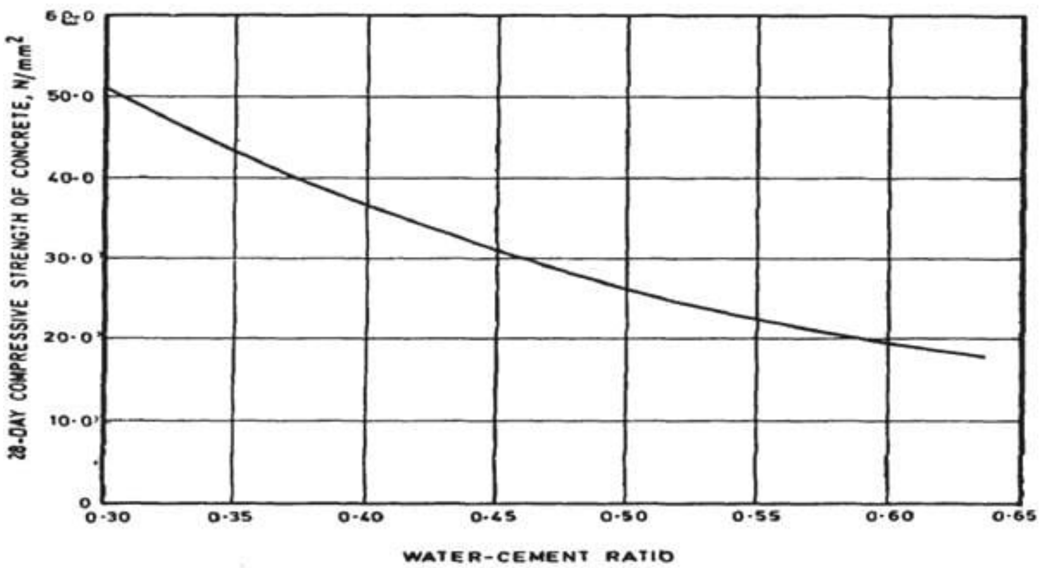


**Fig: Selection of Water-Cement Ratio for Concrete Mix Design**

Similarly, we can determine the water-cement ration from the 7-day concrete strength, the curves are divided on the basis of strength from water cement ratio is decided. Which is observed from the below graph.

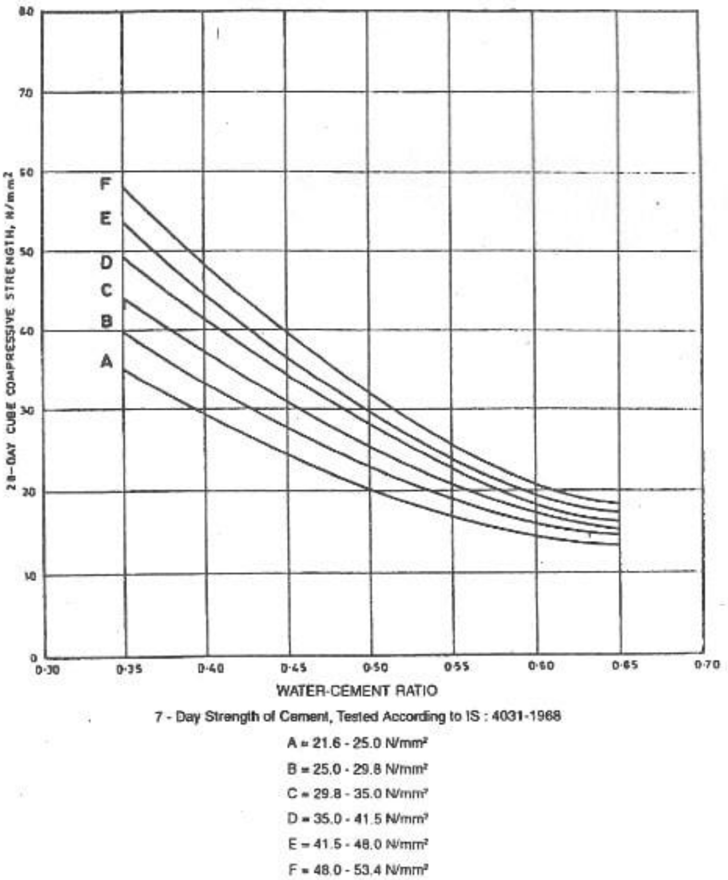


Fig: Concrete Compressive Strength vs. Water Cement Ratio

Step 3: Determination of Aggregate Air content
Air content in the concrete mix is determined by the nominal maximum size of aggregate used. Below table will give the entrapped air content in percentage of volume of concrete.

| Nominal maximum size of aggregate | Air content (% of volume of concrete) |
|---|---|
| 10mm | 5% |
| 20mm | 2% |
| 40mm | 1% |

Step 4: Selection of Water Content for Concrete
Select the water content which is useful to get required workability with the help of nominal maximum size of aggregate as given in below table. The table given below is used when only angular shaped aggregates are used in concrete as well as the slump should be 25 to 50mm.

| Nominal maximum size of aggregate | Maximum water content |
|---|---|
| 10mm | 208 |
| 20mm | 186 |
| 40mm | 165 |

If the shape of aggregate or slump value is differing from above, then some adjustments are required as follows.

| **Condition** | **Adjustment** |
|---|---|
| Sub angular aggregate | Reduce the selected value by 10% |
| Gravel with crushed stone | Reduce the selected value by 20kg |
| Rounded gravel | Reduce the selected value by 25kg |
| Using plasticizer | Decrease the selected value by 5-10% |
| Using super plasticizer | Decrease the selected value by 20-30% |
| For every increment of 25mm slump | Increase the selected value by 3% |

Step 5: Selection of Cement Content for Concrete
Water – cement ratio is determined in step2 and quantity of water is determined in step -4. So, we can easily calculate the quantity of cement from these two conditions. But, the value obtained should satisfy the minimum conditions as given in the below table. The greater of the two values is decided as quantity of cement content.

Cement Content for Plain Cement Concrete

| Exposure | Plain Cement Concrete (P.C.C) | | |
|---|---|---|---|
| | Minimum Cement Content Kg/m$^3$ | Max Free Water – Cement Ratio | Minimum Grade of Concrete |
| Mild | 220 | 0.6 | - |
| Moderate | 240 | 0.6 | M15 |
| Severe | 250 | 0.5 | M20 |
| Very severe | 260 | 0.45 | M20 |
| Extreme | 280 | 0.4 | M25 |

Cement Content for Reinforced Concrete

| Exposure | Reinforced Cement Concrete (RCC) | | |
|---|---|---|---|
| | Minimum Cement Content Kg/m$^3$ | Max Free Water –Cement Ratio | Minimum Grade of Concrete |
| Mild | 300 | 0.55 | M20 |
| Moderate | 300 | 0.5 | M25 |
| Severe | 320 | 0.45 | M30 |
| Very severe | 340 | 0.45 | M35 |
| Extreme | 360 | 0.4 | M40 |

Step 6: Calculation of Aggregate Ratio
For the given nominal maximum size of aggregate, we can calculate the ratio of volumes of coarse aggregate and volume of total aggregates for different zones of fine aggregates from the below table.

| Nominal maximum size of aggregate | Ratio of volume of coarse aggregate and volume of total aggregate for different zones of fine aggregate | | | |
|---|---|---|---|---|
| | Zone - 1 | Zone - 2 | Zone - 3 | Zone - 4 |
| 10mm | 0.44 | 0.46 | 0.48 | 0.50 |
| 20mm | 0.6 | 0.62 | 0.64 | 0.66 |
| 40mm | 0.69 | 0.71 | 0.73 | 0.75 |

Step 7: Calculation of Aggregate Content for Concrete
We already determine the coarse aggregate volume ratio in the total aggregate volume. So, it is very easy that, 1 – volume of coarse aggregate will give the volume of fine aggregate. Alternatively, there are some formulae to find the volume of fine and coarse aggregates as follows.

**Mass of fine aggregate is calculated from below formula**

$$V = [W + \frac{C}{Gc} + (\frac{1}{(1-P)} X \frac{F.A}{Gf})] \times \frac{1}{1000}$$

**Similarly, mass of coarse aggregate is calculated from below formula.**

$$V = [W + \frac{C}{Gc} + (\frac{1}{P} X \frac{C.A}{Gca})] \times \frac{1}{1000}$$

Where, V = volume of concrete
W = water content
C = cement content

Gc = sp. Gravity of cement
P = aggregate ration obtained in step6
F.A & C.A = masses of fine and coarse aggregates
Gf & Gca = sp. Gravities of fine and coarse aggregates.
Step 8: Trial Mixes for Testing Concrete Mix Design Strength
Based on the values obtained above, conduct a trail test by making at least 3 cubes of 150mm size as per above standards. Test that cubes and verify whether the required strength is gained or not. If not, redesign the mix with proper adjustments until required strength of cube occurs.

## VI. Mix Desgn Calculation

APPENDIX –I
Mix design for 0.3w/c ratio:
Fromfigure-2 of IS 10262-1982,
For w/c ratio 0.4 referring the curve E [51.5-56.4N/mm2]
Target mean strength = 53 N/mm2
From IS 10262-2009
1. Selection of water content
From table 2, maximum water content for 20mm down size =186 liters
[For 25-50mm slump]
For 100 mm slump = 186+0.6x186
197.16 liters
2. Calculation of cement content
Cement content = 197.16/0.3
=657.2 Kg/m3
According to IS 456:2000 for 0.3 w/c ratio minimum cement =450 kg/m3 [Hence ok]
3. Proportions of Volume of Coarse Aggregate and Fine Aggregate
From table 3 for zone II
For 20mm aggregate =0.62 for w/c ratio 0.5
0.5=0.62
For the present case w/c ratio =0.3
Therefore increasing the coarse aggregate volume by 0.02
Volume of coarse aggregate for 0.3 w/c ratio= 0.66
Volume of fine aggregate = 1-0.66 = 0.34
Mix Calculations:
a) volume of concrete = 1m3
b) Volume of cement = (mass of cement/ Specific gravity) x (1/1000)
= (657.2/3.15) x (1/1000)
0.2086 m3
c) Volume of water = 197.16/1000
= 0.19716 m3
d) Volume of all in aggregate = [a- (b+ c)]
= [1-(0.2086 + 0.19716)]
= 0.5942 m3
e) Mass of coarse aggregate = 0.5942 x0.66 x2.7 x 1000
= 1058.86 m3
f) Mass of fine aggregate = 0.5942 x 0.34 x 2.6 x 1000
= 525.27 m3

APPENDIX –II
Mix design for 0.4w/c ratio:
Fromfigure-2 of IS 10262-1982 ,
For w/c ratio 0.4 referring the curve E [51.5-56.4N/mm2]
Target mean strength = 44 N/mm2
From IS 10262-2009
1. Selection of water content
From table 2, maximum water content for 20mm down size =186 liters
[for 25-50mm slump]
For 100 mm slump = 186+0.6x186=197.16 liters

2. Calculation of cement content
Cement content = 197.16/0.4=492.9 Kg/m3
According to IS 456:2000 for 0.4 w/c ratio minimum cement =360 kg/m3 [Hence ok]
3. Proportions of Volume of Coarse Aggregate and Fine Aggregate
From table 3 for zone II
For 20mm aggregate =0.62 for w/c ratio 0.5
0.5=0.62
For the present case w/c ratio =0.4
Therefore increasing the coarse aggregate volume by 0.02
Volume of coarse aggregate for 0.4 w/c ratio= 0.64
Volume of fine aggregate = 1-0.64= 0.36

Mix Calculations:
a) Volume of concrete = 1m3
b) Volume of cement = (mass of cement/ Specific gravity) x (1/1000)
= (492.9/3.15) x (1/1000)
0.1564 m3
c) Volume of water = 197.16/1000
= 0.19716 m3
d) Volume of all in aggregate = [a- (b+ c)]
= [1-(0.1564+0.19716)]
= 0.6464 m3
e) Mass of coarse aggregate = 0.6464 x0.64x2.7x1000
= 1116.99 kg/m3
f) Mass of fine aggregate = 0.6464 x 0.36 x2.6x1000
= 604.76 kg/m3

APPENDIX –III
Mix design for 0.5 w/c ratio:
From figure-2 of IS 10262-1982,
For w/c ratio 0.4 referring the curve E [51.5-56.4N/mm2]
Target mean strength = 32 N/mm2
From IS 10262-2009
1. Selection of water content
From table 2, maximum water content for 20mm down size =186 liters
[For 25-50mm slump]
For 100 mm slump = 186+0.6x186
197.16 liters
2. Calculation of cement content
Cement content = 197.16/0.5
=394.32 Kg/m3
According to IS 456:2000 minimum cement content=330 kg/m3 [Hence ok].
3. Proportions of Volume of Coarse Aggregate and Fine Aggregate
From table 3 for zone II
For 20mm aggregate =0.62 for w/c ratio 0.5
0.5=0.62
For the present case w/c ratio =0.5
Volume of coarse aggregate for 0.5 w/c ratio= 0.62
Volume of fine aggregate = 1-0.62= 0.38

Mix Calculations:
a) Volume of concrete = 1m3
b) Volume of cement = (mass of cement/ Specific gravity) x (1/1000)
= (394.32/3.15) x (1/1000) =0.1251 m3
c) Volume of water = 197.16/1000
= 0.19716 m3
d) Volume of all in aggregate = [a- (b+ c)]
= [1-(0.1251 + 0.19716)]
= 0.6778 m3

e) Mass of coarse aggregate = 0.6778 x0.62 x2.7 x 1000
= 1134.54 m3
f) Mass of fine aggregate = 0.6778 x 0.38 x 2.6x 1000
= 682.375 m3

## VII. Results

7.1 Workability of concrete

Workability was measured using slump cone test. Results show that conventional concrete mixture with W/C of 0.5 had a relatively high slump of 150mm.Further concrete mix with W/C ratio of 0.3 shows the lowest slump of 75mm. From the table 7.1 we can observe that workability of all type of concrete mixtures increases as the w/c ratio increases from 0.3 to 0.5 Further, due to the presence of mortar on recycled aggregates water absorption of recycled aggregates will be more. Table7.1 shows that workability of green concrete [R50F30] is less as compared to conventional concrete because recycled aggregate absorb the water.

Table 7.1 Results of slump cone test

| W/C ratio | Concrete type | Slump(mm) |
|---|---|---|
| 0.3 | Ro | 90 |
| | R50F30 | 75 |
| 0.4 | Ro | 110 |
| | R50F30 | 92 |
| 0.5 | Ro | 150 |
| | R50F30 | 130 |

7.2 Compressive strength

In the present study, 3 cubes for each mix proportion were tested and average of 3 cubes was taken as compressive strength of concrete.

7.2.1 Compressive Strength of the concrete for w/c of 0.3

Table 7.2Results of compressive strength for W/C of 0.3

| Concrete type | No. of Specimens | Compressive Strength(Mpa) | | |
|---|---|---|---|---|
| | | 3 days | 7 days | 28 days |
| Conventional concrete[R0] | 9 | 25.38 | 42.43 | 62.2 |
| Green concrete [R50F30] | 9 | 23.7 | 39.2 | 55.4 |

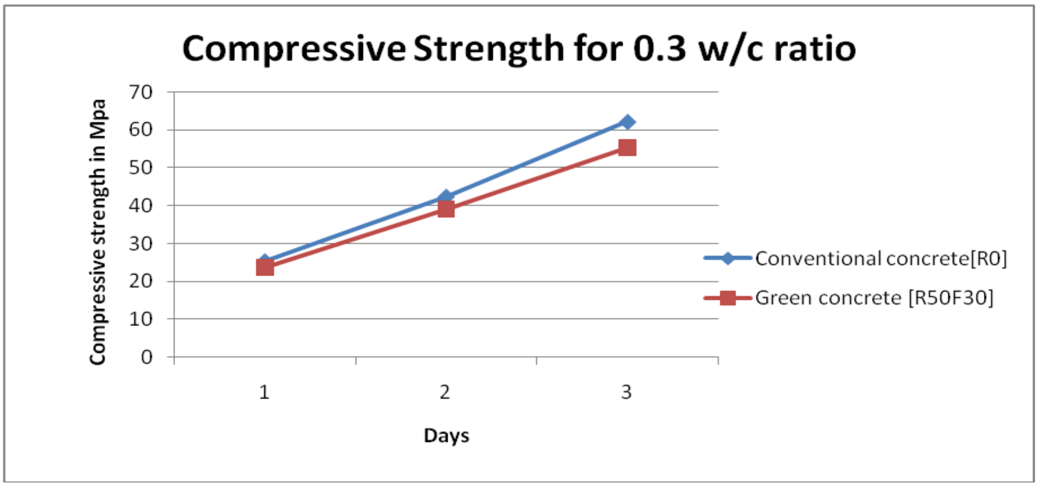


**Figure 7.1** Variation of compressive strength with age for W/C of 0.3

7.2.2 Compressive Strength of the concrete for w/c of 0.4

**Table 7.3** Results of compressive Strength for w/c of 0.4

| Concrete type | No. of Specimens | Compressive Strength(Mpa) |
|---|---|---|

| | | 3 days | 7 days | 28 days |
|---|---|---|---|---|
| Conventional concrete[R0] | 9 | 21.4 | 33.83 | 51 |
| Green concret [R50F30] | 9 | 20.2 | 29.7 | 45.3 |

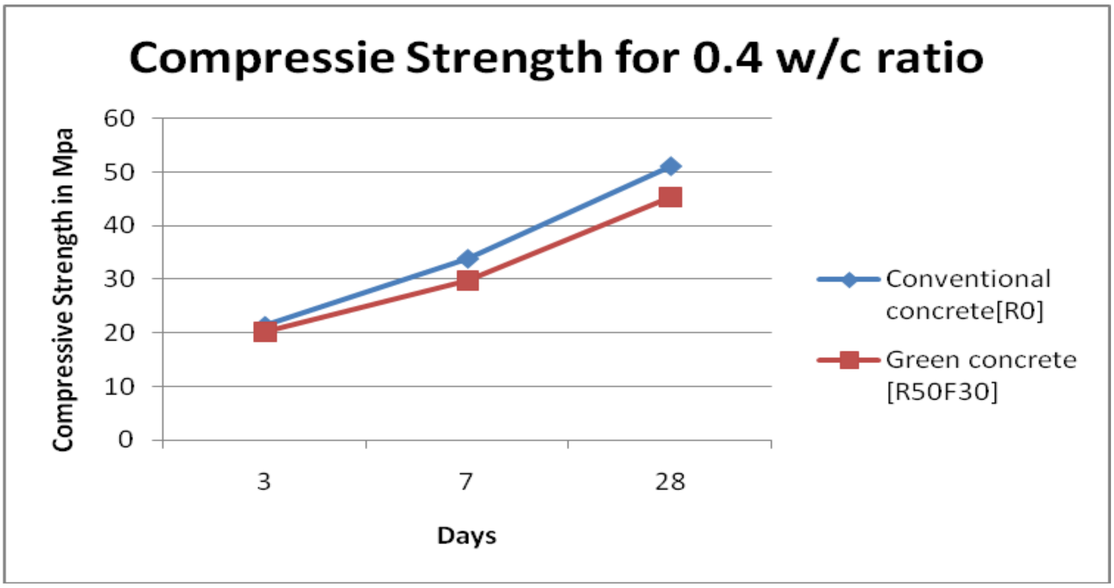


**Figure 7.2** Variation of compressive strength with age for W/C of 0.4

7.2.3 Compressive Strength of the concrete for w/c of 0.5

**Table 7.4** Results of compressive Strength for w/c of 0.5

| Concrete type | No. of Specimens | Compressive Strength(Mpa) | | |
|---|---|---|---|---|
| | | 3 days | 7 days | 28 days |
| Conventional concrete[R0] | 9 | 18 | 29.5 | 42.5 |
| Green concrete [R50F30] | 9 | 17.1 | 27.2 | 37.5 |

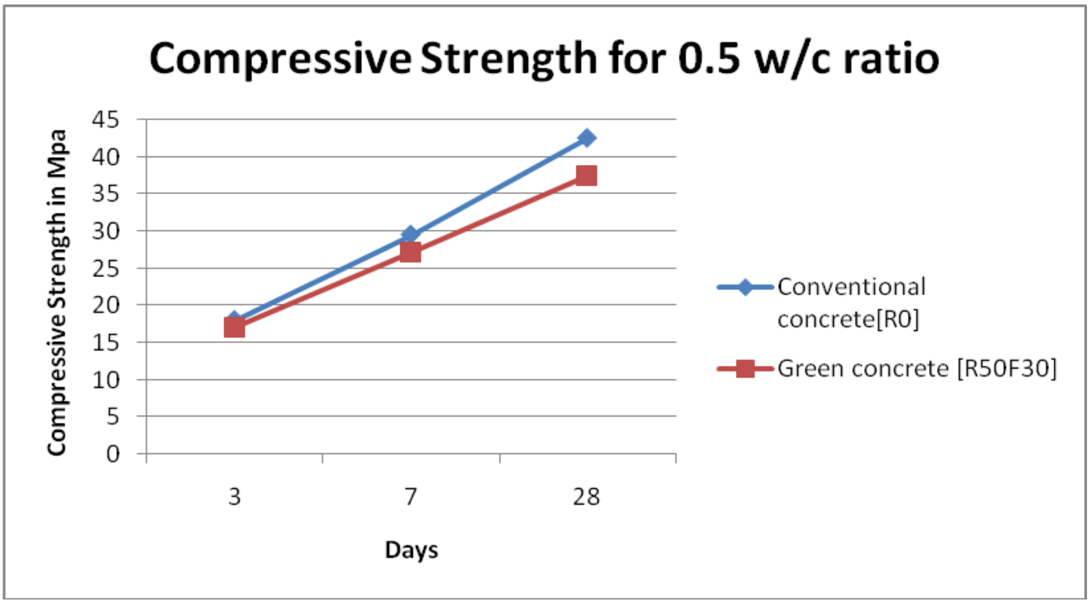

**Figure 7.2** Variation of compressive strength with age for W/C of 0.5

7.2.4 Analysis of compressive strength

The compressive strength of the concrete mixture in series I -III are summarized in table 7.2 to 7.4. Results show that due to the use of recycled coarse aggregates compressive strength decreased. Use of 30% flyash does not improve the compressive strength of concrete. Hence green concrete compressive strength is lower compared to conventional concrete strength. Conventional concrete [R0] with 0.3 W/C ratio gives the maximum compressive strength of 62.2 Mpa and green concrete with water to cement ratio of 0.5 gives the minimum compressive strength of 37.5 Mpa. From the tables 7.2 to 7.4 it is observed that compressive strength of all type of concretes decreases as the W/C ratio increases from 0.3 to 0.5. Further, due to the presence of recycled aggregates in [R50F30] concretes compressive strength is reduced compared to conventional concrete.

The study shows that Green concrete compressive strength is 10 to 12% lesser than conventional concrete. Hence incorporation of 30% flyash does not made much difference in compression strength gain. However, the reduction in compressive strength can be compensated by a decreasing the W/C ratio.

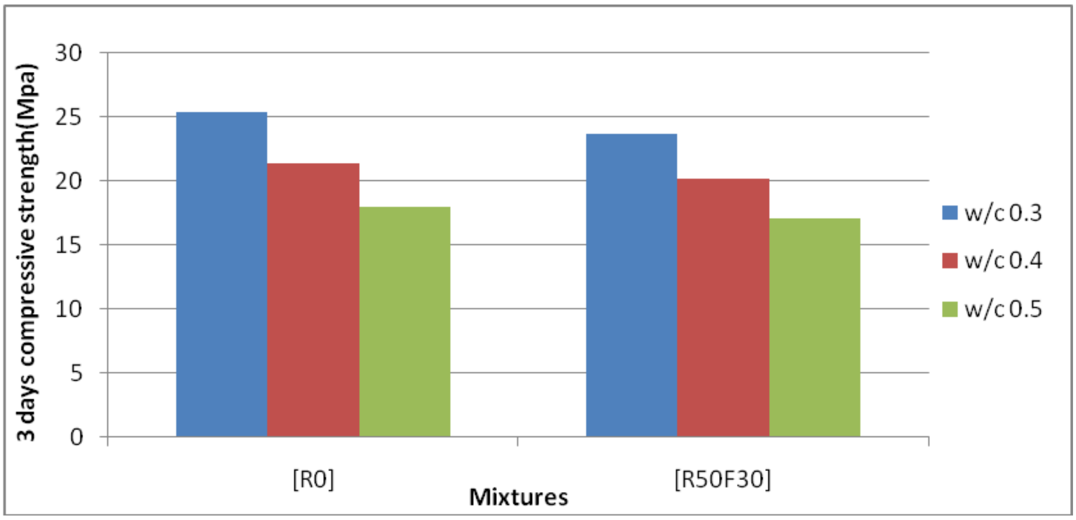


**Figure 7.4** Three days compressive strength of concrete

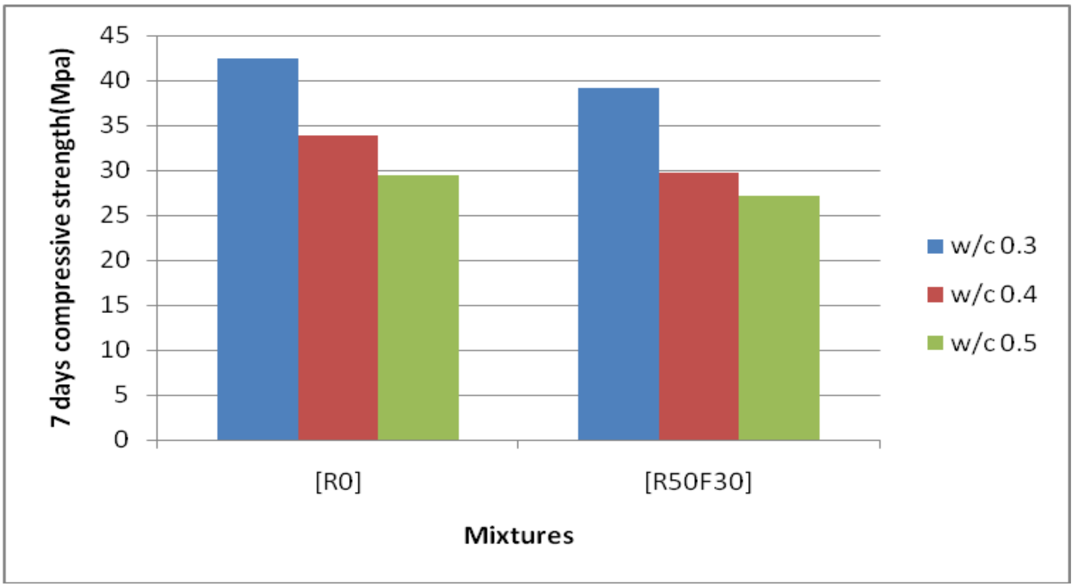


**Fig 7.5** Seven days compressive strength of concrete

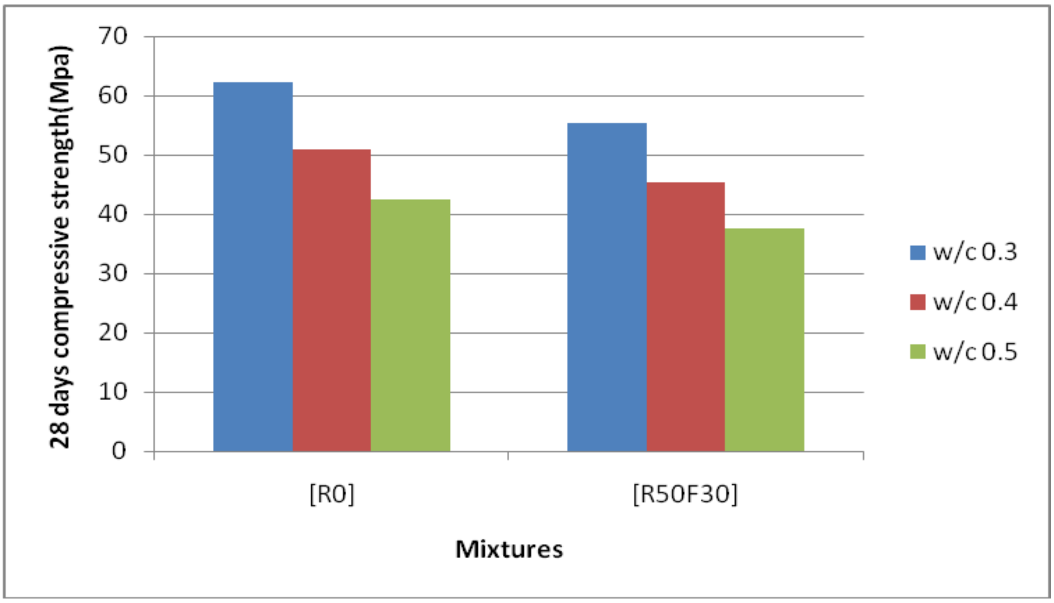


**Figure 7.6** Twenty eight days compressive strength of concrete

7.3 Split tensile strength

Split tensile strength of concrete was tested on 150mm X 300mm cylinder at the age of 28 days.The split tensile strength of the concrete mixture in series I -III are summarized in table 7.5. Study show that split tensile strength of all type of concrete decreases as the water cement ratio increases from 0.3 to 0.5.Conventional concrete with W/C ratio of 0.3 gives maximum split tensile strength of 4.91MPa and green concrete [R50F30] with W/C ratio of 0.5 gives the minimum split tensile strength of 2.72 MPa.

The green concrete mixture and the results shows that split tensile strength of Green concrete [R50F30] decreased by 15 to 22% compared to conventional concrete [R0]. Hence the incorporation of flyash in green concrete [R50F30] decreased the tensile strength of concrete compared to conventional concrete [R0].

**Table 7.5** Results of split tensile strength for W/C of 0.3

| Concrete type | No. of Specimens | Split tensile strength (Mpa) |
|---|---|---|
| Conventional concrete[R0] | 3 | 4.91 |
| Green concrete [R50F30] | 3 | 3.85 |

**Table 7.6** Results of split tensile strength for W/C of 0.4

| Concrete type | No. of Specimens | Split tensile strength(Mpa) |
|---|---|---|
| Conventional concrete[R0] | 3 | 3.75 |
| Green concrete [R50F30] | 3 | 3.1 |

**Table 7.7** Results of split tensile strength for W/C of 0.5

| Concrete type | No. of Specimens | Split tensile strength (Mpa) |
|---|---|---|
| Conventional concrete[R0] | 3 | 3.25 |
| Green concrete [R50F30] | 3 | 2.72 |

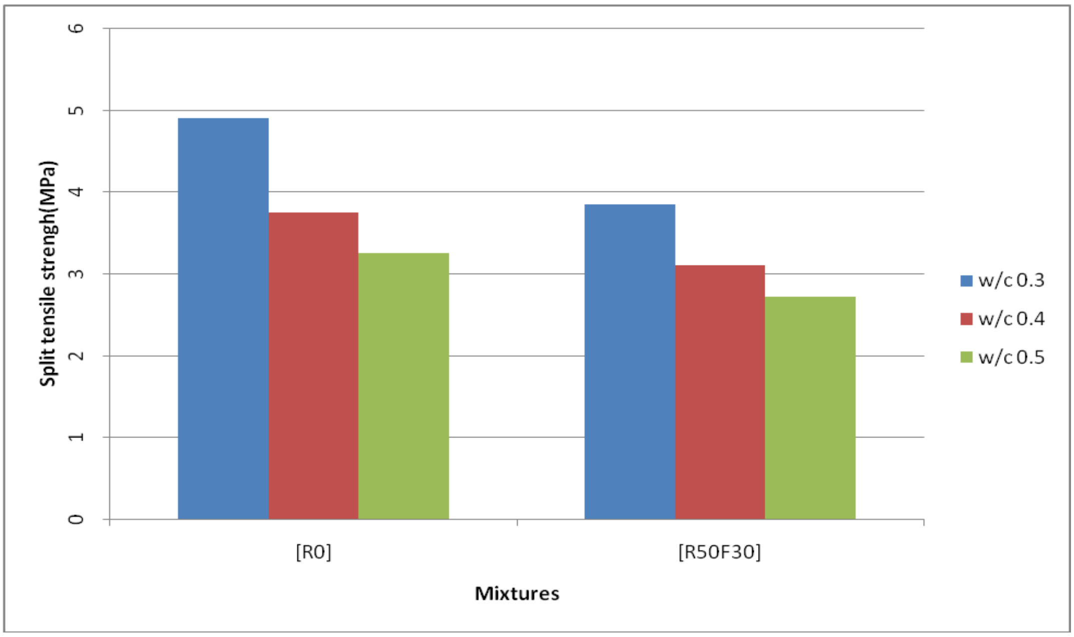


**Figure 7.7** Twenty eight days split tensile strength

## VIII. Conclusions

From the results of the experimental study, following conclusions can be made:

1. Results show that conventional concrete mixture with W/C of 0.5 had a relatively high slump of 150mm. Further concrete mix R50F30 with W/C ratio of 0.3 shows the lowest slump of 75mm. workability of the green concrete is less compared to the conventional concrete.
2. The study shows that Green concrete compressive strength is 10 to 12% lesser than conventional concrete. The decrease in compressive strength can be compensated by a decreasing the W/C ratio.
3. Results shows that Split tensile strength of Green concrete [R50F30] decreased by 18 to 20% compared to conventional concrete [R0].
4. To assess the economical physibility and availability of concrete ingredients.

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