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A Study on Reduction of Carbon Footprint by Partial Replacement of Cement with Kiln Dust and Blast Furnace Slag

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ABSTRACT
The utilization of eco-friendly waste by-product of the various industries instead of using raw cement and aggregates in the production of concrete is very common these days. The obtained concrete is eco-friendly in so many ways and is called as Green Concrete as it helps in reducing the detrimental impacts of normal concrete. In current study, different replacement concrete mixes of M35 were produced by replacing concrete with varying proportion of cement kiln dust (10%, 15% and 20%) and Blast Furnace Slag (10%, 20% and 30%) by weight and strength parameters i.e. compressive, split tensile and flexural strength of control and replacement concrete at 7 and 28 days were determined along with the water absorption and reduction of carbon footprint.

***Keywords**: Replacement Concrete, Bagasse Ash, Ceramic Waste.*

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I. INTRODUCTION

The utilization of eco-friendly waste by-product of the various industries instead of using raw cement and aggregates in the production of concrete is very common these days. The obtained concrete is eco-friendly in so many ways and is called as Green Concrete as it helps in reducing the detrimental impacts of normal concrete. The invention of green concrete was made when the problem of using the raw materials in concrete arises as these raw materials were polluting the environment in one way or the other. The green concrete is manufactured with a proper mix design in such a manner that a sustainable concrete is obtained with a adequate strength and durability. The energy saving, reduction in carbon dioxide emissions, disposal of waste materials from the industry are some of the basic advantages of using green concrete.

There are set of specifications set by the authorities that a green concrete must comply with and these are as follows:

- Reduction of CO2 emissions by at least 30 percent.
- Minimum of 20 % recycled aggregates in the production of the concrete shall be used.
- Utilization of its own by-product and waste product by the various industries.
- Utilization of the waste material that was earlier land filled or disposed in theenvironment.

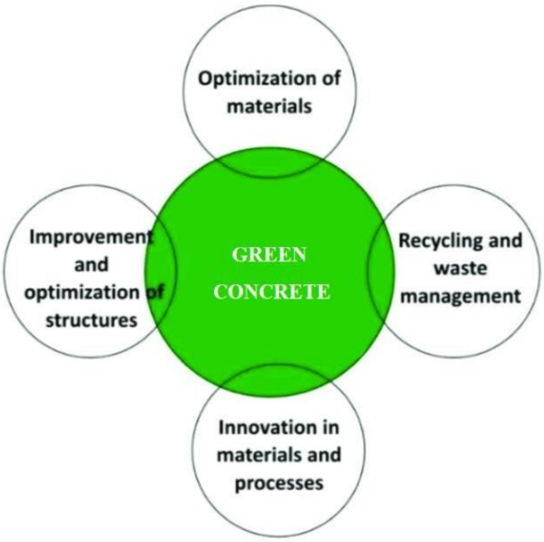

Figure 1. Characteristics of Green Concrete.

The measure of total carbon containing gases and methane into the atmosphere (greenhouse gas GHG) is called as carbon footprint caused by any individual industry or any other source. The carbon containing gases are released into the environment due to the burning of various fossil fuels used for manufacturing various products such as cement, goods, production and consumption of food etc. however, the total carbon print shall not be calculated exactly due to the insufficient data and information of various industries and consumption. The total carbon footprint from the emission of carbon containing gases and methane is approximately calculated from all the relevant sources, storages, and household products, population. The measure of total carbon containing gases and methane into the atmosphere (greenhouse gas GHG) is called as carbon footprint caused by any individual industry or any other source. The carbon containing gases are released into the environment due to the burning of various fossil fuels used for manufacturing various products such as cement, goods, production and consumption of food etc. however, the total carbon print shall not be calculated exactly due to the insufficient data and information of various industries and consumption. The total carbon footprint from the emission of carbon containing gases and methane is approximately calculated from all the relevant sources, storages, and household products, population.

VARIOUS CONCRETE MIX DESIGNATION:

Different designations of various concrete mixes are represented below:

Table: 1. Various Mix Designations.

Mix Designation	Cement Kiln Dust %	Blast Furnace Slag %
CM	0	0
M1	10%	10%
M2	10%	20%
M3	10%	30%
M4	15%	10%
M5	15%	20%
M6	15%	30%
M7	20%	10%
M8	20%	20%
M9	20%	30%

MATERIAL USED:

Cement: ordinary Portland cement of grade 43 shall be used confirming to IS: 8112. Various cement properties were determined through different laboratory tests and the result is shown inthe following table.

Table: 2. Physical Properties of OPC 43 grade.

Property	Cement
Unit weight, Kg/m3	3150
Specific gravity	3.15
Initial Setting Time (min.)	93
Final Setting Time (min.)	228

Fine Aggregates: crushed sand as fine aggregates was used in the current study. The determination of zone of the sand was carried out by sieve analysis as per the guidelines of IS: 383-1970. The various results of fine aggregates are mentioned below:

Table: 3. Physical Properties of Fine Aggregates

Test	Value Obtained
Specific Gravity	2.55
Fineness Modulus	2.32
Silt Content	4.37 %

Coarse aggregates: Crushed, angular normally having a nominal size 20mm and 10mm were combined with the predefined gradation ratio of 2:1 as a coarse aggregate. Different laboratory tests were carried out and the results are mentioned below:

Table: 4. Physical Properties of Graded Coarse Aggregates

Test	Results
Specific Gravity	2.74
Water Absorption	0.58 %

Replacement material: (cement kiln dust and Blast Furnace slag): Replacement materials were collected from local source which passes from 75micron sieve to replace the cement in concrete. The specific gravity of cement kiln dust and blast furnace slag is 3.10 g/cc and 3.02 g/cc.

Table: 5. Chemical Composition of cement kiln dust.

S. No.	Composition	Proportion (%)
1.	SiO_2	15.41
2	Al_2O_3	3.84
3	Fe_2O_3	2.85
4	CaO	42.09
5	MgO	1.49
6	Loss of ignition	3.9

Table: 6. Chemical Composition of Blast Furnace Slag.

S. No.	Composition	Proportion (%)
1.	SiO_2	37.07
2	Al_2O_3	8.54
3	Fe_2O_3	1.51
4	CaO	44.58
5	MgO	7.86

II. RESULTS AND DISCUSSION COMPRESSIVE STRENGTH TEST:

The cubical samples of various concrete mixes were tested for compressive strength andresults are shown below in tables and figures.

Table: 7. Compressive Strength Test Results.

Mix Designation	At 7 days	At 28 days
CM	29.53	43.51
M1	30.49	45.09
M2	29.98	44.48
M3	29.85	43.98
M4	31.06	45.59
M5	30.19	44.85
M6	29.53	43.92
M7	29.66	43.97
M8	29.17	43.28
M9	28.75	42.58

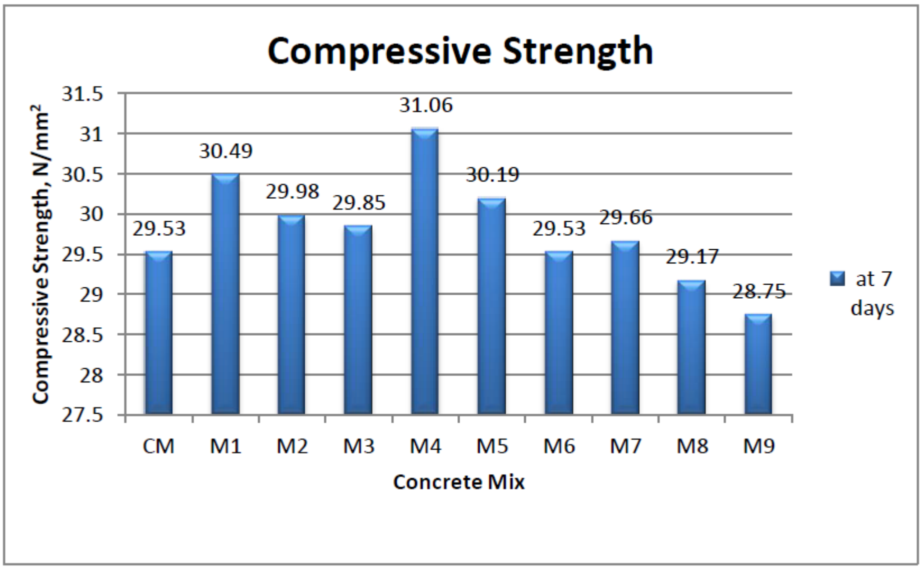

Figure 2. Results of compressive strength at 7 days.

The compressive strength at 7 days of control mix comes out to be 29.53 N/mm2. Whereas, the C.S of M1, M2, M3, M4. M5, M6, M7, M8 and M9 at 7 days comes out to be 30.49 N/mm2,29.98 N/mm2, 29.85 N/mm2, 31.06 N/mm2, 30.19 N/mm2, 29.53 N/mm2, 29.66 N/mm2, 29.17 N/mm2 and 28.75 N/mm2 respectively.

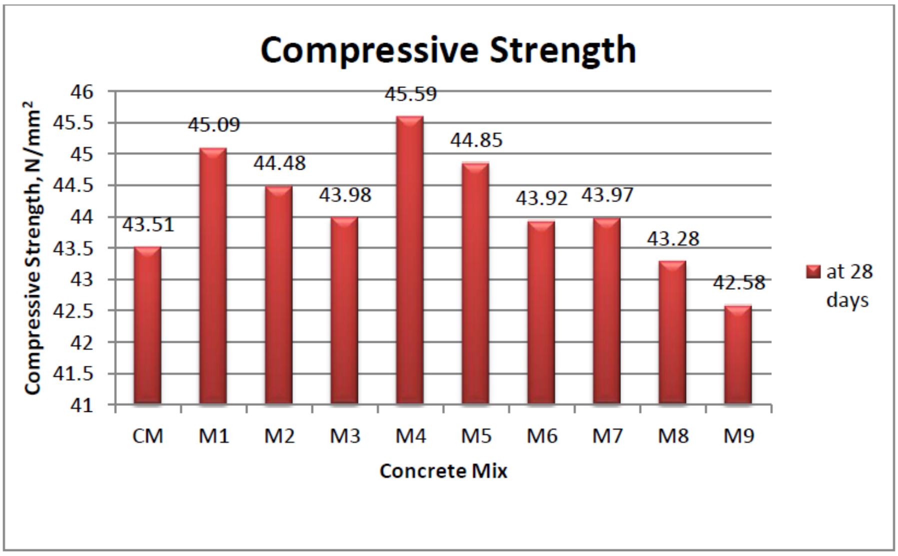

Figure 3. Results of compressive strength at 28 days.

The compressive strength at 28 days of control mix comes out to be 43.51 N/mm2. Whereas, the C.S of M1, M2, M3, M4. M5, M6, M7, M8 and M9 at 28 days comes out to be 45.09 N/mm2, 44.48 N/mm2, 43.98 N/mm2, 45.59 N/mm2, 44.85 N/mm2, 43.92 N/mm2, 43.97 N/mm2, 43.28 N/mm2 and 42.58 N/mm2 respectively.

Split Tensile Strength:

The cylindrical samples of various concrete mixes were tested for Split Tensile Strength and results are shown below in tables and figures.

Table: 8. Split Tensile Strength Test Results.

Mix Designation	At 7 days	At 28 days
CM	2.31	3.53
M1	2.68	3.95
M2	2.61	3.84
M3	2.49	3.71
M4	2.79	4.08
M5	2.69	3.86
M6	2.56	3.79
M7	2.47	3.71
M8	2.38	3.58
M9	2.19	3.42

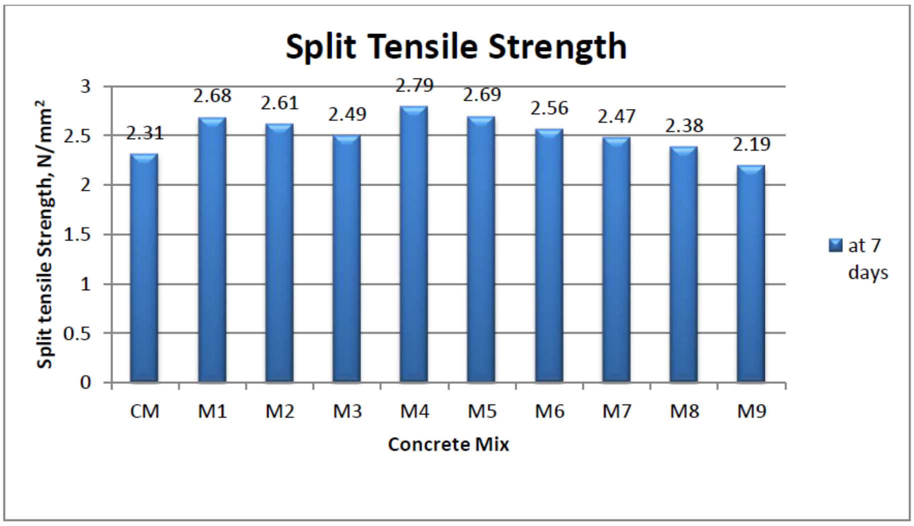

Figure 4. Results of Split Tensile Strength at 7 days

The S.T.S at 7 days of control mix comes out to be 2.31 N/mm2. Whereas, the S.T.S of M1, M2, M3, M4. M5, M6, M7, M8 and M9 at 7 days comes out to be 2.68 N/mm2, 2.61 N/mm2, 2.49 N/mm2, 2.79 N/mm2, 2.69 N/mm2, 2.56 N/mm2, 2.47 N/mm2, 2.38 N/mm2 and 2.19 N/mm2 respectively.

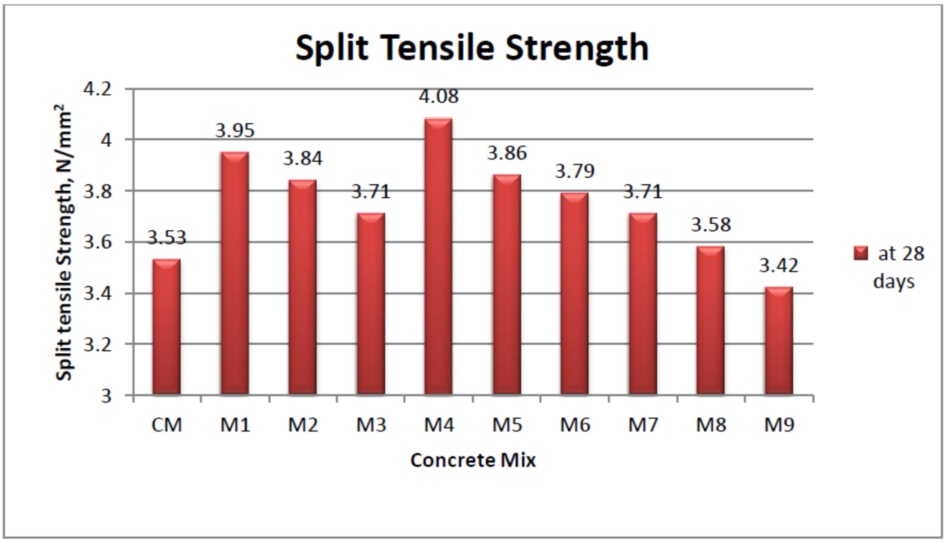

Figure 5. Results of Split Tensile Strength at 28 days.

The S.T.S at 28 days of control mix comes out to be 3.53 N/mm2. Whereas, the S.T.S of M1, M2, M3, M4. M5, M6, M7, M8 and M9 at 28 days comes out to be 3.95 N/mm2, 3.84 N/mm2, 3.71 N/mm2, 4.08 N/mm2, 3.86 N/mm2, 3.79 N/mm2, 3.71 N/mm2, 3.58 N/mm2 and 3.42 N/mm2 respectively.

Flexural Strength:
The beam samples of various concrete mixes were tested for Flexural Strength and results are shown below in tables and figures.

Table: 9. Flexural Strength Test Results.

Mix Designation	At 7 days	At 28 days
CM	3.51	5.21
M1	3.79	5.68
M2	3.71	5.53
M3	3.65	5.46
M4	3.97	5.82

M5	3.81	5.69
M6	3.7	5.51
M7	3.68	5.39
M8	3.56	5.25
M9	3.41	5.08

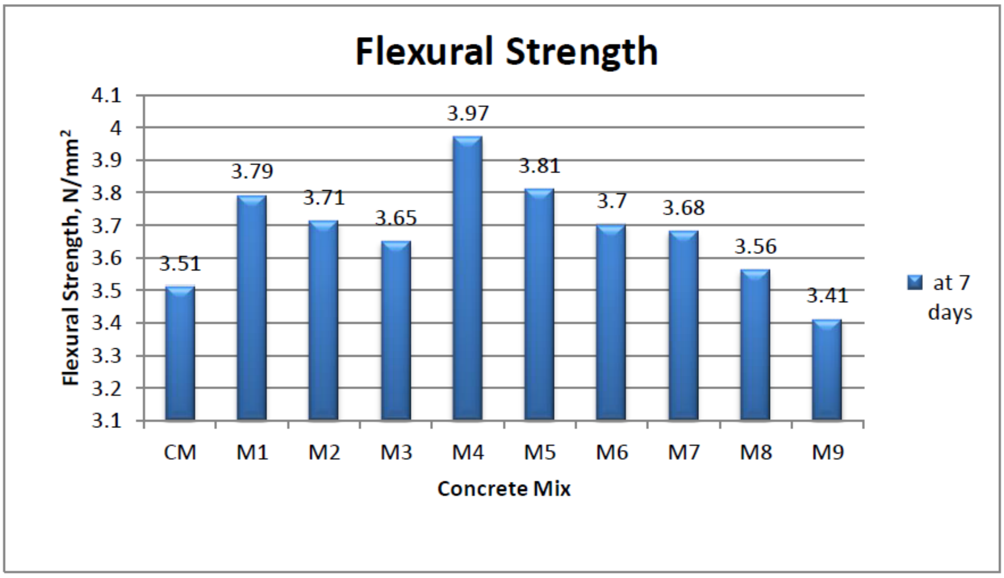

Figure 6. Results of Flexural Strength at 7 days.

The F.S at 7 days of control mix comes out to be 3.51 N/mm2. Whereas, the F.S of M1, M2, M3, M4. M5, M6, M7, M8 and M9 at 7 days comes out to be 3.79 N/mm2, 3.71 N/mm2, 3.65 N/mm2, 3.97 N/mm2, 3.81 N/mm2, 3.70 N/mm2, 3.68 N/mm2, 3.56 N/mm2 and 3.41 N/mm2 respectively.

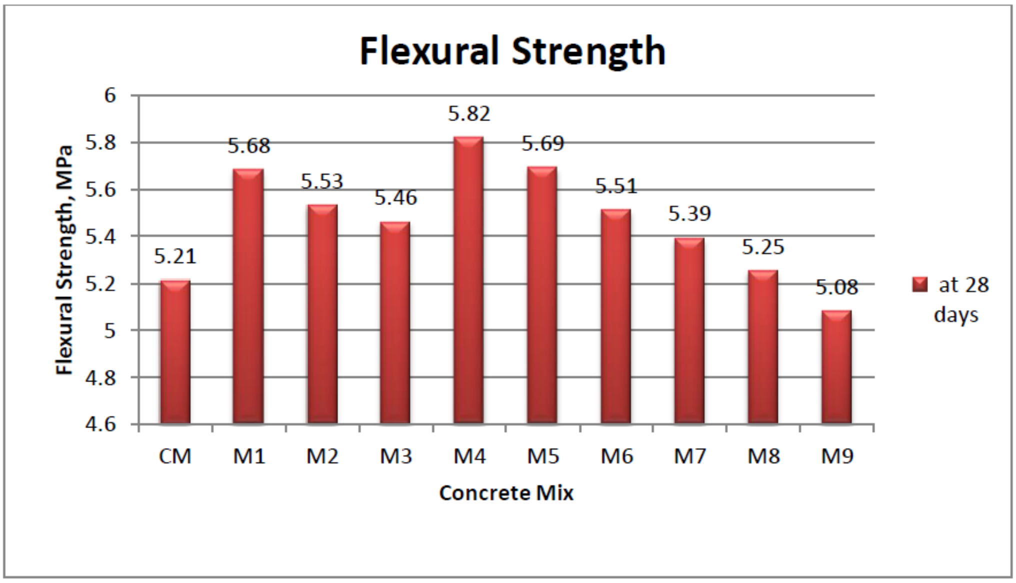

Figure 7. Results of Flexural Strength at 28 days.

The F.S at 28 days of control mix comes out to be 5.21 N/mm2. Whereas, the F.S of M1, M2, M3, M4. M5, M6, M7, M8 and M9 at 28 days comes out to be 5.68 N/mm2, 5.53 N/mm2, 5.46 N/mm2, 5.82 N/mm2, 5.69 N/mm2, 5.51 N/mm2, 5.39 N/mm2, 5.25 N/mm2 and 5.08 N/mm2 respectively.

Water Absorption Test:
The cubical samples of various concrete mixes were tested for water absorption and resultsare shown below in tables and figures.

Table: 10. Water Absorption Test Results.

Mix Designation	% water Absorption
CM	2.62
M1	2.54
M2	2.43
M3	2.33
M4	2.41
M5	2.28
M6	2.20
M7	2.27
M8	2.15
M9	2.06

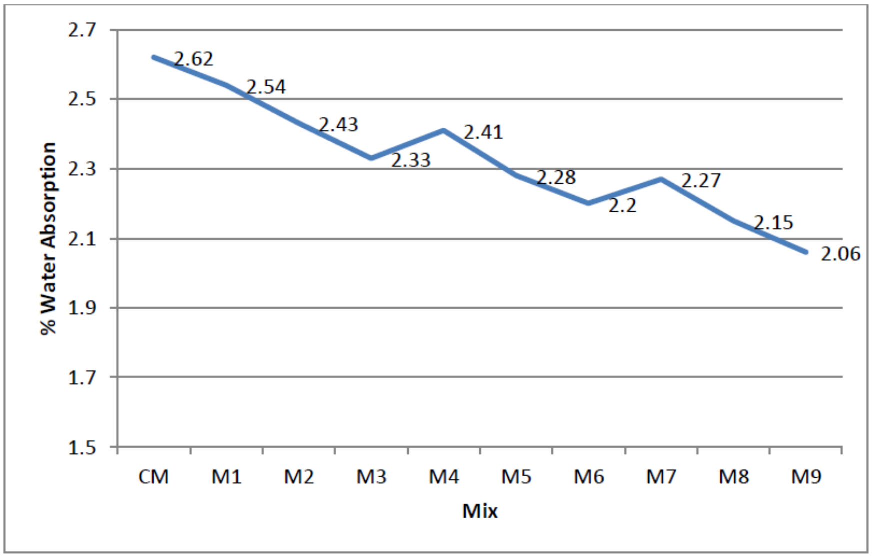

Figure 8. Water Absorption Test Results.

The % water Absorption of control mix comes out to be 2.62%. Whereas, the % water absorption of M1, M2, M3, M4. M5, M6, M7, M8 and M9 is 2.54%, 2.43%, 2.33%, 2.41%, 2.28%, 2.20%, 2.27%, 2.15% and 2.06% respectively.

Reduction in Carbon Footprint and Other Environmental Benefits:
The cubical samples of various concrete mixes were tested for water absorption and results are shown below in tables and figures
Almost all the modified concrete mixes showed enhanced strength properties. After calculating the total cement replacement percentage in all the mixes (shown in table), the reduction of carbon footprint was calculated for a RCC structure.

Table: 11. Total Cement Qty replaced with Cement kiln Dust (CKD) and Blast Furnace Slag(BFS).

Mix Designation	Total Cement Qty replaced with CKD andBFS
CM	-
M1	20%
M2	30%

M3	40%
M4	25%
M5	35%
M6	45%
M7	30%
M8	40%
M9	50%

According to [10] it has been concluded that for every 1 ton of cement production, almost 0.8 tones of CO2 is being released into the environment. Therefore, to reduce the production of carbon dioxide from the cement factory, the utilization of raw cement should be decreased. And in this current study, the cement is partially replaced with cement kiln dust and blast furnace slag ranging from 20% to 50%. For 8 storey RCC building, the total quantity of concrete required is approximately 1368 cumec [18]. If the partial amount of cement used in the construction of this 7 storey RCC building was replaced with cement kiln dust and blast furnace slag then we can calculate the reduction of carbon footprint. The calculation of the amount of reduction in carbon footprint is as follows:

As per the mix design calculation of concrete grade of M35, the quantity of cement for 1 cumec of concrete was 406kg/m3. Now, for 1368 cumec of concrete, total quantity of cement for 8 storey building comes out to be 1368*406 = 555408 kg, or 555.5 tons. Therefore, now if this cement is partially replaced with the substitute materials then the remaining quantity of the cement along with the reduction of carbon footprint will be calculated. (Refer table).

Table: 12. Total Reduction in Carbon Footprint for 8 storey RCC building.

Mix Designation	Total cement qty of 8 storey building (tons)	Total Cement Qty replaced %	Total cement quantity reduced (tons)*	Total reduction incarbon footprint (tons)**
CM	555.5	-	-	-
M1	555.5	20%	111.1	88.9
M2	555.5	30%	166.7	133.4
M3	555.5	40%	222.2	177.8
M4	555.5	25%	138.9	111.1
M5	555.5	35%	194.5	155.6
M6	555.5	45%	250.0	200.0
M7	555.5	30%	166.7	133.4
M8	555.5	40%	222.2	177.8
M9	555.5	50%	277.8	222.2

*Total cement quantity reduced (tons) = total cement qty in 8 storey building * replacement percentage of cement.

**Total reduction in carbon footprint (tons) = 0.8 * Total cement quantity reduced (tons)

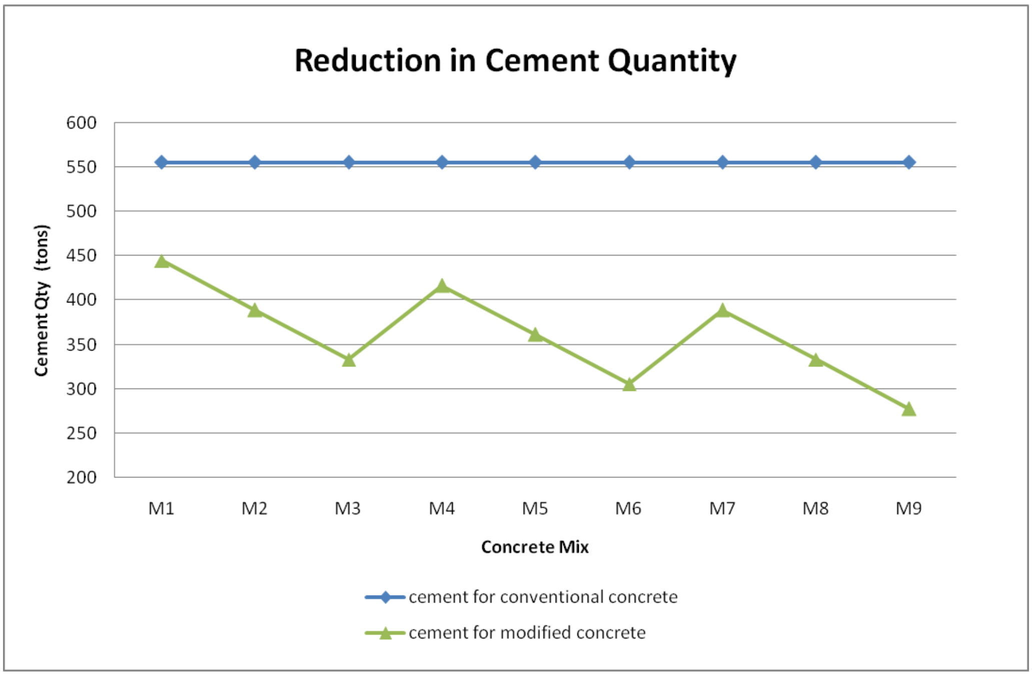

Figure 9. Reduction in Cement Quantity for modified concrete.

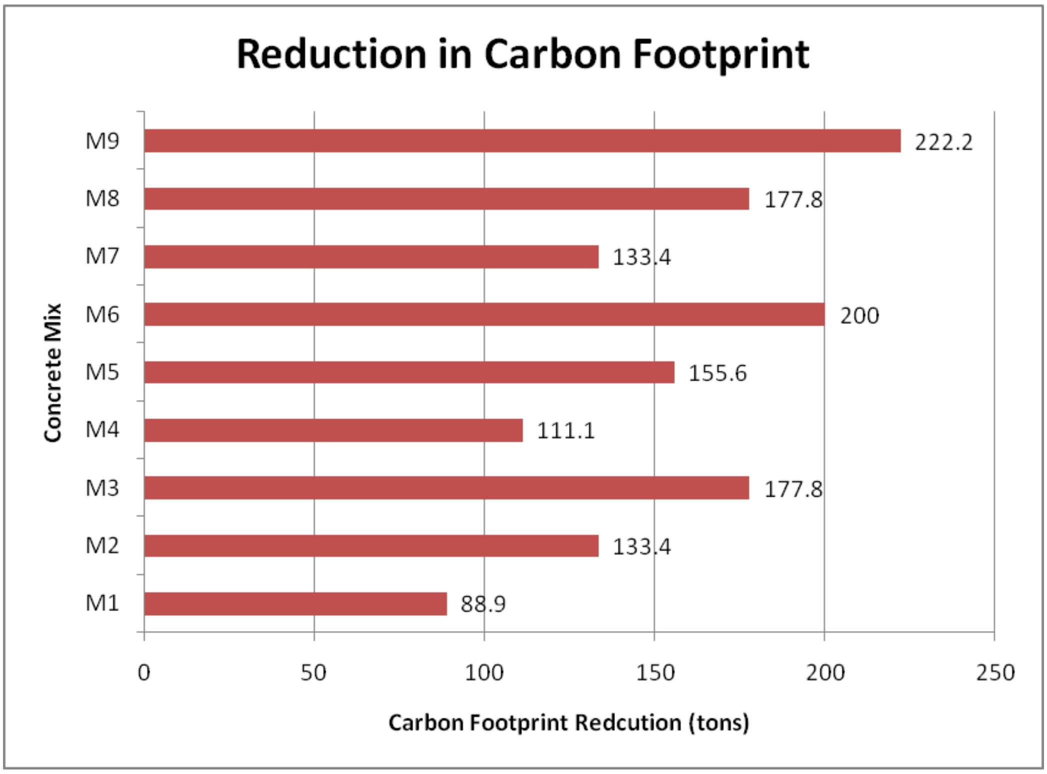

Figure 10. Reduction in Carbon Footprint for all the modified concrete mixes.

From the above fig., it is observed that the maximum reduction in carbon footprint i.e. 222.2 tons can be seen for M9 concrete mix where 50% of the cement was replaced with CKD and Blast furnace slag. However, the results of M9 mix slightly decreased as compared to the control mix. Therefore, M4 showed the maximum improved results and reduction in carbon footprint for M4 mix is 111.1 tons.

The other environmental benefits of using the alternate cementitous materials cement kiln dust and blast furnace slag instead of raw cement apart from reduction in carbon footprint areas follows:

1. Significant reduction in the landfills of the waste materials from various industries which alleviates the disposal problem. This also leads to the reduction of cost used for handling landfills and its disposal. Moreover,

the land used for landfills is also reduced.
2. Reduction of environmental pollution.
3. Minimizing the usage of raw and natural resources and reduce the burden onenvironment therefore, conservation of natural resources.
4. Reduction in energy consumption in the process of cement manufacturing andgreenhouse gases up to 60%.
5. More economical as it involves the waste materials/end by-product which is cheaperthan cement.

III. CONCLUSION

The final conclusions which have been drawn for the present study are as follows:
1. The percentage increase/decrease in the compressive strength of concrete mix M1, M2, M3, M4. M5, M6, M7, M8 and M9 at 28 days were +3.63%, +2.23%, +1.08%, +4.78%, +3.08%, +0.94%, +1.06%, -0.53% and -2.14% respectively. Therefore, maximum compressive strength was shown by M4 concrete mix.
2. The percentage increase/decrease in the Split tensile strength of concrete mix M1, M2, M3, M4. M5, M6, M7, M8 and M9 at 28 days were +11.90%, +8.78%, +5.10%, +15.58%, +9.35%, +7.37%, +5.10%, +1.42% and -3.12% respectively. Therefore, maximum Split tensile strength was shown by M4 concrete mix.
3. The percentage increase/decrease in the Flexural strength of concrete mix M1, M2, M3, M4. M5, M6, M7, M8 and M9 at 28 days were +9.02%, +6.14%, +4.80%, +11.71%, +9.21%, +5.76%, +3.45%, +0.77% and -2.50% respectively. Therefore, maximum Flexural strength was shown by M4 concrete mix.
4. The percentage increase/decrease in the water absorption of concrete mix M1, M2, M3, M4. M5, M6, M7, M8 and M9 at 28 days were -3.05%, -7.25%, -11.07%, - 8.02%, -12.98%, -16.30%, -13.36%, -17.94% and -21.37% respectively.
5. The results revealed that the higher the percentage of cement replacement with cement kiln dust and blast furnace slag, the lesser the enhancement in the mechanical properties of modified concrete.
6. The maximum reduction in carbon footprint i.e. 222.2 tons can be seen for M9 concrete mix where 50% of the cement was replaced with CKD and Blast furnace slag. However, the results of M9 mix slightly decreased as compared to the control mix. Therefore, M4 showed the maximum improved results and reduction in carbon footprint for M4 mix is 111.1 tons.

Therefore, it is suggested to use the 15% of cement kiln dust and 10% of blast furnace slag by replacing the raw cement as it showed the maximum results of the current experimental study.

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