COMPRESSIVE STRENGTH STUDY OF GREEN CONCRETE BY USING FERROCK

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ABSTRACT:

As a part of development, rate of building construction is also high, so it means there is lots of use of concrete. It has been observed that 0.9 tons of CO_2 is produced per ton of cement production. Thus, by the use of green concrete it is possible to reduce the CO_2 emission in atmosphere towards eco-friendly construction. In this project there is replacement of cement with the percentage of ferrock. Ferrock is a waste material of steel and having a tensile property. In this M20 Grade concrete is used and for that the mix design was done having the different composition of cement, Fine Aggregate, Coarse Aggregate, Ferrock and Water. The cubes are tested after the curing duration of 7 days, 28 days, and 56 days. In this research work, there was replacement of the cement with the ferrock having a percentage variation 5%, 10 %, 15%, 20%. With the replacement of cement with ferrock it was found that compressive strength of the green concrete was increased, and durability of the concrete was also increased. Also, it was economical as ferrock is a waste material which is available free of cost, so it reduced the overall cost of the work. Also, the Ferrock has a property to absorb the Carbon dioxide from the environment so it is also reducing the air pollution.

Keywords: Green Concrete, Concrete Mix Design, Ferrock, Carbon Dioxide, Compressive Strength.

1. INTRODUCTION

India is a developing country and due to this reason various construction work is going on. The main material which is used as construction work in India is Cement. Cement is responsible for the huge production of carbon dioxide in the environment. This huge production of carbon dioxide in the environment leads to the environment problems such as air pollution, skin disease, respiratory problems, global warming, climate change etc. Green concrete does not have any relation with the green colour. Green concrete means to protect the environment by using the waste product in a constructive way. Ferrock is created from waste steel dust (which would normally be thrown out) and silica from ground up glass, which when poured and upon reaction with carbon dioxide creates iron carbonate which binds carbon dioxide from the atmosphere into the Ferrock. Ferrock are tensile in nature which leads to increase in the compressive strength and durability of the green concrete.

2. OBJECTIVES

Following are the objectives of this research work:

- To study the effect of Ferrock on the Environment.
- To study the effectiveness of concrete by the partial replacement of the cement with ferrock.
- To determine the compressive strength of new mix design of grade M 20.
- To determine the test result for the compressive strength of green concrete.
- To determine the optimum percentage of ferrock in cement so that we can achieve maximum compressive strength.

3. RESEARCH METHODOLOGY

To fulfil the above objectives following research methodology is applied:

- To do the literature review on the green concrete.
- To do the deep study of the different ingredients of the green concrete.
- To do the Mix Design for M 20 Concrete as per the Indian Codal Provisions.
- To cast cubes by using different ingredients as per the Indian Standards.
- To test the casted cubes for strength after 7, 28 and 56 days of curing respectively by performing compressive strength test.
- To compare between conventional concrete and green concrete based on various parameters.

4. LITERATURE REVIEW

Some of the research papers literature review are mentioned here. In this different researchers used the different material for the casting of green concrete in different proportions which is mentioned below and also shown the research gap (future work scope).

Table 1: Literature Review

Sr. No.	Paper Name	Literature Review	Research Gap
1.	High Volume Fly Ash Mixed Green Concrete For Civil Engineering Purposes[21].	Class F Fly ash is used for replacing the cement and M 30 grade of Concrete is used having a two different proportions of water i.e. 0.42 and 0.40 as per Indian Codal Provision. As per the Codal provision 25% of the cement content was replaced by Fly Ash. The samples are tested	In initial phase the compressive strength of green concrete is less as compare to the normal concrete and its flexural strength is also less.

		for a compressive strength at a duration of 28 days, 56 days, and 90 days. High volume fly ash added with green concrete was having higher strength and durability as compare to normal concrete.	
2.	Experimental Study on Green Concrete[20].	Addition of micro silica in cement reduces the air pollution. The optimum replacement of cement with silica 5 % to 15 % leads to increase in strength whereas 20 % replacement leads to the decrease in the strength. It gains more strength in less time as silica fume particle size is very small as compare to the cement. By replacing the fine aggregate with demolished brick will not lead to increase in strength of concrete but overall cost of the project will be reduced about 20 %.	Compressive strength of concrete is decreasing after the 15 % replacement of cement with silica. Silica is also the product which is responsible for the air pollution.
3.	Green Concrete: An Innovative Approach to Sustainable Development[8].	This paper deals with the usage of different by products such as fly ash, pozzocrete, used foundry sand etc. It also deals with finding out the compressive strength of the concrete when the cement is replaced by Pozzocrete P60 as 30 % by weight of cement and fine aggregate are replaced by foundry sand 10 %, 25 % and 50 % by weight of cement. This paper concludes that the use of Pozzocrete P 60 and foundry	The study on the impact of long-term properties of concrete such as creep, deflection, and shrinkage etc.

		sand in the form of partial replacement of cement and fine aggregate is quite feasible for strength.	
4.	A Review on the Study of Green Concrete[18].	It includes the convenience of the usage of various by products such as dust, fly ash, marble, plastic waste, marble granules, silica fumes, blast furnance slag etc. Use of such materials approximately 20 % of cement. Green concrete has greater strength and durability as compare to the conventional concrete.	The drawback of this work is it has less flexural strength, high water absorption, higher shrinkage, and creep.
5.	Green Concrete for Better Sustainable Development[19].	Waste material has a significant potential on green concrete. To manufacture economical and environment friendly concrete , the replacement of traditional ingredients of concrete by waste materials and by products plays a very important role . It gives opportunity to produce environment friendly concrete .	Did not considered the by-products effect on strength of the concrete.

5. MATERIAL USED

5.1 Cement

In this project work, 53 grade of Ordinary Portland Cement is used. As per the Indian Standard the different tests are done for the accuracy such as Fineness Test, Soundness Test, Consistency Test & Initial and Final Setting time. Apart from this the other things regarding cement are monitored such as color test, presence of lumps, adulteration test, temperature test, float tests, strength test and date of packaging. After the testing it was found that this cement can be used for the practical purpose.

5.2 Aggregate

Aggregate is one of the most important ingredient of the concrete which is responsible to provide the strength to the structure. To get the better result we used the angular aggregate and as per the Indian Codal Provisions we did the test such as crushing test, Abrasion test, Impact test, Soundness test, Shape test, Specific Gravity and Water Abosrption Test. In these test the sample is passed as per the Indian Codal Norms.

5.3 Ferrock

Ferrock is created from waste steel dust (which would normally be thrown out) and silica from ground up glass, which when poured and upon reaction with carbon dioxide creates iron carbonate which binds carbon dioxide from the atmosphere into the Ferrock. Compared to Portland cement (made from chalk and clay and resembling Portland stone in colour), which is one of the leading types in use throughout the world today, ferrock is actually five times stronger. It can withstand more compression before breaking and is far more flexible, meaning it could potentially resist the earth moment cause by seismic activity or industrial processes. One of the unique properties of ferrock is that it becomes even stronger in saltwater environments, making it ideal for marine base construction projects. And rather than emitting large amounts of CO2 as it dries, ferrock actually absorbs and binds it! These results in carbon-negative process that actually helps to trap greenhouse gases.

6. INDIAN CODAL PROVISIONS FOR CONCRETE MIX DESIGN

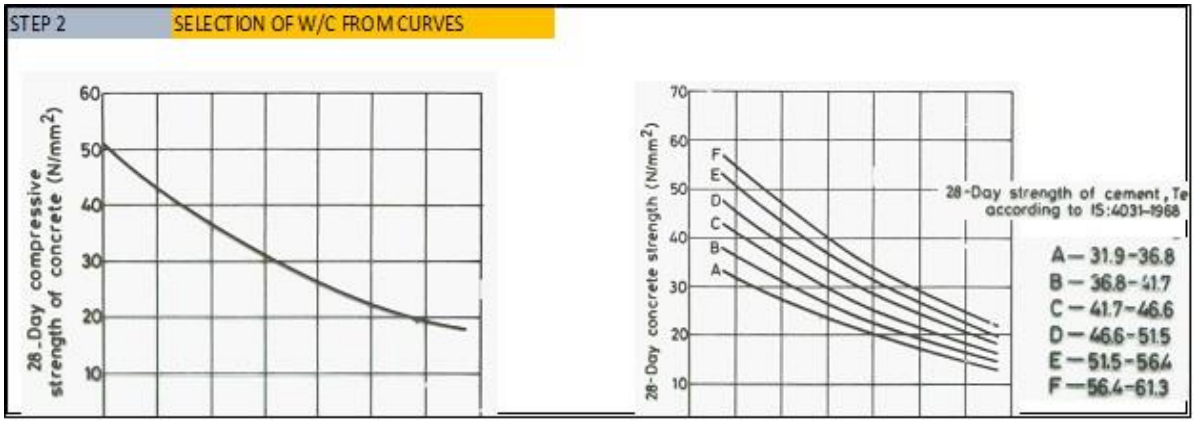
6.1 Step 1 : To Find the Standard Deviation as per Indian Standards

Table 2: Standard Deviation Value for M20 Grade Concrete

Step 1	f m = fck + 1.65s	
THE STANDARD DEVIATIONS ARE		
GRADE	**VALUE**	**UNIT**
M20-M25	4	MPA

6.2 Step 2: To Determine the W/C from Curves Provided in Indian Standards

Graph 1: Selection of W/C from Curves



6.3 Step 3: Water Content and Sand Contents for Concrete Grade up to M35

Table 3: Water Content and Sand Contents

M.S.A (MM)	W (KG/M3)	p = Fagg Vol. (% of total)
20	186	35

As per the Indian Standard for Concrete Mix:

- Fine Aggregate Zone = 2
- W/C = 0.6 upto M35
- W/C = 0.35 > M35
- Compaction Factor = 0.8

→ Estimate water content & sand content for concrete grades up to M35/ above M35 (Adjustments)

→ For change in values in water cement ratio, compaction factor and sand belonging to zone 3 the following adjustment required.

Table 4: Percentage of Sand in Total Aggregates

Change in Condition	Water Content	Percentage of sand in total aggregates
For decrease in water cement ratio	0	-2
(0.6 – 0.5) that is 0.1		
0.1/0.05*1 = 2.0		
For increase in compaction factor	3	0
(0.9 – 0.8) = 0.1		
For sand compacting to zone 3	3	-3.5

6.4 Step 4 : To Calculate the Cement Content and Aggregate Content as per IS

Calculate cement content, aggregate contents,

- w/c = Min (W/C_{curve} , $W/C_{durability}$)
- C = Max (W/w/c* , $C_{durability}$)

$$V = [W + C/S_C + 1/p \times F_{agg} / S_{Fagg}] \times 1/1000$$

$$V = [W + C / S_C + 1 / (1-p) \times C_{agg} / S_{Cagg}] \times 1/1000$$

Table 5: IS Requirements for RCC

IS requirement (RCC)			
Exposure	Min C	Max w/c	Min Grade
Mild	300	0.55	20

Where,

- MSA (MM) = 20
- Content (%) = 2

7. MIX DESIGN FOR M 20 GRADE CONCRETE AS PER INDIAN STANDARDS

7.1 Given Data

- Grade of concrete = M20
- Grade of cement = 53 N/mm^2
- Moderate exposure zone 3 sand
- Degree of workability = 0.9 C.F
- Max. size of aggregate = 20 mm
- Angular aggregate
- Degree of quality control = good
- Type of exposure = mild

7.2 Material Testing Data

- PPC 53 grade cement is used, with 28 days strength 51N/mm^2
- Specific gravity of cement = 3.15
- Bulk density = 1450 kg/m^3

Table 6: Properties of fine and Coarse aggregate

Aggregate	Fine aggregate	Coarse aggregate
S.G	2.66	2.75
Bulk density	1700	1800
Water absorption	1	0.5
Free moisture	2	NIL

7.3 To Find the Target Mean Strength for M 20 Concrete

Target mean strength (Fm) = fck + 1.65s

Fm = 26.6 N/mm^2 (MPA)

7.4 Selection of W/C from Curve

W/C = 0.5

7.5 Estimate Water Content and Sand Contents for M 20 Grade Concrete

For maximum size of aggregate of 20 mm, the air content is taken as = 2

Water = 186 kg/m^3

- Sand = 35 % of total aggregate by absolute volume
- Required water content = 191.58 lit / m^3
- Required sand content = 31.5 %

7.6 Determination of Cement Content

- Water cement ratio = 0.5
- Water = 191.58 lit. or kg
- Cement = 383.16 kg/m^3 > 300 kg/m^3 , therefore O.K.

7.6.1 IS Method

Calculate cement content, aggregate contents,

- w/c = Min (W/C_{curve} , $W/C_{durability}$)
- C = Max ($W/w/c^*$, $C_{durability}$)

$$V= [W+ C/S_C + 1/ p\times F_{agg} / S_{Fagg}] \times 1/1000$$

$$V = [W + C / S_C + 1 / (1-p)\times C_{agg} / S_{Cagg}] \times 1/1000$$

7.7 Determination of Fine Aggregate and Coarse Aggregate

- Consider volume of concrete = $1m^3$
- Entrapped air in wet concrete = 2%
- Volume of fresh concrete (V) = $0.98m^3$

With the quantities of water & cement per unit volume of concrete & the ratio of fine to total aggregate already determined, the total aggregate content per unit volume of concrete may be calculated from the following equations.

7.7.1 For Fine Aggregates

- Fine aggregate = 558.6966 kg mass of F.A.
- Coarse aggregate = 1256.05 kg mass of C.A.

Table 7: Quantity of Different Materials used for the Concrete

Name of the Material	Quantity in kg
Cement	383.16
Fine Aggregate	558.70
Coarse Aggregate	1256.05

Table 8 : Variation in the Quantity of Cement when it is Replaced with Ferrock

WHEN ADDED FERROCK (%) IN CEMENT (IT IS FOR 1 M3)					IT IS FOR =		0.003375	M3
% OF FERROCK	CEMENT (KG)	FERROCK (KG)	F.A. (KG)	C.A. (KG)	CEMENT (KG)	FERRPCK (KG)	F.A. (KG)	C.A. (KG)
0	383.16	0	558.7	1256.05	1.293	0	1.886	4.239
5	364.02	19.16	558.7	1256.05	1.229	0.065	1.886	4.239
10	344.84	38.32	558.7	1256.05	1.164	0.129	1.886	4.239
15	325.68	57.47	558.7	1256.05	1.099	0.194	1.886	4.239
20	306.52	76.63	558.7	1256.05	1.035	0.259	1.886	4.239
25	287.37	95.79	558.7	1256.05	0.97	0.323	1.886	4.239
30	268.21	114.95	558.7	1256.05	0.905	0.388	1.886	4.239
35	249.05	134.11	558.7	1256.05	0.841	0.453	1.886	4.239
40	229.89	153.26	558.7	1256.05	0.776	0.517	1.886	4.239
45	210.73	172.42	558.7	1256.05	0.711	0.582	1.886	4.239
50	191.58	191.58	558.7	1256.05	0.647	0.647	1.886	4.239
TOTAL	3161.05	1053.69	6145.7	13816.55	10.67	3.557	20.746	46.629

7.8 Proportion of Material as per the Mix Design for M20 Grade Concrete

Table 9: Proportions of Material

WATER	CEMENT	F.A.	C.A.	UNIT
0.28	1	1.458129	3.278136	KG

Table 10: Total Estimate of Quantity of Material used for the Making of Green Concrete Cubes

WATER (kg)	FERROCK (%)	CEMENT (KG)	FERROCK (KG)	F.A. (KG)	C.A. (KG)	NO. OF CUBES	TOTAL WEIGHT (kg)
12.49668	0	7.780498286	0	11.34497019	25.50553153	6	44.631
12.49668	1	7.702693303	0.077804983	11.34497019	25.50553153	6	44.631
12.49668	2	7.62488832	0.155609966	11.34497019	25.50553153	6	44.631
12.49668	3	7.547083337	0.233414949	11.34497019	25.50553153	6	44.631
12.49668	4	7.469278354	0.311219931	11.34497019	25.50553153	6	44.631
12.49668	5	7.391473372	0.389024914	11.34497019	25.50553153	6	44.631
12.49668	6	7.313668389	0.466829897	11.34497019	25.50553153	6	44.631
12.49668	7	7.235863406	0.544634888	11.34497019	25.50553153	6	44.631
12.49668	8	7.158058423	0.622439863	11.34497019	25.50553153	6	44.631
12.49668	9	7.08025344	0.700244846	11.34497019	25.50553153	6	44.631
12.49668	10	7.002448457	0.778049829	11.34497019	25.50553153	6	44.631
12.49668	15	6.613423543	1.167074743	11.34497019	25.50553153	6	44.631

12.49668	20	6.224398629	1.556099657	11.34497019	25.50553153	6	44.631
12.49668	25	5.835373714	1.945124571	11.34497019	25.50553153	6	44.631
12.49668	30	5.4463488	2.334149486	11.34497019	25.50553153	6	44.631
12.49668	35	5.057323886	2.7231744	11.34497019	25.50553153	6	44.631
12.49668	40	4.668298972	3.112199314	11.34497019	25.50553153	6	44.631
12.49668	45	4.279274057	3.501224229	11.34497019	25.50553153	6	44.631
12.49668	50	3.890249143	3.890249143	11.34497019	25.50553153	6	44.631
237.43692	GRAND TOTAL	123.3208978	24.5085696	215.5544335	484.6050991	114	

Table 11: Data of Green Concrete Cube

SIZE OF ONE CUBE	0.15	M^3
NUMBER OF CUBES	6	NOS.
WET VOLUME OF CUBE	0.03078	M^3
DENSITY OF CEMENT	1450	KG/M^3
WET MATERIAL	0.52	
DRY VOLUME OF CUBE	0.02025	
WATER CONTENT	0.28	

8. COMPRESSIVE STRENGTH TEST RESULT OF CUBES

Table 12: Compressive Strength of Cubes

SR. NO.	CUBE NO.	DAYS	STRENGTH (N/MM^2)	AVERAGE STRENGTH	FERROCK (%)
1	1	3	6.82	7.57	**0%**
	2		8.06		
	3		7.85		
	4	28	18.98	20.64	
	5		20.74		
	6		22.2		

	7	56	21.03	22.69	
	8		22.03		
	9		24.99		
2	1	7	15.44	15.07	**1%**
	2		14.65		
	3		15.13		
	4	28	20.15	20.76	
	5		21.53		
	6		20.62		
	7	56	26.43	27.19	
	8		25.25		
	9		29.91		
3	1	7	17.56	17.34	**2%**
	2		16.62		
	3		17.86		
	4	28	22.32	21.92	
	5		20.28		
	6		23.15		
	7	56	26.55	28.59	
	8		34.3		
	9		24.93		
4	1	7	18.27	19.92	**3%**
	2		18.92		
	3		22.58		
	4	28	21.97	22.09	
	5		22.56		
	6		21.75		
	7	56	24.8	27.13	
	8		28.91		
	9		27.7		
5	1	7	18.94	20.58	**4%**
	2		17.92		
	3		24.89		
	4	28	21.38	22.77	
	5		23.46		
	6		23.47		
	7	56	25.98	27.83	
	8		27.87		
	9		29.65		
6	1	7	19.02	21.09	**5%**
	2		20.29		
	3		23.98		
	4	28	22.56	23.47	
	5		22.98		

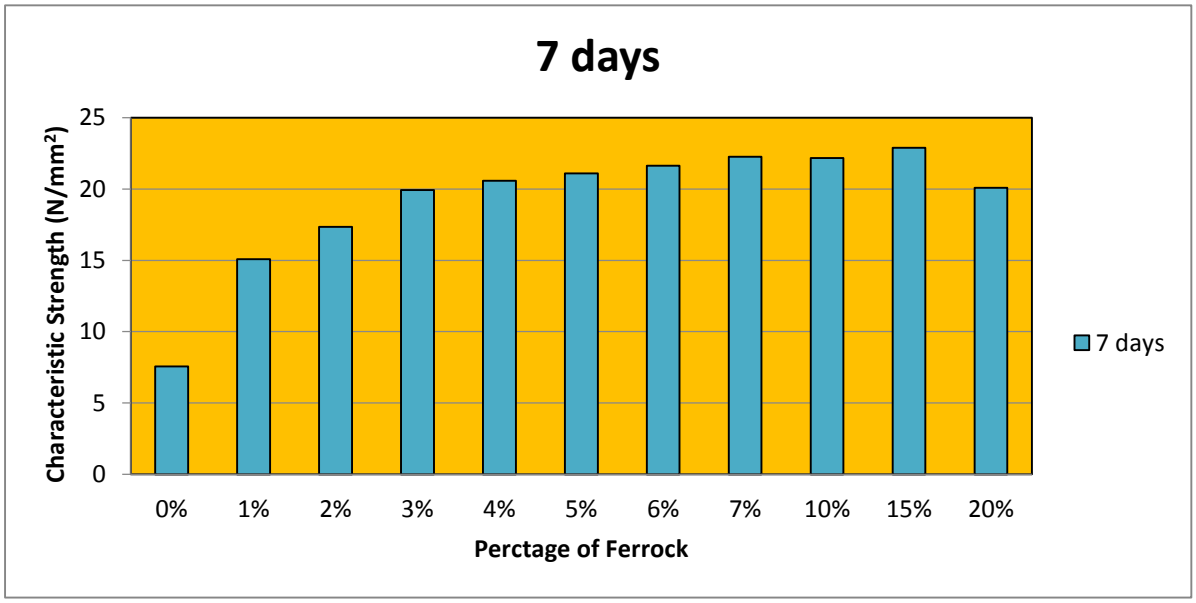
	6		24.89		
	7	56	26.87	28.44	
	8		28.67		
	9		29.78		
7	1	7	19.57	21.64	**6%**
	2		20.24		
	3		25.12		
	4	28	24.23	24.4	
	5		23.56		
	6		25.43		
	7	56	26.97	29.76	
	8		29.78		
	9		32.54		
8	1	7	20.76	21.81	**7%**
	2		22.81		
	3		22.87		
	4	28	25.46	25.62	
	5		24.64		
	6		26.76		
	7	56	28.23	31.24	
	8		30.74		
	9		34.76		
9	1	7	21.63	22.16	**10%**
	2		22.39		
	3		22.48		
	4	28	24.78	25.94	
	5		27.59		
	6		25.46		
	7	56	36.48	36.67	
	8		36.34		
	9		37.2		
10	1	7	22.35	22.88	**15%**
	2		23.54		
	3		22.75		
	4	28	29.33	30.78	
	5		28.56		
	6		34.46		
	7	56	33.16	34.86	
	8		36.53		
	9		34.89		
11	1	7	20.45	20.08	**20%**
	2		20.16		
	3		19.63		
	4	28	30.56	30.67	

	5		30.26		
	6		31.21		
	7		28.12		
	8	56	29.65	29.14	
	9		29.65		

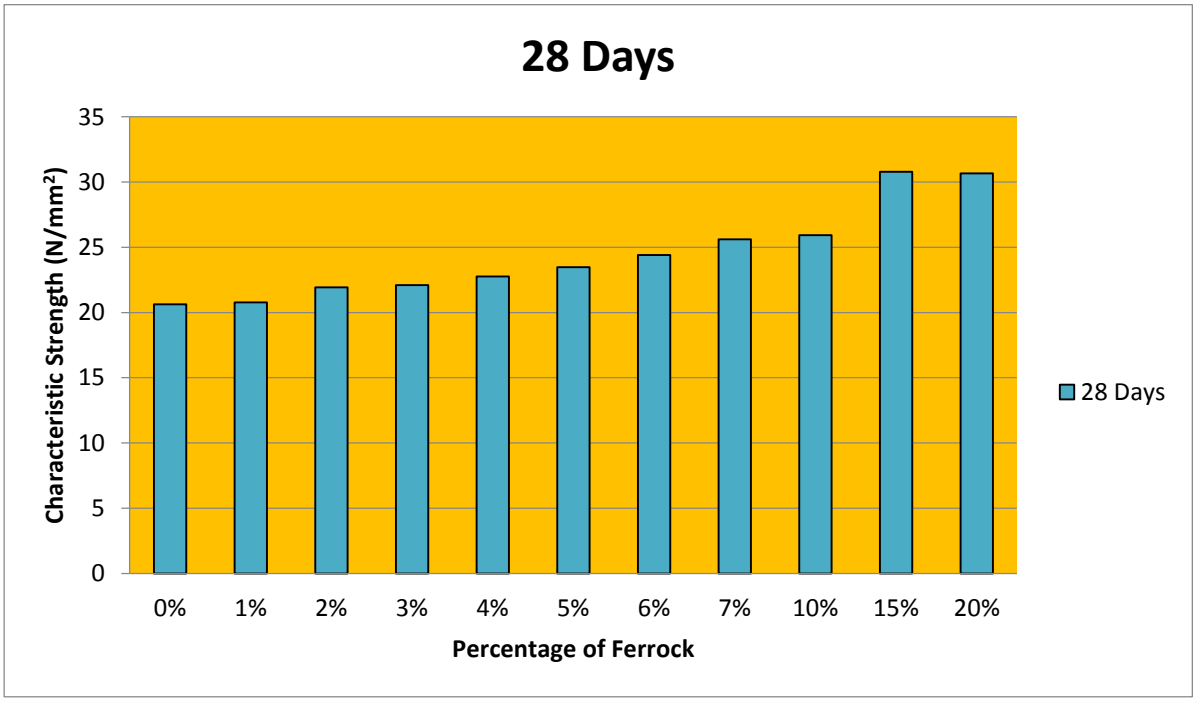
9. ANALYSIS OF THE RESULT

Following are the result analysis at different percentage of replacement of cement with ferrock at the different curing period of 7 days, 28 days, and 58 days.

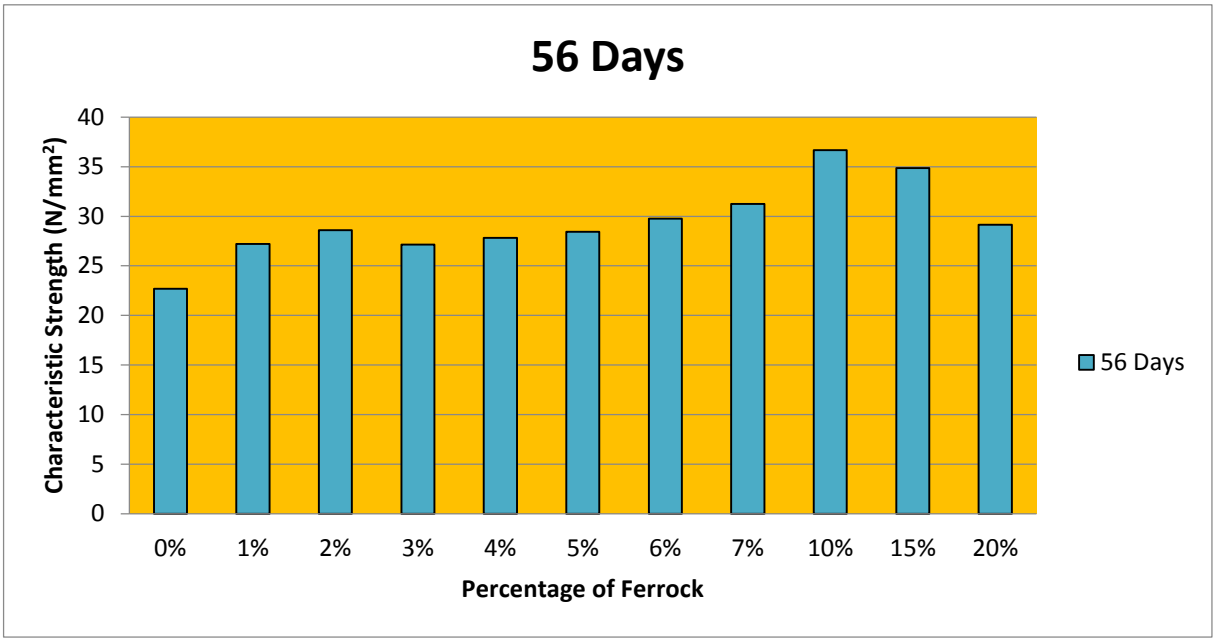
Graph 2: Compressive Strength of Green Concrete after 7 Days of Curing



Graph 3: Compressive Strength of Green Concrete after 28 Days of Curing



Graph 4: Compressive Strength of Green Concrete after 56 Days of Curing



10. CONCLUSION

- From Graph no.2, we get strength of concrete after 7 days:

Table 13: Compressive Strength of Green Concrete after 7 Days of Curing having a Varying % of Ferrock

% of Ferrock	0	1	2	3	4	5	6	7	10	15	20
Strength (N/mm^2)	7.57	15.07	17.34	19.92	20.58	21.09	21.64	22.25	22.16	22.88	20.08

- From Graph no.3, we get strength of concrete after 28 days:

Table 14: Compressive Strength of Green Concrete after 28 Days of Curing having a varying % of Ferrock

% of Ferrock	0	1	2	3	4	5	6	7	10	15	20
Strength (N/mm^2)	20.64	20.77	21.92	22.09	22.77	23.48	24.41	25.62	25.94	30.78	30.67

- From Graph no.4, we get strength of concrete after 56 days:

Table 15: Compressive Strength of Green Concrete after 56 Days of Curing having a Varying % of Ferrock

% of Ferrock	0	1	2	3	4	5	6	7	10	15	20
Strength (N/mm^2)	22.69	27.2	28.59	27.14	27.83	28.44	29.76	31.24	36.67	34.86	32.67

- Green concrete having reduced environmental impact with reduction of the concrete industries CO_2 emission by 30%.
- Green concrete is having good thermal and fire resistant.
- In this concrete recycling use of waste material such as ceramic wastes, aggregates, so increased, so increased concrete industry's use of waste products by 30%.
- Hence green concrete consumes less energy and becomes economical.
- So definitely use of concrete products like green concrete in future will not only reduce the emission of CO_2 in environment and environmental impact but also economical to produce.
- From the result it was concluded that compressive strength and durability of green concrete is more as compare to the conventional concrete up to 15 % replacement of cement with Ferrock and from 20% the compressive strength of concrete is decreasing.

11. FUTURE WORK SCOPE

Following are the future work scope of this work:

1. To do the parametric study based on the flexural strength of the green concrete.
2. To do the analysis with the help of software and to do parametric study based on that.
3. To do more research on ferrock as environment sustainable material.

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