

FERROCK: A COMPARATIVE STUDY TO ORDINARY PORTLAND CEMENT

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ABSTRACT

In this fast-growing world, people are focusing on the infrastructural development, where construction sector plays an important role. Cement is the most important material being used in construction industry that emits approximately 8-10% of the total carbon dioxide in the world during its production which is the major constituent of global warming. Thus, focusing on the carbon emission reduction and also utilization of the waste products for a better environment, a product named Fer-rock was constituted.

This paper is a review over a product that is stepping towards carbon negotiation and waste material management. It shows the best usage of iron ore waste powder obtained during the mining process that is just dumped away from the mines, causing air pollution, health hazards and also consuming larger area. The product indirectly reduces the carbon dioxide released by its unique strength gaining mechanism, which is in contrary with that of the cement and thus stands out among many other supplements of cement.

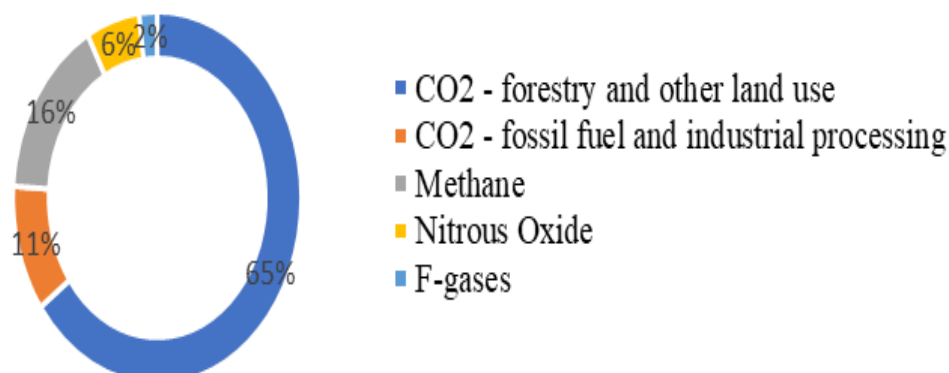
Fer-rock involves a curing process with carbonation and air curing in varied number of days for better strength in terms of compression, tensile strengths and achieving desirable properties. Fer-rock is thus a more promising eco-friendly binding material in terms of its carbon negotiation and in best usage of the waste of iron.

Keywords: Carbon footprint, cement replacement, waste management, ferrock, carbon negative

1. INTRODUCTION

Now a day's global warming is one of the major threats to our eco-system. Amongst the greenhouse gases leading to global warming, carbon dioxide is of the maximum percentage that is 76% is as shown in Fig. 1. Aiming to reduce the total percentage of carbon dioxide being emitted, analysis over the sources of it were done and sorted. Working on towards a greener environment, civil engineers are contributing by analyzing the carbon emitters and finding ways to solve it.

In this fast-growing world, infrastructure development is given more importance leading to a linear increase in constructions of multi-stories or high-rise buildings, roads, bridges, towers, etc... The most important material used in this construction is the cement. Cement is the binding material used to gain strength in order to sustain the loads applied on it. It is an artificially manufactured product which releases carbon dioxide in the process of its manufacture which contributes to the total environment by approximately 6 to 8% .



GENERAL

Concrete is the most utilized structural ingredient in all places. Roughly 1 ton of cement is created every year from each person on the planet. In view of the broad use, it is critical to assess the effects of this material in the environment precisely. These days, a material's ecological effect is assessed with its individual impact on ozone harming gas discharges and environmental change. From this perspective, the Green concrete idea was evolved. Globally, cement production is in charge of 5 to 7 percent of carbon dioxide generated. David Stone, a former PhD student at the University of Arizona (UA) Department of Soil, Water and Environmental Science has developed an alternative to Portland cement known as Ferrock. Ferrock is a binder that is a blend of Iron Powder, Fly ash, Lime Powder, Metakaolin and Oxalic acid. Oxalic acid acts as a catalyst and on reaction with CO₂ and water produces Iron Carbonates, which is the hardened product. It can enhance the environment by absorbing the atmospheric CO₂ for its hardening process. From studies, it is found that the optimum molarities of oxalic acid as catalyst was 10 moles and ferrock also absorbs considerable amount of CO₂ from the atmosphere and reduces the amount of CO₂ emitted from the industries. It's giving promising suggestions as a choice to concrete and a far greener construction material. Being environment friendly, Fer rock uses all the materials from scratch, waste metal powder, Limestone, Metakaolin and Fly ash. This concreting technology is far greener, stronger and durable compared to its predecessor

WHY CHOOSE FERROCK OVER CONCRETE?

Concrete is a tried and true product that has been used around for hundreds of years. But despite the extensive use of concrete, there is a good reason we should want to fit other possible building materials. Manufacturing concrete and cement-which is produced separately and is added to the concrete to make it firm up and bind together to form a hard shape-, releases a ton of carbon dioxide into the air. The reason why there's so much CO₂ is that cement has to be heated to extremely high temperature in order to break down the limestone, as in scorching 2,800°F (1537.778°C). That is, for 1000 kilograms of cement, 900 kilograms of carbon dioxide is released from the factories and into the air. In comparison, Ferrock which has been found to absorb carbon dioxide and fuse it into the matrix. The more CO₂ it consumes, the stronger it becomes. It seems like a no-brainer that we would want to use more of a product that can do the same things as concrete, but that cleans up our air too.

AIM

Cement is a widely used material in construction, but its production results in the emission of around 6-8% of the total carbon dioxide in the world, contributing significantly to global warming. To address this issue and promote better waste management, the Ferrock product was developed.

2 LITERATURE REVIEW

2.1 Kavita Singh

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 CO₂ is produced per ton of cement production. Thus, by the use of green concrete it is possible to reduce the CO₂ 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.

2.2 Jaison SelvarajSKI*,Dr G.Srinivasan2

Cement is the main component of concrete. It is very important in the construction industry. Despite this product, cement releases carbon dioxide. That's why iron ore is used instead of cement. Ferrock is an iron- based composite that is carbon neutral to cement and can be used to produce a variety of household products from various wastewaters. Ferrock is a binder made from a mixture of iron oxide powder, fly ash, lime powder, metakaolin and oxalic acid. Oxalic acid acts as a catalyst. Iron oxide reacts with carbon dioxide and water to form iron carbonate. It can improve the environment by absorbing atmospheric carbon dioxide for the hardening process. By using iron ore, you can reduce the emission rate of the most harmful greenhouse gases. During treatment, carbon dioxide is used instead of antibiotics. This helps reduce water consumption.

2.3 VidyaJose1,VasudevR2

Cement is considered as one of the prominent building materials used for construction. It is considered as the second most used entity next to water in the world today. Though it has many significant advantages, it has a major disadvantage of CO₂ emission. For every ton of cement generated more or less eight ton of CO₂ is released to the atmosphere. Hence it is high time to find a substitute for cement. Ferrock is such a substitute which utilizes a variety of waste products to produce a versatile building material. It is a binder that is a blend of iron oxide powder, fly ash, lime powder, metakaolin and oxalic acid. This review mainly focuses on characteristics, advantages and application of ferrock in building construction.

2.4 Sukhpreet SinghSaluja1,Dr VinayKumarCH2

Cement industry further going to grow at high speed with Government of India giving boost to infrastructure projects and housing facilities. As per the World business council for sustainable development (WBCSD, 2005) the cement industry produces 5% of global man-made carbon dioxide, a major gas contributing to climate change and responsible for global warming. A product called Ferrock was created as a result, concentrating on the reduction of carbon emissions as well as the utilization of waste materials for a better environment. This study examines this product that moves in the direction of waste reduction and carbon neutrality. It demonstrates the most effective use of iron ore waste powder obtained during the mining process, which is often dumped outside of the mines and causes air pollution, health risks, and bigger area use. By having a strength-gaining mechanism that is unlike cement's and unique among cement supplements, the product indirectly lowers the carbon dioxide discharged into the atmosphere. For greater strength in terms of compression and tensile strengths and to achieve desired qualities, ferrock is subjected to a curing process that includes carbonation and air curing over a range of days. Because it uses waste effectively and has a negative carbon footprint, ferrock is a more promising environmentally friendly binding material.

Keywords: Ferrock, waste management, cement replacement, and carbon negative are other related terms.

OBJECTIVES

1. To determine the compressive strength of Ferrock
2. To determine the mechanical properties of ferrock cement concrete using water curing and carbon dioxide curing.
3. To determine durability properties of ferrock cement concrete using water curing and carbon dioxide curing.
4. To compare curing of ferrock cement concrete using water curing and carbon dioxide curing.

3 METHODOLOGY

Ferrock is a mixture of iron dust, fly ash, lime powder, metakaolin, and oxalic acid that is used as a binder. It reacts with CO₂ and water, producing iron carbonates thanks to the action of an oxalic acid catalyst. During the hardening process, ferrock concrete absorbs carbon dioxide. 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.

Table No 01. Summary of raw materials required for ferrock manufacturing

Sr. No	Material	Percentage (by weight)	Specifications
1	Iron powder	60%	Waste metallic iron powder with a median particle size of 19.03 μm
2	Fly Ash or Glass	20%	Class F fly ash conforming to ASTM C618 or Ground glass particles
3	Limestone	10%	Lime stone powder (medium particle size of 0.7 μm) conforming to ASTM C 568
4	Metakaolin	8%	Conforming to ASTM C618
5	Weak Oxalic Acid	2%	Oxalic acid has been used as catalyst in previous research

Note 1: Water-to-solids ratio (w/s) of 0.24, with a range of 0.18 to 0.30, serving mainly as an agent of mass-transfer and does not chemically participate in the reaction.

Note 2: Fully cured samples contain between 8% and 11% of captured CO₂ by weight.

MANUFACTURING PROCESSES

The data derived from the manufacturing process of Ferrock is much less energy intensive than OPC because it does not require any heat to catalyze the curing process. Since Ferrock manufacturing only involves the blending and grinding of raw resources, for an industrial- scale manufacturing application the assumption is made that Ferrock will have the same energy values as the “finish, grinding and blending” phase of Ordinary Cement production, found in Huntzinger and Eatmon’s journal article, A life-cycle assessment of Portland cement manufacturing: comparing the traditional process with alternative technologies [3].

Based on this report, the associated environmental burden reported for this phase is estimated to be 170.2 MJ/tonne.

CASTING, HARDENING AND CURING

The machinery and methods used to cast an OPC-based structural material, like concrete, and a Ferrock- based structural material are generally the same. However, there are variable differences between the water-solid ratio for each compound and their relationship with CO₂. Also, OPC does not produce H₂ gas during curing.

Table No 02 Curing properties of ferrock & cement

	Ferrock	OPC
Water-Solid Ratio	0.18 to 0.30	0.40 to 0.70*
CO ₂	Absorbs CO ₂ in a ratio of 0.1 tonnes CO ₂ /tonne	No relationship during Curing
H ₂	17 kg H ₂ / tonne produced	No relationship during curing

ADVANTAGES

1. Carbon neutral-The rate of emission of CO₂ due to cement production in the industry is reduced.
2. While ferrock is in the liquid form, it uses carbon dioxide to help it harden. CO₂ fuses into the mixture, trapping the gas inside the rock as it turns into a solid. So in essence, Ferrock acts as a carbon dioxide filter, removing some of the CO₂ in atmosphere. It uses the absorbed CO₂ to form its final shape, a sheet of solid hard Ferrock.
3. Greenhouse gas emission-As CO₂ is used during the hardening process it helps reduce one of the most dangerous of greenhouse gases.
4. Durable-Ferrock can withstand temperatures over 1000°F (600°C), making it excellent for fireproofing or insulating when turned into foam.
5. Chemically inactive-They are considered chemically inactive, which means the material does not degrade when exposed to gases or chemicals, while concrete can deteriorate over time and exposure to chemicals.
6. For this reason Ferrock is used in marine construction, as it is immune to effects of saltwater. In fact, Ferrock actually gets more durable when exposed to seawater, so it’s excellent for underground environments.
7. It is also resistant to conditions like UV radiation, corrosion, rotting, rust, and oxidation, making it a viable option for pipes and tubes that are typically used for water transmission and wastewater removal.
8. Five times harder than concrete-As the experimental investigation concludes, it is evident that the strength of ferrock is five times that of conventional concrete. This means it can withstand more weight, compression, and damage without being destroyed.

LIMITATIONS

1. Ferrock involves high cost- It is believed that the material is more suitable for niche products but will not be a cost-effective solution for large-scale projects such as roads and highway developments.
2. Many industry believe that if the steel dust goes directly from being a waste to being a useful building material, the cost of producing Ferrock will be exponentially high, which makes the construction process all the more costlier.
3. As of now, Ferrock is not a popular construction material in India, going forward it is expected to become one of the crucial building materials with its multiple advantages surpassing its debated high- cost.
4. Availability of raw materials-Ferrock needs steel dust waste and silica, both of which are the by products or leftover scraps of another process. Therefore both of these products are in limited supply. It takes a lot of silica and metal shavings to make Ferrock, which makes it challenging to do large projects.

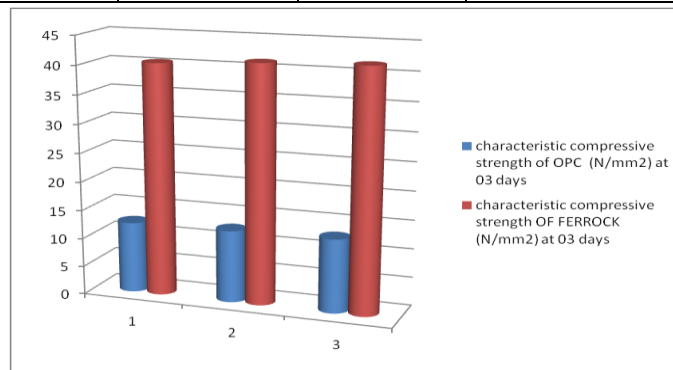
4 RESULTS

Table No 03. Characteristic compressive strength of M25 Concrete (N/mm²) after 03 days curing for Ordinary Portland Cement.

Sr.No.	Sample No.	Date of Casting Cube	Date of Testing of Cube	Load (P) Taken by Cube (KN)	characteristic compressive strength (N/mm ²) at 03 days	Average Comp. Strength (N/mm ²) at 03 days
1	1	05/01/2024	07/01/2024	280	12.45	12.67
2	2	05/01/2024	07/01/2024	285	12.65	
3	3	05/01/2024	07/01/2024	290	12.90	

Table No 04. Characteristic compressive strength of M25 Concrete (N/mm²) after 03 days for FERROCK.

Sr.No.	Sample No.	Date of Casting Cube	Date of Testing of Cube	Load (P) Taken by Cube (KN)	characteristic compressive strength (N/mm ²) at 03 days	Average Comp. Strength (N/mm ²) at 03 days
1	1	14/02/2024	16/02/2024	910	40.44	41.18
2	2	14/02/2024	16/02/2024	930	41.33	
3	3	14/02/2024	16/02/2024	940	41.78	



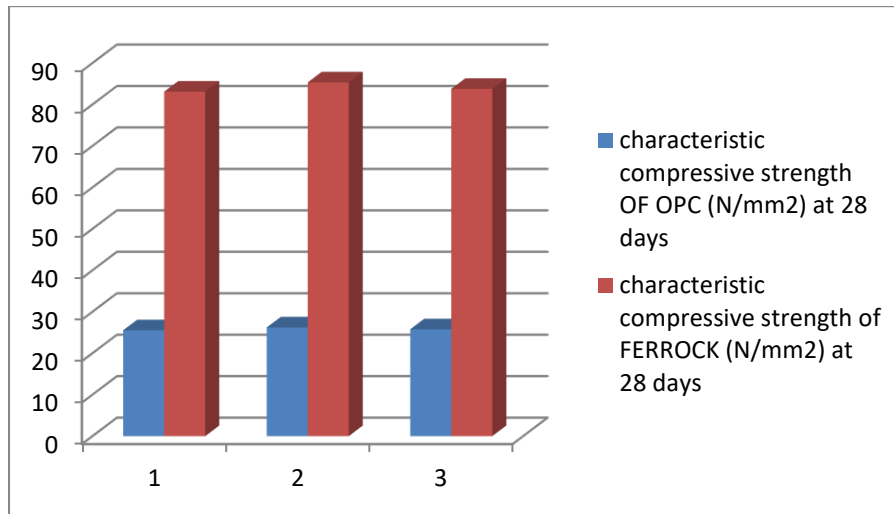
Graph No.01 Compressive Strength of OPC VS Ferrock after 3 days

Table No 05. Characteristic compressive strength of M25 Concrete (N/mm²) after 28 days curing for Ordinary Portland Cement.

Sr.No.	Sample No.	Date of Casting Cube	Date of Testing of Cube	Load (P) Taken by Cube (KN)	characteristic compressive strength (N/mm ²) at 28 days	Average Comp. Strength (N/mm ²) at 28 days
1	1	05/01/2024	02/02/2024	575	25.55	25.85
2	2	05/01/2024	02/02/2024	590	26.22	
3	3	05/01/2024	02/02/2024	580	25.78	

Table No 06. Characteristic compressive strength of M25 Concrete (N/mm²) after 28 days for FERROCK.

Sr.No.	Sample No.	Date of Casting Cube	Date of Testing of Cube	Load (P) Taken by Cube (KN)	characteristic compressive strength (N/mm ²) at 28 days	Average Comp. Strength (N/mm ²) at 28 days
1	1	14/02/2024	12/03/2024	1870	83.11	84.07
2	2	14/02/2024	12/03/2024	1920	85.33	
3	3	14/02/2024	12/03/2024	1885	83.78	



Graph No.02 Compressive Strength of OPC VS Ferrock after 28 days

5 CONCLUSION

Roughly 95% of the Fer rock is made from recycled materials, Fer rock is both stronger and more flexible than ordinary Portland cement, allowing it to be used in highly active environments where there is a consideration for seismic activity.

This proposes to evaluate the ability of Ferrock to be used as one of the best possible substitute for cement in concrete. It is an iron based binding compound which utilizes variety of waste materials to form a carbon negative building material.

Conventional concrete is cured using water. Casted ferrock concrete of M25 (1:1:2) , (ferrock : sand: aggregate). After mixing the ferrock mix was casted into moulds of cube size 150mm X 150mm X 150mm. Ferrock concrete is cured using carbonation (carbon dioxide).

The ferrock is more strong & durable than the conventional concrete for the construction industry.

Also due to the use of ferrock than conventional concrete, the percentage of carbon dioxide in air will be reduced.

6 REFERENCES

- [1] KAVITA SINGH, "COMPRESSIVE STRENGTH STUDY OF GREEN CONCRETE BY USING FERROCK," Multidisciplinary International Research Journal of Gujarat Technological University ISSN: 2581-8880
- [2] Jaison Selvaraj S K1*, Dr G. Srinivasan2 "EXPERIMENTAL STUDY ON MECHANICAL BEHAVIOUR OF FERROCK –A SUBSTITUTE FOR CEMENT", Experimental Study On Mechanical Behaviour Of Ferrock –A Substitute For Cement Section A-Research paper.
- [3] Vidya Jose1, Vasudev R2, "Ferrock: carbon negative substitute for cement- a review." Sustainability, Agri, Food and Environmental Research, (ISSN:0719-3726),12(X),2024: <http://dx.doi.org/>
- [4] Sukhpreet Singh Saluja1, Dr Vinay Kumar CH2, "Ferrock A Carbon Negative Sustainable Concrete: A Review", International Journal for Multidisciplinary Research (IJFMR) E-ISSN: 2582-2160.
- [5] Shivani A.B.1, Nihana N.2, Gowri A.S.3 Hasna Jalal 4, Arjun R.5, Jinudarsh M.S. P6, "EXPERIMENTAL INVESTIGATION OF FERROCK BY COMPLETE AND PARTIAL REPLACEMENT OF CEMENT IN CONCRETE" International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056.
- [6] Pushkar Bharambe, Abhishek Kumar, Shaikh Umar, Ajaykumar Vishwakarma, Mubashshir Khan, Rajesh Verma, "EXPERIMENTAL ANALYSIS OF FERROCK MATERIAL SUBSTITUTE TO CEMENT CONCRETE", International Journal of Scientific Research in Engineering and Management (IJSREM).
- [7] Sakshi Agarwal and Devesh Jaysawal, "Ferrock material: A case study", International Journal of Research in Civil Engineering and Technology 2023; 4(2): 01-03.
- [8] Parvathy U, 2Anagha M C, 3Aiseweriya S, 4Anjana A B, 5Vinay Vikram, "Life Cycle Assessment of Concrete with Ferrock as partial replacement of cement", 2023 IJNRD | Volume 8, Issue 7 July 2023 | ISSN:2456-4184 | IJNRD.ORG.