Literature Review on Ferrock – A Greener Substitute

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Abstract- *Ferrock is created from waste steel dust 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. This review is mainly focused on the characteristics and application of Ferrock and how it acts as a greener substitute for cement. Along with this, the future scope and manufacturing difficulties of ferrock was reviewed.*

Keywords- ferrock, carbon dioxide, greener substant

I. INTRODUCTION

Methods to reduce greenhouse gases like CO_2 in the atmosphere are an active research area today. Climate change has prompted scientists to search for newer alternatives in this regard in all kinds of fields. Cement in concrete, the second most used entity after water in the world today, is the fourth largest source of anthropogenic carbon emissions. It's been called the foundation of modern civilization. Portland cement, the generic name, is the glue that allows concrete to harden. And concrete is everywhere, in highways, bridges, sidewalks, buildings of all sizes, and much more. Four billion tons of cement is manufactured each year worldwide, a half-ton for every person on Earth.

The world's infatuation with this high carbon intensive material has grown to be real pandemic as the accumulation of these emissions contributes to the growing threat of Global climatic catastrophe. For every one ton of cement produced approximately 8 ton of CO_2 is released. It's alarmingly polluting the environment. So this project checks how far ferrock can be used as a substitute to cement. This proprietary blend was created by David Stone, when he was a PhD student experimenting on iron rust and the changes it brings to original material. The key ingredient is iron dust, a waste from iron mill which goes straight to the landfill as it's not recycled conventionally and the process of recovering iron from this powder is uneconomical. The iron dust reacts with carbon-di-oxide and rust, which creates an iron carbonate matrix to form Ferrock while it dries.[1]

The accepted reaction steps for this process are:

$$Fe + 2CO_2 + H_2O \rightarrow Fe^{2+} + 2HCO_3^- + H_2 \uparrow$$
$$Fe^{2+} + 2HCO_3^- \rightarrow FeCO_3 + CO_2 + H_2O$$

The net reaction then is:

$$Fe + CO_2 + H_2O \rightarrow FeCO_3 + H_2 \uparrow$$

Though the basic reaction scheme seems straightforward and simplistic, the kinetics of the reaction and the rate of product formation are often very slow so as to be of any use for beneficial industrial applications. Hence dissolution agents (organic) that have the potential to enhance the corrosion rate of iron due to their high reducing power and complexing capacity need to be employed to control corrosion rates. Here we use materials such as Metakoalin, limestone, flyash along with iron dust for proper binding and performance requirements. As per the available literature we know that the best possible proportion of ingredients are iron dust (60%), fly ash(20%), metakoalin (12%) and limestone (8%). Analysis (atomic absorption spectroscopy) shows that fully cured samples contain between 8 and 11% captured CO2 by weight.

Ferrock is therefore "carbon negative" unlike Portland cement, which during manufacture is a major source of CO2 and other air pollutants.

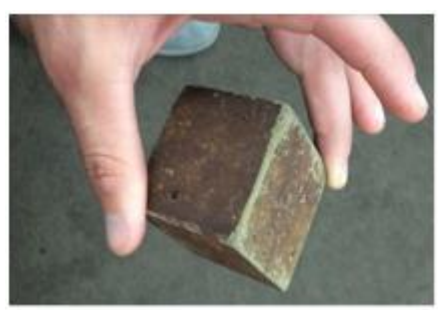

Figure 1 Ferrock

Technical Characteristics OfFerrock:

Besides its unique chemical properties as a carbon sink that emits valuable hydrogen gas as a byproduct, Ferrock additionally presents technical characteristics that have potential to make it a promising substitute for cement. Ferrock has similar functional properties in terms of its fresh-state behavior and workability. In addition, the iron-based binder requires a fractional amount of time to cure compared to OPC; 4 days of carbonation compared to the 28 days of hydration that is required for cement to cure. The curing process for Ferrock also has the theoretical potential to be further expedited based on the purity of the compressed carbon dioxide. [6]

Additional characteristics are defined by a comparison with the pore structure of 28-day cured OPC pastes, showing that the overall pore volume was lower in iron-carbonated binders, but the critical pore sizes were larger. This explains that the value of permeability of Ferrock after 4 days of carbonation (k = 2.5 x 10-16 m2) is significantly higher than 28-day cured cement paste (k = 6.17 x 10-20 m2).[7]

Research studies also show that the iron-based binder is chemically stable in marine environments and does not break down upon exposure to salt waters. In fact, results show that Ferrock has the capacity to incorporate some of the salt, especially the chlorine ions into the mineral structure. This trapping capacity seems to extend to some toxic contaminants such as arsenic.[8]

Materials required for Ferrock

MATERIAL	PERCENT (BY WEIGHT)[8]	SPECIFICATION/COMMENTS
Iron Powder	60%	Waste metallic iron powder with a median particle size of 19.03 μm
Fly Ash or Glass	20%	Class F fly ash conforming to ASTM C 618 or Ground glass particles
Limestone	10%	Limestone powder (median particle size of 0.7 μm) conforming to ASTM C 568
Metakaolin	8%	Conforming to ASTM C 618
Weak organic acid	2%	Oxalic acid has been used in previous research as catalyst

Fig 1.1 Materials Required for Ferrock

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 [8, 9].

Curing Properties

Table 2 Curing Properties

	Ferrock
Water-Solid Ratio	0.18 to 0.30
CO2	Absorbs CO2 in a ratio of 0.1 tonnes CO2/tonne [8]
H2	17 kg H2 /tonne produced [10]

Advantages and Limitations:

- The main advantage of ferrock is eco-friendly as well as the formation of hydrogen gas as a by-product of Ferrock production represents an intriguing opportunity for further applications of this material, especially as the energy industry looks for alternative sources of fuel. The clean-burning nature of hydrogen gas positions it as one of the leading fuels to aid the transition away from fossil-fuel energy sources.[13]
- Using a replicable precast methodology, the curing environment can be controlled, meaning the opportunity for harvesting the effluent hydrogen becomes more practical. The precast structure could be loaded into a vacuum sealed chamber where the chemical process is catalysed by a source of CO2, the emitting H2 gas would then be drawn through the chamber's ducting and compressed into consumable cylinders [13]. By introducing Ferrock as a potential generating source for this high-value fuel its overall market potential is seemingly limitless.

II. LITERATURE REVIEW

David Stone, et al. [1] In this paper, the pore and micro-structural features of a novel binding material based on the carbonation of waste metallic iron powder are reported. The binder contains metallic iron powder as the major ingredient, followed by additives containing silica and alumina to facilitate favourable reaction product formation. Compressive strengths sufficient for a majority of concrete applications are attained. The material pore structure is investigated primarily through mercury intrusion porosimetry whereas electron microscopy is used for micro-structural characterization. Reduction in the overall porosity and the average pore size with an increase in carbonation duration from 1 day to 4 days is noticed.

Sumanta Das, et al. [2] This paper explores, the possibility of carbonating waste metallic iron powder to develop sustainable binder systems for concrete. The fundamental premise of this work is that metallic iron will react with aqueous CO2 under controlled conditions to form complex iron carbonates which have binding capabilities. The compressive and flexural strengths of optimized iron-based binder systems increase with carbonation duration and the specimens carbonated for 4 days exhibit mechanical properties that are comparable to those of companion ordinary Portland cement systems that are most commonly used as the binder in building and infrastructural construction.

Ali and Koranne [3] studied the behavior of stone dust and fly ash with Expansive soil and their effect on properties of soil. They showed there markable improvement in the characteristics of Expansive soil and also the significant control in swelling nature if fly as hand stone dust are mixed in equal proportions.

III. CONCLUSION AND DISCUSSION

From the various literature review of ferrock the literature review will be greatly helpful in improving the deep knowledge about green substate.

- Green concrete having reduced environmental impact with reduction of the concrete industries CO2 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 CO2 in environment and environmental impact but also economical to produce.

REFERENCES

[1] Stone, David. *"Top Ten List of Characteristics for Ferrock TM —a New Green Building Material"* Unpublished manuscript.

[2] Das S. et al*."Flexural Fracture Response of a Novel Iron Carbonate Matrix – Glass Fiber Composite and Its Comparison to Portland Cement-based Composites."*Science Direct. Construction and Building Materials, n.d. Web.27 Feb. 2017

[3] Ali M S and Koranne S S (2011), *"Performance Analysis of Expansive Soil Treated With Granite dust and Fly ash",* EJGE, Vol. 16, Bund. I, pp. 973-982.

[4] In Khatib, J. M. (2016). *"Sustainability of construction materials. Chapter 17: Low clinker cement as a sustainable construction material".* Cambridge, UK: Woodhead Publishing.

[5] McLellan B.C., Williams R.P., Lay J., Van Riessen A., CorderG.D*."Costs and carbon emissions for geopolymer pastes in comparison to Ordinary Portland Cement".* Journal of Cleaner Production. 19(9-10), 1080-1090 http://dx.doi.org/10.1016/j.jclepro.2011.02.010>.

[6] EPA*."Creating a Carbon-Negative Building Material from Recycled Glass, Steel Dust, and Carbon Dioxide (Tohono O'odham Community College)".* 2013-2014 Program Report for Tribal ecoAmbassadors. Available from: <https://www.epa.gov/tribal/2013-2014-program-report-tribal-ecoambassadors>.

[7] ENGINEERING INTRO. 2012*. "Cement Manufacturing Process".* [ONLINE] Available at: http://www.engineeringintro.com/uncategorized/cement-manufacturing-process/. [Accessed 2 April 2017].

[8] Das S. et al. *"Flexural Fracture Response of a Novel Iron Carbonate Matrix – Glass Fiber Composite and Its Comparison to Portland Cement-based Composites."* Science Direct. Construction and Building Materials, n.d. Web.27 Feb. 2017.

[9] Das S. et al..*"Pore- and Micro-structural Characterization of a Novel Structural Binder Based on Iron Carbonation."* Science Direct. Materials Characterization, Dec. 2014. Web. 27 Feb. 2017.

[10] Dr. Stone, D. (2017, April 18). Inventor of Ferrock. Telephone interview.