FERROCK: A COMPARATIVE STUDY TO ORDINARY PORTLAND CEMENT

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ABSTRACT

Cement is a major binding component in concrete. It is of great importance in construction industry. Even though cement has these prominent properties, it emits carbon dioxide. So ferrock is used as an alternative for cement. Ferrock is an iron-based binding compound that offers a carbon-negative alternative to cement in concrete. It utilizes various waste streams and has properties that can help reduce the environmental impact of traditional concrete production. Ferrock is made from a blend of iron oxide powder, fly ash, lime powder, metakaolin, and oxalic acid, with the oxalic acid acting as a catalyst.

The key benefit of Ferrock is its ability to absorb carbon dioxide from the atmosphere during the hardening process, making it an environmentally friendly option. This absorption of carbon dioxide helps reduce the emission of greenhouse gases. Additionally, Ferrock can be cured using carbon dioxide instead of traditional water curing, which reduces water usage in the production process.

Overall, Ferrock shows promise as a sustainable alternative to cement in concrete production, offering environmental benefits and utilizing waste materials in its composition.

Keywords: Cement, Ferrock, Oxalic Acid, Carbon Dioxide Absorption, Carbon, Cement Replacement.

I. INTRODUCTION

In the infrastructure development in all over the world is resulting in a linear increase in the construction of row houses buildings, high-rise buildings, infrastructure development (roads), bridges, towers, etc. The most of vital material used in this construction sector is the cement. Cement is the binding material to gain strength so as to sustain the weight applied on any member or item, it is associated by artificial means of factory-made product that releases carbon dioxide within the method of its manufacture that contributes to the entire atmosphere by more or less about 6 to 8%. For this proposes to gauge the power of ferrock to be used jointly as the simplest substitutes for cement in concrete. It is mostly associated with iron based binding compound that utilises different type of waste materials to make a carbon negative materials.

1.1 Significance

Nowadays Cement in concrete is the second most used entity in the world. So that the fourth largest supply of phylogenies carbon emissions. The worlds infatuation with this high carbon intensive material has full-grown to be real pandemic, because the accumulation of those emissions contributes to the growing threat of worldwide climatically hazardous to humanbeing.

Ferrock is a material that is gaining attention as a potential alternative to traditional concrete. It is made from recycled materials, including steel dust, which is a byproduct of the steel industry, and silica from ground-up glass. When these materials are combined with a binder made of calcium carbonate and magnesium carbonate, they form a compound that is similar to concrete but with some unique properties. One of the key advantages of Ferrock is its environmental friendliness. It uses recycled materials, which reduces the need for new raw materials and helps to divert waste from landfills. Additionally, the production of Ferrock generates less carbon dioxide compared to traditional concrete, making it a more sustainable option.

Another advantage of Ferrock is its strength and durability. It is reported to be up to five times stronger than traditional concrete, as well as more resistant to cracking and corrosion. This makes it an attractive option for use in construction projects where strength and durability are important.

Research into Ferrock is ongoing, and there is still much to learn about its properties and potential applications. However, it shows promise as a sustainable and durable alternative to traditional concrete.
1.2 Objectives
To determine the compressive strength of Ferrock
To determine the mechanical properties of ferrock cement concrete using water curing and carbon dioxide curing.
To determine durability properties of ferrock cement concrete using water curing and carbon dioxide curing.
To compare curing of ferrock cement concrete using water curing and carbon dioxide curing.

1.3 Scope
- Ferrock production shows an intriguing opportunity for future applications, especially as the energy industry looks for alternative sources of fuel.
- Ferrock have been represented as an extremely enticing, but the ambiguity of its unique properties has the potential to have a much greater impact on the sustainable well-being of the abode and the prosperity of human advancement.
- Focusing on carbon emission reduction as well as utilization of waste materials to produce a better environment.
- Development of new engineered cementitious material which has more future opportunities.

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.

II. 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 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.

2.2 Jaison Selvaraj S K1*, 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.

Keywords: Light Weight SCC, Perlite, Metakaolin, Flow properties, Mechanical

2.3 Vidya Jose1, Vasudev R2
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.

**Keywords:** Ferrock, Carbon negative, waste management, cement substitute

### 2.4 Sukhpreet Singh Saluja, Dr Vinay Kumar Ch2

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.

### 2.5 Shivani A.B.1, Nihana N.2, Gowri A.S.3 Hasna Jalal 4, Arjun R.5, Jinudarsh M.S. P6

Concrete is a major binding component in concrete. It is of great importance in construction industry. Even though cement has these prominent properties, it emits carbon dioxide. So ferrock is used as an alternative for cement. Ferrock is an innovative iron-based binding compound, which presents a carbon-negative alternative to cement that utilizes a variety of waste streams to produce a versatile building material. Ferrock is a binder that is a blend 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 produces iron carbonate. It can enhance the environment by absorbing the atmospheric carbon dioxide for its hardening process. By the use of ferrock the rate of emission of most dangerous greenhouse gases are reduced. During the curing process, carbon dioxide is used instead of traditional water curing. This helps in reducing the usage of water.

**Key Words:** Ferrock, oxalic acid, carbon dioxide absorption, cement replacement, waste management, carbon negative

### 2.6 Pushkar Bharambe, Abhishek Kumar, Shaikh Umar, Ajaykumar Vishwakarma, Mubashshir Khan, Rajesh Verma

Concrete, after water across the world, the second most broadly utilized material involving 8-10% of all yields of CO2, is predominantly because of cement. The iron residue (an iron business loss) that would end in sites somehow alongside small quantities of limestone, Metakaolin, and fly ash is being used to make this an efficient substance. Our research focuses unexpectedly on their commitment to carbon dioxide contamination, energy use, water use, the ecologic impact of ordinary Portland cement and Ferrock (limestone 8%, Metakaolin 12%, and fly ash 20%, and iron residue 60%). By substituting concrete with Ferrock in fluctuating proportions of 5%, 10%, 15%, and 20% in solid, we attempt to find the ideal proportion of substitution, which, along with sustainability, would boost wanted outcomes for both (compressive and divided tensile). In all this proportion, the test result shows 10% is more efficient than others. Here we use materials such as Metakaolin, limestone, fly- a along with iron dust for proper As per the available literature we know that the best possible proportion of ingredients is iron dust (60%), fly- ash (20%), Metakaolin (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 the major source of CO2 and other air pollutants.

**Key Word:** Ferrock Concrete, Concrete, Fly-Ash, Metakolin, Lime Powder
2.7 Sakshi Agarwal and Devesh Jaysawal

Ferrock is established from waste gird dust and silica from ground up jar, that when spewed and upon response accompanying colorless odorless gas founds iron carbonate that binds colorless odorless gas from the air into the Ferrock. This review is primarily fixated on the traits and request of Ferrock and by what method it acts as a greener give assistance cement. Along with this, the future opportunity and production troubles of ferrock was inspected.

Thus, attracting on the element diffusion reduction and likewise exercise of the waste device for a better atmosphere, a product chosen ferrock was comprised. Ferrock is so a more powerful and helpful eco friendlier binding material in agreements of allure element habitual skepticism and in waste usage of waste.

**Keywords:** Waste steel dust, cement substitute, resistance to rust, oxidation, reduce carbon foot print, sustainable building

2.8 Parvathy U, 2Anagha M C, 3Aiseweriya S, 4Anjana A B, 5Vinay Vikram

Due to the significant amount of cement used during the production process, concrete has a negative impact on the environment during its entire life cycle. The main constituents of Ferrock, a novel iron-based binding substance, are waste products. It is a carbon-negative substance with a compressive strength that is nearly five times greater than that of regular concrete. This study sought to compare the effectiveness of concrete incorporating Ferrock using the Life Cycle Assessment (LCA) technique. In the Kerala district of Palakkad, in the village of Pandaruthu, the LCA study was carried out. It was decided to conduct a manufacturing and transportation-focused cradle-to-gate life cycle analysis. The study’s objective was to suggest Ferrock as a cement substitute that is superior in terms of durability and strength. This is done by doing a Life Cycle Assessment (LCA) on Ferrock and Ferrock concrete, and comparing the resulting environment profiles with those of OPC and regular concrete, respectively. Thus, it was possible to determine the emissions and energy requirements of Ferrock concrete and regular concrete. The analysis was carried out using OpenLCA software, the Ecoinvent database, and the Ecoindicator-99 impact assessment method. Additionally, laboratory studies are used to evaluate the strength characteristics of concrete containing Ferrock and determine the ideal ratio.

2.9 Vasavi Madala 1, Takkellapati .Sujatha 2

Today, the construction of buildings and infrastructure has increased as a part of development, resulting in a significant demand for concrete and cement. The large-scale production of cement and extraction of river sand can have negative impacts on environment and depletion of natural resources. Due to the production of 1 ton of cement produces 0.9 ton of CO2 emissions. To mitigate this pollution a green substance called FERROCK (Iron dust 60%, Flyash20%, Metakaolin 10%, Lime powder 8%, Oxalic acid 2%) is used as a partial replacement of cement with selected ratio (10%, 20%, and 30%) by weight of cement. This study includes the complete replacement of river sand with M sand (85%) and glass powder (15%) to reduce the usage of natural sand (river sand) for the selected grades of concrete M40, M60 by performing the mechanical and durability test on the designed concrete grades with selected ferrock ratios, the mechanical and durability properties were enhanced with 20% ferrock replacement by weightof cement in concrete.

**Keywords:** Ferrock, Lime Powder, Oxalic Acid, M Sand, Glass Powder, Life Cycle Assessment

2.10 Niveditha M1*, Y M Manjunath1, Setting H S Prasanna1

In this fast-growing world, people are focusing on the infrastructural development, where construction sector plays an important role. Cement is the most prominent material being used in construction that emits approximately 6-8% 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 Ferrock was constituted. This paper is a review over a product that is stepping towards carbon negativity and waste 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. Ferrock 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. Ferrock is thus a more promising eco friendlier binding material in terms of its carbon
Keywords: Carbon footprint, cement replacement, waste management, ferrock, carbon negative.

III. 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.

3.1 Cement

Cement is the most widely used building material used all around the globe because of its low cost, ease of use and its versatility. Cement is a binding material, a substance used for construction that hardens and adheres to aggregates to bind them together to form concrete. Cements used in construction are usually inorganic, often with a lime or calcium silicate base and can be characterized as either hydraulic or nonhydraulic, based on its ability to set in the presence of water. Portland cement which is largely used in the construction industry is an example of hydraulic cement. They set and become adhesive due to an exothermic chemical reaction between the cement and the water. The chemical reaction also called as hydration of cement results in mineral hydrates. This reaction results in the hardening and strength gaining of cement (Turner, 2013).

3.2 Ingredients

The raw materials used in the manufacturing of cement mainly consist of lime, silica, alumina and iron oxide. The oxides interact with one another in the kiln at high temperature to form more complex compounds. The relative proportions of these oxide compositions are responsible for influencing the wide range of properties of cement. The table 1 shows the approximate oxide composition limits of ordinary Portland cement.

<table>
<thead>
<tr>
<th>Sr. No</th>
<th>Oxides</th>
<th>Percentage Content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>CaO</td>
<td>60-67</td>
</tr>
<tr>
<td>02</td>
<td>SiO2</td>
<td>17-25</td>
</tr>
<tr>
<td>03</td>
<td>Al2O3</td>
<td>3.0-8.0</td>
</tr>
<tr>
<td>04</td>
<td>Fe2O3</td>
<td>0.5-6.0</td>
</tr>
<tr>
<td>05</td>
<td>MgO</td>
<td>0.1-4.0</td>
</tr>
<tr>
<td>06</td>
<td>Alkalies (K2O,Na2O)</td>
<td>0.4-1.3</td>
</tr>
<tr>
<td>07</td>
<td>SO3</td>
<td>1.3-3.0</td>
</tr>
</tbody>
</table>

3.3 Manufacturing Procedure

Although the structural applications for both materials are very similar, the manufacturing and chemical processes involved are vastly different. Cement is produced by first mining clay and limestone from rock quarries, using explosives to blast the raw material loose from the earth. The material is then hauled to a crushing facility where it is pulverized into 1-½” rocks and blended into a homogenized mixture. The mixture is temporarily stored and then hauled to a milling factory where the size is reduced to a fine powder. The raw blend is then loaded into a 13 kiln, fired at 1400 degrees Celsius and undergoes a chemical reaction, known as calcinations. On a molecular level, the calcium carbonate (CaCO3), found in the limestone, begins to decompose at a high heat, releasing carbon dioxide (CO2). In the final stage, the heated mixture is sent through a second stage of milling, in which gypsum is added to extend setting time and then sent to a storage facility where it will be stored until it is shipped to the consumer.

At this stage, cement is primarily used for concrete production, which results from the mixing of cement, water and aggregates in the necessary proportions. The combination of cement with water results in an exothermic reaction due to the hydration of the principal chemical components of cement, namely, tricalcium (Ca3) and dicalcium silicate (Ca2SiO4), tricalcium aluminate (Ca3Al2O6), and tetracalcium aluminoferrite (Ca4Al2Fe2O10). These hydrated components harden into a binding material that acts as an agglutinant for the

[2313]
mineral structure formed by the aggregates. Cement also finds its application as a soil stabilizer in geotechnical engineering, and stabilizer for environmental applications [2].

In comparison, Ferrock also uses clay and limestone as part of its composition, but the ratio of clay and limestone used is much smaller compared to OPC, eight and ten percent respectively. The majority of the mixture, totaling 80%, is composed of low-value waste products. The main ingredient is metallic iron powder, which is a by-product of shot blasting, a finishing technique for steel manufacturing. During the shot blasting process the iron powder is ground to a micro-particle scale (~19.03μm) [9], which becomes a considerable nuisance to the blasting facility because of its ineffectual applicability and the inherent respiratory hazard associated with working with such a fine material. These ingredients are combined as a dry-mix with a source of silica, such as fly ash or recycled glass. Oxalic acid is also added to facilitate the chemical process and then blended to create a uniform mixture.

Fe (O) +CO2+H2O Fe CO3+ H2

Table 2 - Summary of raw materials required for ferrock manufacturing

<table>
<thead>
<tr>
<th>Sr. No</th>
<th>Material</th>
<th>Percentage(by weight)</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Iron powder</td>
<td>60%</td>
<td>Waste metallic iron powder with a median particle size of 19.03μm</td>
</tr>
<tr>
<td>2</td>
<td>Fly Ash or Glass</td>
<td>20%</td>
<td>Class F fly ash conforming to ASTM C 618 or ground glass particles</td>
</tr>
<tr>
<td>3</td>
<td>Limestone</td>
<td>10%</td>
<td>Limestone powder (medium particle size of 0.7 μm) conforming to ASTM C 568</td>
</tr>
<tr>
<td>4</td>
<td>Metakaolin</td>
<td>8%</td>
<td>Conforming to ASTM C 618</td>
</tr>
<tr>
<td>5</td>
<td>Weak Oxalic Acid</td>
<td>2%</td>
<td>Oxalic acid has been used as catalyst in previous research</td>
</tr>
</tbody>
</table>

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 3- Curing Properties

<table>
<thead>
<tr>
<th></th>
<th>Ferrock</th>
<th>OPC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water-Solid Ratio</td>
<td>0.18 to 0.30</td>
<td>0.40 to 0.70*</td>
</tr>
<tr>
<td>CO2</td>
<td>Absorbs CO2 in a ratio of 0.1 tonnes CO2/tonne</td>
<td>No relationship during Curing</td>
</tr>
<tr>
<td>H2</td>
<td>17 kg H2 /tonne produced</td>
<td>No relationship during curing</td>
</tr>
</tbody>
</table>
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 byproducts or leftover scraps of another process. Therefore both of these product are in limited supply. It takes a lot of silica and metal shavings to make Ferrock, which makes it challenging to do large projects.

IV. CONCLUSION

This study compares the environmental impacts of ordinary Portland cement and ferrock (iron oxide powder-60%, flyash-20%, metakaolin -12%, and limestone-8%) focussing specially on their contribution to carbon pollution, water use and energy consumption. By substituting cement with ferrock in varying proportions as 5%, 10%, and 15% in concrete we are trying to find the optimum ratio of replacement which would give desired results in both strength( compressive, split tensile & flexural strength). In all the test results 10% shows the good result in strength. It is also seen that Specific gravity of ferrock mix is less than specific gravity of cement.Ferrock cube achieved an maximum compressive strength of 2.72 N/mm² only. This is due to the variation in particle size of iron powder and environmental condition. From the test results it is seen that mechanical strength of ferrock cement concrete is greater than that of conventional concrete.

V. REFERENCES


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