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Polymer Modified and Microfiber Reinforcements in Concrete: A comparative Analysis Advanced Construction Materials

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Abstract: Concrete has always been a cornerstone material in construction due to its durability and versatility. However, as a subsequence to its susceptibility to cracking and its brittleness, people have been driven towards finding innovative solutions to enhance its mechanical properties and durability.

Two innovative methods for improving the performance of concrete, which are Polymer Modified Concrete (PMC) and Microfiber Reinforced Concrete (MRC), will be explored and comparatively analysed in this paper.

PMC is about the incorporation of polymer in concrete as a way to improve its tensile strength, reduce its absorbent nature and improve adhesion. While on the other hand, MRC through using fine fibers, for instance glass or polypropylene ones, aims to lower the spread of cracks which thereafter improves the behaviour of concrete post-cracking.

By reviewing the mechanical, costs and durability of the above-mentioned concrete modifying methods, this paper aims to analytically evaluate the advantages and disadvantages, as well as the applications of each method which are considered more optimal.

This review and analysis will be done through studies on the knowledge available on this product as well as through the practical applications that have been studied and observed on these methods.

Key Words: PMC – Polymer Modified Concrete, MFRC – Microfiber, Reinforced Concrete, Concrete technology, Durability, Tensile Strength, Crack Resistance

1. Introduction

Concrete is one of the most extensively used construction materials in the world.

Among its various shortcomings, concrete has low tensile strength, making it susceptible to cracking under stress or load. This weakness causes costly repairs and maintenance over time, especially in construction projects which are classified as high-demand.

As a result, the development and incorporation of other alternative materials into concrete have become an essential point in modern construction engineering. One of the most important innovations in this area is the incorporation of fibers (MFRC) and polymers (PMC) in the composition of concrete, which have been essential in addressing these issues. These methods of concrete reinforcement extensively improve the material's overall performance by enhancing its tensile strength and resistance to cracking.

Including these methods in the modification of concrete, makes it suitable for a large range of applications in construction, whether residential or industrial.

Various kinds of fibers have been explored for reinforcing concrete and each kind has its own advantages which it offers, depending on the desired application and the environmental conditions the concrete will face. Each has distinct characteristics which work for different scenarios and construction necessities.

The paper will focus on these two kinds of concrete technology enhancement. It will compare and contrast the properties, applications, advantages, and disadvantages of these two types of methods, namely Polymer Modified Concrete and Microfiber Reinforced Concrete, which will thereafter aid professionals in making decisions which are well informed, on the appropriate kind of material to use in their projects.

2. Literature Review

This literature review will summarize the key findings on recent studies and reports that have stemmed from them on the knowledge of PMC and MFRC.

2.1 Polymer Modified Concrete (PMC)

Polymer Modified Concrete is the method where a composite material which integrates polymers into the concrete is used, to improve and enhance the performance of concrete. Polymers could be of the following kinds: latex, water-soluble powders, resins in liquid form, monomers etc. The incorporation of such polymers leads to a result where the organic polymer and cement gel matrices become homogenous. (*Shivani R. Bothra, Yuvraj Ghugal, 2015)*

The inclusion of polymers into concrete production has proved to have improved its mechanical characteristics and properties, such as enhanced flexibility, increased tensile and compressive strengths. Making these enhancements contribute to better concrete performance in different kinds of applications. (*Pushpendra Kumar Sharma, 2021)*

Additionally, the inclusion of polymers in concrete makes it more durable due to the reductions they cause in permeability, which therefore enhance its resistance to water ingress and chemical intrusions. Therefore, making PMC an incredibly suitable option for the construction of structures that are exposed to harsh environmental conditions. (*Joshua B. Kardon, 1997)*

Applications of PMC in the constructions industry are vast. For instance, PMC ca be used for Repair and Rehabilitation which is ideal for the restoration of old or damaged structures, due to its superior and remarkable capabilities of bonding. Another application has to do with the construction of industrial floors due to PMC's resistance to abrasion and chemicals, which makes it the optimal choice for areas that experience high traffic like warehouses and factories, especially frequented by high weight vehicles.

Marine Structures also benefit from the characteristics of PMC due to the above-mentioned quality of its mitigated water absorption or in other words its permeability as well as it's resistance to chloride ions. PMC is also used in the construction of infrastructure such as bridge decks, surfacing of roads and overlays since it is durable and quick curing time. (*Bhavna Tripathi, 2024*)

To summarize, PMC is a significant and prominent advancement in construction materials and its qualities which were discussed previously make it the optimal choice for a versatility of applications.

2.2 Microfiber reinforced concrete (MFRC)

Microfiber-reinforced concrete, has emerged and is valued for its ability to improve the mechanical properties and durability of the traditional form of concrete.

When focusing on the mechanical properties of MFRC, it has been evidenced that it improves the flexibility and tensile strengths of traditional concrete. A review from MDPI emphasizes that the addition of fibers enhances durability performance, flexibility and tensile strength. The incorporation of fibers also causes a shrinkage in the cracks of the concrete. (*Anas, Khan, Bilal, Jadoon and Nadeem, 2022)*

MFRC also enhances durability. According to a practical review published in PMC, fiber reinforced concrete is discussed in terms of its durability, highlighting its efficiency in achieving longevity of concrete infrastructures. (*Suvash Chandra Paul, Gideon PAG can Zijl, Šavija, 2020)*

Moreover, MFRC offers improvements in shrinkage cracking, which is an inherent issue in concrete structures. Up to date research expresses that the addition of microfibers can lower the effects of this problem. A study done on a. case of micro-fiber reinforced cement paste and mortar overlays, reached the conclusion that including wollastonite micro-fibers mitigated shrinkage strains and made the structure more crack resistant. (*Shashi Kant Sharma, G.D Aditya Anupam Kumar, G.D Ransinchung R.N, Praveen Kumar, 2013)*

Microfibers, as recent studies have shown, can also be combined with other materials. Research published in *Nature* found that combining nano-silica and microfibers, termed micro-concrete reinforced with steel fibers inserting nano-silica, and concluded in significant in enhancement in mechanical properties. (*Ashokan, Rajendran and Dhairiyasamy, 2023)*

To conclude, integrating microfibers into concrete enhances the mechanical properties and durability of traditional concrete, however there is ongoing research on making the use of microfibers more understandable and optimize their use.

3. Advantages and Disadvantages of Polymer Modified Concrete and Microfiber Reinforced Concrete

3.1 Polymer-Modified Concrete (PMC): Advantages and Disadvantages

PMC, when compared to traditional concrete, offers superior qualities of tensile, flexural and compressive strength, making it the optimal choice for heavy-duty or industrial-level applications The ability of Polymer Modified Concrete to resists chemical intrusions makes it the optimal choice for usage in industries that are affected by heavy chemicals like acids, alkalis etc.

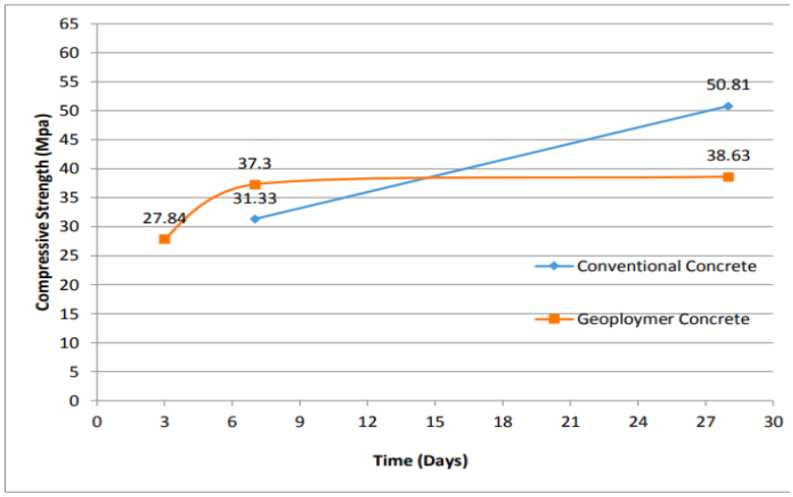
Compressive Strength ranges from 70 MPa to 120 MPa, compared to traditional concrete which is 20-50 MPa.

Flexural Strength:

- P: Load at failure
- L: Length of the beam
- b: Width of the specimen
- d: Depth of the specimen

$$\sigma_f = \frac{3PL}{2bd^2}$$

(Polymer Concrete for Modern Construction by Civil Engineer DK, 2025)



Graph Showing Comparison of Geo-polymer Concrete and Traditional Concrete having Polypropylene Fibres

(Sathe, Patil, 2021)

3.2 Microfiber reinforced concrete (MFRC)

MFRC's capability to prevent cracking through its fibers is one of its most useful advantages. As it is widely known that traditional concrete is prone to cracking, when the water and moisture levels decrease from the concrete mix, the fibers help with the shrinkage cracking. (*M.T Copeland Technologies, 2022)*

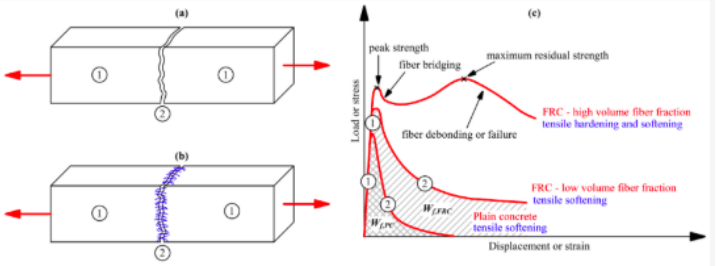
The fibers can do this through increasing the tensile strength of the concrete. Including fibers such as for example, acrylic, glass, polypropylene and more, distributes the pressures of the shrinkage evenly through the concrete mix. This can make the concrete structure more durable and increase its longevity. (*How to Reduce Cracking with Concrete Fibers, R-E-D industrial Products, 2024)*

Hence, MFRC is an incredibly useful technology in the construction of industrial floors or pavements, which need to endure large weights and frequent movement and MFRC helps by creating resistance to abrasion and impact. (*chryso, Saint Gobain, 2020)*

MFRC also offers better resistance to impact due to its flexural qualities, aiding the concrete in resisting bending under pressure. Transportation Research Record presents a study that states that the addition of fibers into the concrete mix, increased the resistance to "first-crack strength by 15% to 90%" and the "static flexural strength by 15% to 129%."

(V. RAMAKRISHNAN, GEORGE Y. Wu, AND Girish Hosalli, 1989)

Figure 1. The behavior of plain concrete and fiber-reinforced concrete: (**a**) plain concrete; (**b**) fiber-reinforced concrete; (**c**) load–displacement diagrams.

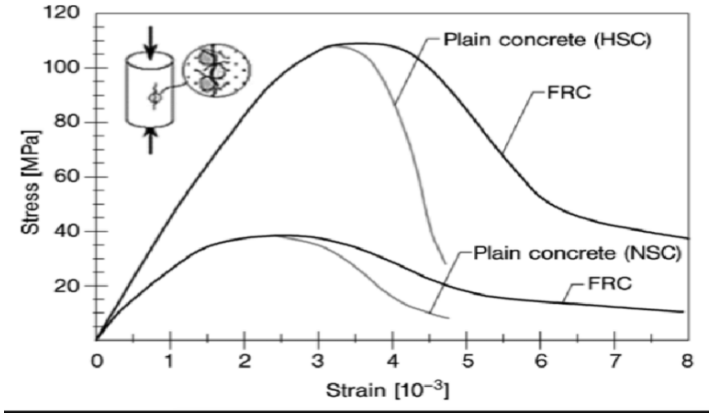


(Marcalikova, Cajka, Bilek, Bujdos and Sucharda, 2020)

In terms of disadvantages the usage of large amounts of microfibers can cause difficulty in mixing and therefore making working with it more difficult and more time consuming. (*FAQs on Fiber Reinforced Concrete" by FRCA)*

As a subsequence the use of a high dosage of fibers can easily lead to fibers clumping together. *(Fiber Mesh vs Wire Mesh: Which Should You Use?, Bracing Systems inc, 2024)*

This would defeat MFRC's purpose to evenly distribute the stresses evenly throughout the structure at hand. The only way to prevent it, is by carefully mixing the fibers into the wet concrete. MRFC also has higher costs than traditional concrete, which despite its many advantages, is worth mentioning.



(Khalil, 2017)

4. A short side-by-side comparison of PMC and MFRC (Table)

Initially, the composition of both technologies is different. PMC inserts polymers into the concrete mix while MFRC inserts microfibers, which as a subsequence gives the concrete in each scenario, different properties.

PMC is mostly valued for its chemical resistance, and while MFRC lacks the chemical resistance but is, in comparison to PMC, more durable to high pressure and loads.

PMC due to its chemical resistant qualities, is often used in structures such as marine structures to avoid abrasion, while MFRC is used in construction settings subject to higher pressures of force and weight such as industrial floors, pavements etc.

MFRC is more cost effective due to the fact that incorporating fibers in the mix increases material costs far less than the incorporation of polymers. (*Polymer Reinforced Concrete, CONSTGUIDE, 2021)*

Variable	PMC	MFRC
Mixture composition	Polymers ; Eg. Latex, epoxy etc.	Microfibers ; E.g Polypropylene, steel, glass
Primary properties	Improvement of compressive, tensile strength and high resistance to chemicals	Improvement of tensile strength and most importantly impact resistance. Shrinkage crack control
Crack Control	Better adhesion helps reduce cracking and lack of porosity but it is not mainly used for crack control	The optimal choice of crack control due to the fibers bridging and distributing pressures evenly throughout the structure
Durability	Highly durable in chemically harsh environments.	Highly durable under pressure, impact and heavy loading conditions.
Applications	Marine structures, industrial floors, repairs, chemical containers.	Pavements, slabs, precast elements.
Cost	Initial costs are high due to the addition of polymers.	Less expensive but this depends on the amount of fibers used.
Workability	Needs skilled labour and careful handling due to its fast curing time, so generally workability is difficult.	Fiber clumping can reduce workability, but mixing is simpler than PMC.
Curing time	Much more rapid than traditional concrete.	Similar curing time but it is time costly due to the need to ensure proper fiber distribution through mixing.
Chemical Resistance	Excellent. It is superior.	Limited resistance.
Impact resistance	Moderate	Superior

5. Conclusion and what future research needs to address about PMC and MFRC

While PMC and MFRC are incredible innovations in the field of concrete technology for their useful properties in creating more durable and generally more resistant structures, there are still gaps in research that need to be addressed in the future in order to perfect these technologies.

Research needs to take place in order to find more cost-effective alternatives to the costly polymer additives.

In the case of MFRC, research is needed to make the mixture more workable and address the issue of fiber clumping, to thereafter make it easier to work with and more time-efficient.

Furthermore, due to the fact that these are relatively new technologies, further research would help confirm whether these technologies are in alignment with the world's sustainability goals.

Despite these research gaps, MFRC and PMC are immensely useful concrete technologies that offer many advantages to the construction industry through the properties they possess.

Their distinct properties make it possible to address different needs in different construction structures, allowing for the application either one of them, in respect of the necessity of the construction scenario.

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