Synthetic Mesofibers: The Sustainable and Practical Solution for Shotcrete´s Pool Industry

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The construction industry has witnessed a paradigm shift in recent years with a growing emphasis on innovative materials and techniques. One such advancement that has gained significant attention is the use of synthetic fiber-reinforced shotcrete (SFRS) in the construction of swimming pools. Traditional concrete structures face challenges such as volume change due to drying shrinkage, as well as moisture and temperature variations. This article explores using synthetic fibers in shotcreted concrete, a highly versatile construction material, to enhance the durability and performance of pool structures.

Shotcrete is a placement method for concrete. It involves projecting or spraying concrete onto a surface. This makes it a popular choice for creating intricate shapes and reducing time for construction. The integration of synthetic fibers in the concrete mixture offers a promising solution to improve the performance of the pool shell. These fibers act as reinforcement to help reduce cracking and improve the strength of the structure. As we delve into the synthesis of these materials, their unique properties, and their impact on pool construction, a comprehensive understanding of the benefits and challenges associated with SFRS will emerge.

The focus of this paper extends beyond the technical aspects of SFRS and delves into its practical applications in pool design and construction. Examining real-world case studies, we will explore how this innovative construction approach contributes to the longevity and sustainability of pool structures. Additionally, considerations such as cost-effectiveness, environmental impact, and maintenance will be addressed, providing a holistic perspective on the feasibility and desirability of adopting SFRS in the construction of today's swimming pools. In exploring the use of SFRS, we aim to contribute valuable insights to the evolving landscape of construction materials and methodologies by fostering advancements that meet the demands of a dynamic and forward-thinking industry.

Fiber-reinforced concrete (FRC) is a type of concrete that incorporates discrete fibers to enhance its structural properties. Adding fibers, such as steel, glass, synthetic, or natural fibers, provides improved toughness, durability, and crack resistance (residual strength) to the concrete matrix. These fibers act as a reinforcement mechanism by distributing and helping to restrain cracks due to various factors like shrinkage, temperature changes, or applied loads.

Improved residual strength and toughness are key mechanical properties in FRC, contributing to enhanced performance of concrete structures, especially after the onset of cracking. Residual strength refers to the ability of a material (in this case, concrete) to carry loads even after the formation of cracks. In FRC, fibers provide a bridging effect across cracks, preventing them from widening and improving the material's post-cracking load-carrying performance. This bridging action allows FRC to maintain a significant portion of its load-carrying capacity even in the presence of cracks, which leads to improved structural reliability and durability.

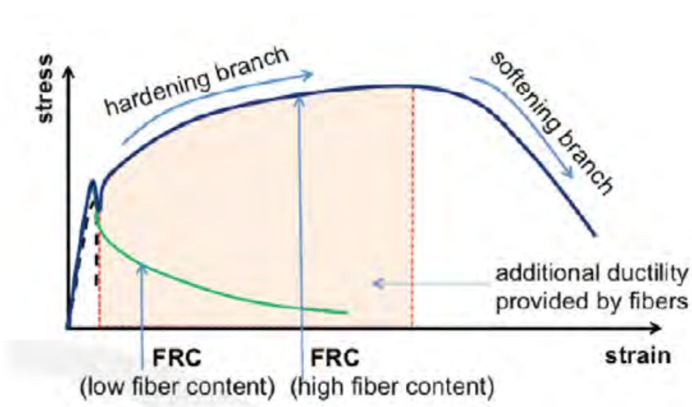

Fig 1: Concrete ductility increased by using fiber

Toughness in FRC refers to the material's ability to absorb energy and deform plastically before failure. Fibers dispersed in the concrete matrix act as reinforcement and create a network that resists crack propagation and enhances the overall toughness of the material. The improved toughness of FRC yields structures that can better withstand dynamic loading, impact, and cyclic loading conditions. This characteristic is particularly beneficial in applications where resistance to cracking and enhanced energy absorption are critical, such as earthquake-prone or high-impact areas.

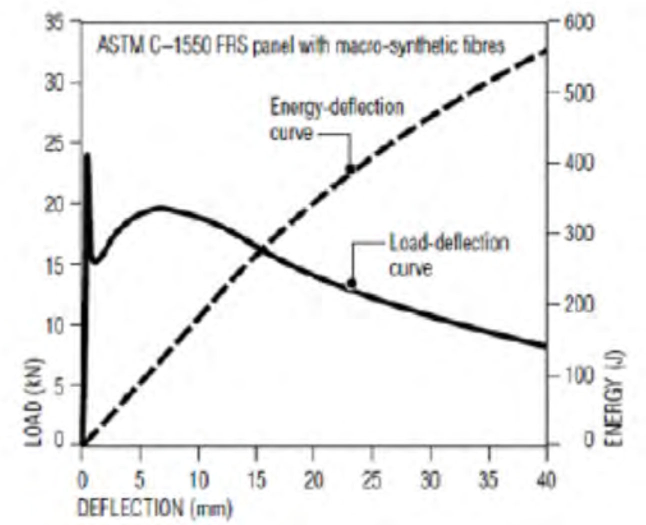

Fig 2: ASTM C1550 test results showing FRC energy absorption

The combination of residual strength and toughness in FRC is a significant benefit over traditional concrete. While traditional concrete may exhibit brittle behavior after cracking, FRC maintains a higher degree of structural integrity and continues to carry loads, which mitigates the risk of sudden and catastrophic failure. These properties make fiber-reinforced concrete a valuable material for a wide range of applications, including any type of shotcrete applications: tunneling, slopes, canals, and pools, where improved durability and structural performance are essential considerations.

One phenomenon associated with the incorporation of fibers in concrete is the "fiber balling effect." This occurs during the mixing process when the fibers clump together and form small balls or clusters. Fiber balling can hinder the uniform distribution of fibers throughout the concrete mix, potentially leading to variations in mechanical properties and compromising the intended purpose of the fiber reinforcement. To mitigate this effect, proper mixture design, mixing techniques, and the length and form of the fiber are essential when you are planning to use a high dosage of fibers to comply with certain toughness requirements.

This paper provides a conceptual study of four types of pool structural designs with a proposal for substituting the area of steel provided by steel reinforcing bars with a new type of synthetic fiber, sustainable mesofibers, that will provide increased durability, lower cost, easier finishing, and a significant reduction in CO_2 emissions.

Let's consider a theoretical structural design of a concrete pool with a 6 in. (150 mm) wall reinforced with #3 and #4 (#10M and #13M) rebar spaced at 12 in. (300 mm) in one or two layers.

The following table refers to the area of steel in these traditional designs for the 6 inches thickness (h), from higher to lower ratios (p):

Steel Rebar Fy 60,000 psi (410 MPa)	Steel Ratio (p)
Rebar #3 @ 12 in. (single)	0.158%
Rebar #4 @ 12 in. (single)	0.280%
Rebar #3 @ 12 in. (double)	0.316%
Rebar #4 @ 12 in. (double)	0.560%

To propose a dosage of synthetic structural fiber to substitute for these steel ratios, we are going to use the ACI 544.4-18 Chapter 4 method[1], where you must consider the following equation to provide the same level of crack control as Grade 60 steel:

Tensile force provided by steel = $F_{ts} = p*F_y$

p = steel ratio

Considering the allowable tension stress from steel reinforcement as, F_{ws}:

$$F_{ws} = 0.667*F_{ts}$$

And that the flexural residual strength of the FRC, f_{e3}, is:

$$f_{e3} = F_{ws} / 0.37$$

For the traditional rebar-reinforced pools, this table shows the tensile and flexural residual strengths achievable for FRC to provide equivalent crack control to the shotcrete wall:

Steel Rebar Fy 60,000 psi	Steel Ratio (p)	Tensile Force Provided by Steel (F_{ts})	Allowable Tensile Stress (F_{ws})	FRC Flexural Residual Strength (f_{e3})
Rebar #3 @ 12 in. (single)	0.158%	94 psi (0.65 Mpa)	63 psi (0.43 Mpa)	170 psi (1.17 Mpa)
Rebar #4 @ 12in (single)	0.280%	167 psi (1.15 Mpa)	112 psi (0.77 Mpa)	302 psi (2.08 Mpa)
Rebar #3 @ 12in (double)	0.316%	189 psi (1.30 Mpa)	126 psi (0.87 Mpa)	340 psi (2.34 Mpa)
Rebar #4 @ 12in (double)	0.560%	335 psi (2.31 Mpa)	223 psi (1.54 Mpa)	603 psi (4.16 Mpa)

Before providing a table of dosages for synthetic mesofiber that will result in the desired flexural residual strength, let's look at why using these types of fibers is desirable.

What are synthetic structural mesofibers and what are the differences between microfibers and macrofibers routinely used today?

Synthetic mesofibers for concrete are fibers that fall between macrofibers and microfibers in size and aspect ratio. These mesofibers are typically shorter than macrofibers but longer than microfibers, and they are designed to enhance the performance of concrete in terms of toughness, crack resistance, and durability similar to macrofibers.

MACROFIBERS:

Size and Aspect Ratio: Macrofibers are relatively large fibers, typically exceeding 0.012 in. (0.3 mm) in diameter. They can be 0.5 to 2.5 in. (12 to 63 mm) in length with aspect ratios (length to diameter ratio) ranging from 30 to 100.

Applications: Macrofibers are commonly used to provide post-cracking reinforcement in concrete. They effectively control crack widths and improve toughness in applications such as industrial floors, pavements, and shotcrete.

MICROFIBERS:

Size and Aspect Ratio: Microfibers are significantly smaller than macrofibers with diameters generally less than 0.012 in. They are short fibers and typically range from 0.125 to 2 in. (3 to 50 mm) in length with lower aspect ratios compared to macrofibers.

Applications: Microfibers are often used to control early-age plastic shrinkage cracking in concrete. They effectively prevent the formation of small cracks during the early stages of concrete hardening. Polypropylene and glass microfibers are common types used in concrete mixes.

MESOFIBERS:

Size and Aspect Ratio: Mesofibers fall in between macrofibers and microfibers in terms of size and aspect ratio. The diameters and lengths of mesofibers can vary, and they provide a balance between the benefits of macrofibers and microfibers.

Applications: Mesofibers are designed to offer a combination of post-cracking performance and early-age crack control. They are suitable for applications where a balance between crack resistance and workability is desired, such as in various types of structural and non-structural concrete elements.

Common synthetic mesofibers include polypropylene, polyethylene, and nylon fibers. These fibers contribute to the performance of concrete by improving its resistance to cracking and enhancing durability, which makes them valuable additives in concrete mixes.

Fig 3: Typical synthetic microfibers, mesofibers and macrofibers

IMPORTANCE OF ADHESION BY STRUCTURAL FIBERS WITH MECHANICAL ANCHORAGE VS. SMOOTH FIBERS

In the fiber-reinforced concrete industry, a wide variety of macrofibers and mesofibers can be found. However, just as not all have the same tensile strengths and elastic modulus, they also have different shapes or geometries. The anchorage of synthetic macrofibers or mesofibers within the concrete paste is crucial to creating a ductile and tough material, as shown in the following graph:

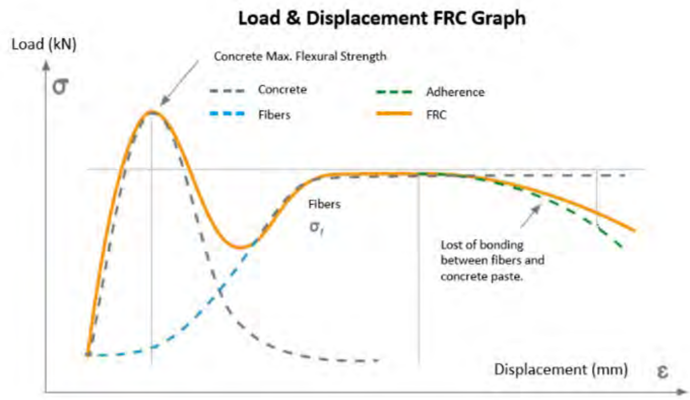

Fig 4: Ability of FRC to carry post-cracking load

The strength provided by macrofibers or mesofibers is residual, which means that once the concrete reaches its maximum load, it will fail suddenly if it does not have reinforcement at the crack location. This is where the union of the concrete paste and synthetic macrofibers or mesofibers come into play. As displayed in the graph, the ductility will depend on the loss of fiber anchorage. Hence, the importance of the geometry of the synthetic fibers to continue to safely support the imposed loads in our concrete structures and increasing the lifespan of the constructed structure.

The geometry of macrofibers or mesofibers was studied in the thesis of Civil Engineer, David Joseph Carnovale: "Behavior and Analysis of Fiber-Reinforced Concrete with Steel and Macro synthetic Fibers Subjected to Inverted Cyclic Loading: Pilot Research" from the University of Toronto[2]. In this thesis, the table below discusses Tb = Fiber anchorage resistance (MPa):

Table 2.4: Bond Strengths of Macro-Synthetic Fibres with Mechanical Anchorages (Won et al., 2006)

Mechanical Anchorage Type	τ_b [MPa]	$\tau_b / \tau_{b,sraight}$
Straight	0.28	1.00
Crimped	1.82	6.50
Twisted	0.56	2.00
Enlarged Ends	0.71	2.54
Sinusoidal Ends	0.72	2.57
End-Hooked	0.40	1.43
Double Duoform	1.10	3.93

Fig 5: Bond strength of synthetic macrofibers with mechanical anchorages

Won et al. (2006)[3] conducted a series of extraction tests on monofilament synthetic macrofibers with different types of mechanical anchors. The bonding forces improved significantly compared to a straight and smooth synthetic macrofiber against a corrugated synthetic macrofiber by a factor of 650%. There was also a much higher adhesion, Tb, compared to sinusoidal (zigzag) fibers, exceeding 250%.

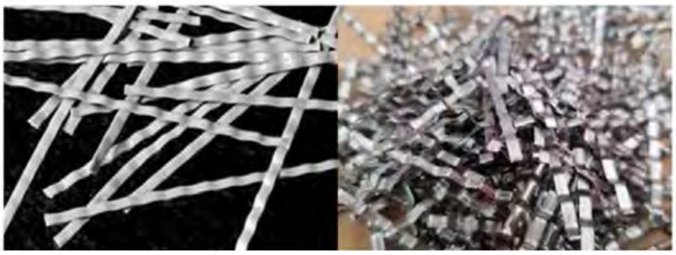

Fig 6: Sinusoidal synthetic and steel fibers

Later, Choi et al. (2012)[4] studied what would happen with the cross-sectional area of the macrofiber and re-evaluated Tb = Fiber anchorage resistance (MPa) with different shapes (clover, cross, star, and hexagram) of smooth and corrugated fibers.

Table 2.5: Bond Strengths of Macro-Synthetic Fibres with Varying Cross Sections (Choi et al., 2012)

Cross Section	$SA^* / SA_{circular\ fibre}$	$\tau_{b,straight}$ [MPa]	$\tau_{b,crimped}$ [MPa]
Clover	1.11	0.37	3.38
Cross	1.48	0.49	3.23
Star	1.51	0.43	2.69
Hexagram	1.73	0.48	4.13

* SA is the fibre surface area

Fig 7: Bond strength of synthetic macrofibers with varying cross sections

Again, the conclusion was that corrugated fibers, with the same cross-sectional area, had much higher Tb resistance in MPa and an 860% higher mechanical resistance to anchorage failure with the concrete paste.

The following image represents types of smooth synthetic macrofibers and mesofibers with a rectangular (closest to hexagonal) shape from the international market:

Fig 8: Smooth synthetic fibers with a rectangular shape

For this study we have chosen synthetic mesofibers with cross-sectional geometries closest to a hexagram and crimped-embossed "rod-type" mechanical anchors. Looking towards a more sustainable path, these synthetic mesofibers were manufactured as a 100% recycled polypropylene blend and designed to meet the minimum tensile strength required in ACI 544.4R-18 for being considered a structural concrete fiber.

Fig 9: The mesofiber selected for this study

These geometries gave us the most ductile residual strength and toughness results with curves in load-deformation graphs without loss of anchorage adherence, even at deformations of 1.6 in. (40 mm) in the ASTM C1550[5] test and surpassing the concrete maximum flexural strength at deformations of 0.12 in. (3.0 mm) with the ASTM C1609[6] test. These graphs include some of the dosages proposed for mesofiber:

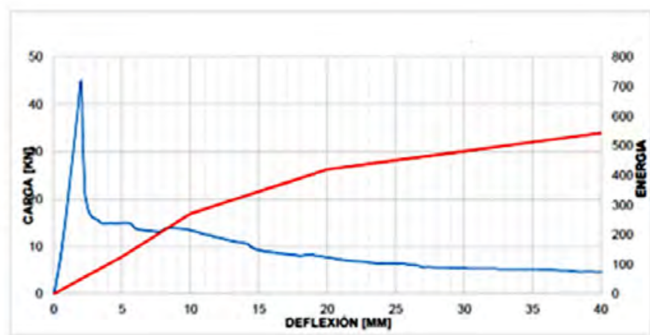

Fig 10: Results of an ASTM C1550 test with mesofibers

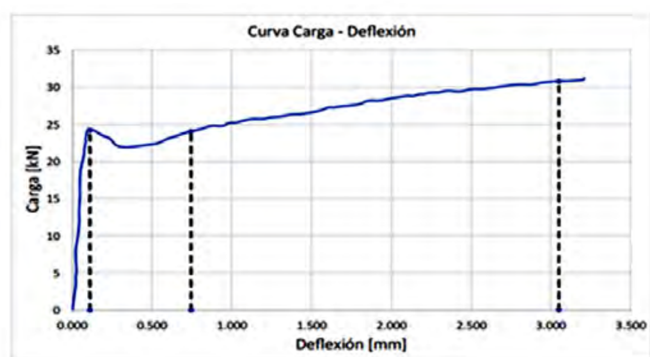

Fig 11: Results of an ASTM C1609 test with mesofibers

After identifying the characteristics for the type of structural fiber we needed for this evaluation, below are the dosages of the synthetic mesofiber that will meet with the desired reinforcing steel ratios and replace the steel reinforcement in pool walls, specifically of 6 in. width.

Steel Rebar Fy 60,000 psi	Steel Ratio (p)	Dosage: Synthetic Mesofiber Lb/yd^3 (Kg/m^3)
Rebar #3 @ 12in (single)	0.158%	7.0 (4.2)
Rebar #4 @ 12in (single)	0.280%	12.0 (7.2)
Rebar #3 @ 12in (double)	0.316%	14.0 (8.4)
Rebar #4 @ 12in (double)	0.560%	24.0 (14.4)

Fibers may exhibit impressive performance in laboratory assessments but can pose significant challenges when applied in real-world construction settings. Achieving a harmonious balance between these two aspects is crucial. Various fibers come with distinct protocols regarding their optimal inclusion in concrete and specific time requirements for the addition process. The addition of fibers in a manner resembling "chicken feed" can be cumbersome for concrete producers, especially in high-speed mixing systems used in paving applications and applications needing with elevated fiber dosages.

Fig 12: Balling up of fibers introduced into a concrete mixture

The potential for fibers to form balls and clump together presents substantial issues during shotcrete placement, and this impacts processes such as pumping and finishing. Ensuring a uniformly distributed network of fibers throughout the concrete is paramount for performance and crack control. Fiber balls pose challenges at the job site and lead to an overall reduction in the effective fiber dosage whenever a ball is removed from the slab. Additionally, hidden fiber balls within the slab may pose future risks, potentially causing soft spots, leakage and even structural failure.

The significance of the mixture design cannot be understated in addressing the fiber balling issue. However, with the use of synthetic mesofibers, many of these concerns can be mitigated or even eliminated. The inherent characteristics of mesofibers, including their length, aspect ratio, surface properties, and compatibility contribute to a more controlled and uniform dispersion within the concrete mixture, and this minimizes the risk of fiber balling. This gives synthetic mesofibers an advantage in enhancing the performance and durability of concrete structures.

THE SUSTAINABILITY OF USING SYNTHETIC MESOFIBERS WITH 100% RECYCLED POLYPROPYLENE BLEND

The use of synthetic mesofibers in concrete, particularly those manufactured from 100% recycled materials, is often considered more sustainable than the use of steel reinforcement. One key factor contributing to this sustainability is the environmental impact associated with steel production. The manufacturing of steel involves significant energy consumption and the release of carbon dioxide emissions, which contributes to a substantial carbon footprint. In contrast, mesofibers produced from recycled materials require less energy and help divert waste from landfills, which aligns with the principles of recycling and resource conservation.

Another aspect of sustainability in favor of synthetic mesofibers is their resistance to corrosion. Steel reinforcement in concrete structures is susceptible to corrosion over time, especially in harsh environmental conditions. This leads to degradation and maintenance issues. Corrosion not only compromises the structural integrity of the concrete but also requires additional resources for repair and replacement. Mesofibers, being synthetic in nature, do not corrode and offer long-term durability without the need for constant maintenance. Therefore, they reduce the overall environmental impact because of the extended life with lower maintenance of the structure.

1. Steel-Rebar Kg CO_2eq/Kg:

Reinforcement Consideration No.	Steel-Rebar Mesh	Steel* Kg / m^2	Steel Kg CO_2eq/Kg	Kg CO_2eq/m^2	m^2 / pool**	Steel Kg CO_2eq/Pool
1	Var #3 @ 12 in. (single layer)	3.73	2.06	7.68	200 (2200 ft^2)	1,536
2	Var #4 @ 12 in. (single layer)	6.63		13.67		2,734
2	Var #3 @ 12 in. (double layer)	7.47		15.38		3,072
4	Var #4 @ 12 in. (double layer)	13.25		27.31		5,468

**Considering the #3 has a 0.375 in. diameter with 0.56 Kg/m and the #4 has a 0.5 in. (13 mm) diameter with 0.994 Kg/m.*
***Considering a 200 m^2 pool-wall (2200 ft^2) with 6 in. width, that will consume 30 m^3 (39 yd^3) of shotcrete.*

2. 100% Recycled Polypropylene Structural Mesofiber Kg CO_2eq/Kg:

Considerations for the 100% recycled polypropylene mesofiber:

Manufacturing Stage of Sustainable MesofibersSteel* Kg / m²		
A1	Raw material "sustainable polypropylene"	**0.18 Kg CO_2eq/Kg**
A2	Raw material transport	**0.04 Kg CO_2eq/Kg**
A3	Mesofibers manufacture	**0.54 Kg CO_2eq/Kg**
Total Kg CO_2eq/Kg "Sustainable Mesofiber"		**0.76 Kg CO_2eq/Kg**

Reinforcement Consideration No.	Mesofiber Dosage (Kg/m³)	Mesofiber Kg / m²	Mesofiber Kg CO_2eq/Kg	Kg CO_2eq/m_2	m² / pool*	Mesofiber Kg CO_2eq/Pool
1	4.2 (7.0 Lb/yd³)	0.63	0.76	0.48	200 (2200 ft²)	96
2	7.2 (12.0 Lb/yd³)	1.08		0.82		164
3	8.4 (14.0 Lb/yd³)	1.26		0.96		192
4	14.4 (24.0 Lb/yd³)	2.16		1.64		328

**Considering a 200m² pool-wall (2200 ft²) with 6in. width, that will consume 30m³ (39 yd³) of shotcrete.*

2. Comparing the Steel-Rebar vs the Sustainable Mesofiber Kg CO2eq/Kg tables:

Reinforcement Consideration No.	Steel-Rebar Kg CO_2eq/Pool	Mesofiber Kg CO_2eq/Pool
1	1,536	96
2	2,734	164
3	3,072	192
4	5,468	328

Additionally, the light weight of synthetic mesofibers yields reduced transportation costs and emissions during construction, further enhancing their environmental benefit. As sustainable construction practices gain prominence, the utilization of synthetic mesofibers emerges as an eco-friendly alternative while promoting a more resilient and environmentally-conscious approach to concrete reinforcement compared to traditional steel reinforcement.

COST BENEFIT BETWEEN INSTALLING STEEL REBAR MESH VS. ADDING SUSTAINABLE MESOFIBERS TO A SHOTCRETE MIX

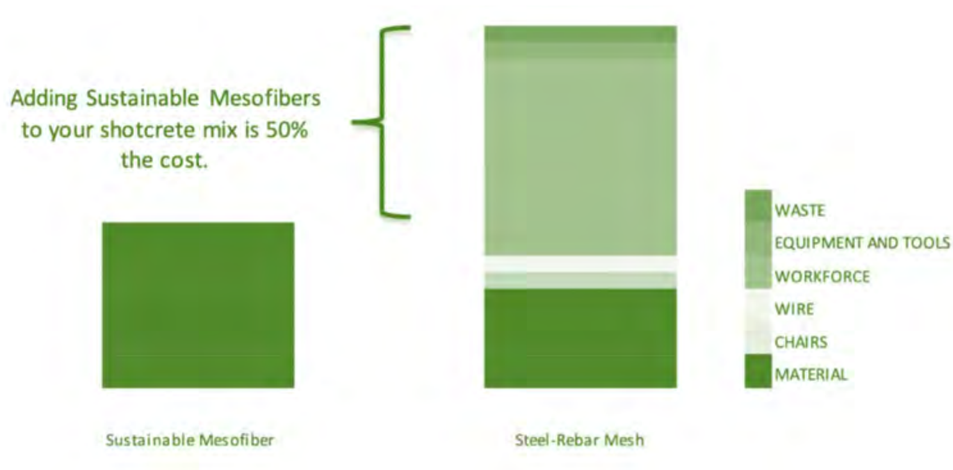

Fig 13: Sustainability benefits of mesofibers compared to traditional reinforcing steel

PROCEDURE TO CONSTRUCT A CONCRETE SWIMMING POOL

Constructing an in-ground concrete swimming pool involves a series of well-defined steps to ensure durability, functionality, and aesthetics. Below is a detailed procedure outlining each stage of the construction process:

Step 1: Selection of Location and Design

The initial phase of constructing a concrete swimming pool is to select an appropriate location and design. Factors such as the shape, depth, area, filtration system, and overall size of the pool are considered. The chosen location should facilitate easy maintenance and be situated away from trees to prevent leaves from falling into the pool. Additionally, the orientation of the pool should maximize exposure to sunlight.

Step 2: Excavation of Earth

Following the design selection, the construction process begins with excavating the designated area for the pool. Wooden stakes are used to mark the perimeter of the pool, and earth removal equipment, such as a backhoe, is employed to dig within the marked boundaries. Care is taken to avoid any underground utilities or drainage lines during excavation.

Step 3: Construction of Swimming Pool Base

The construction of a sturdy base is crucial for the longevity of the swimming pool. After excavation, the area is filled and compacted with firm soil or gravel to create a level surface. A layer of lean concrete can be poured onto the compacted base, ensuring uniformity and strength. Proper drainage slopes are incorporated into the base design to facilitate water flow to the filtration system.

Step 4: Shotcrete Reinforcement

Steel Cage Reinforcement

Steel reinforcement is installed along the pool walls and floor to provide structural integrity. The reinforcement is designed and laid out for shotcrete placement. Using shotcrete placement creates a seamless structure without joints between the walls and floor. Plumbing lines and drainage systems are integrated within the steel cage arrangement or outside the wall to support water circulation.

Fiber-reinforced-shotcrete

Using SFRS for pool construction offers several advantages over traditional steel reinforcement. Firstly, the installation of steel reinforcing bar in shotcrete pool construction is a time-consuming process. The placement of each rebar requires close attention to detail and can slow down the construction timeline significantly. Moreover, ensuring that the reinforcing bars are perfectly positioned and rigidly secured within the wall is challenging and often results in less-than-optimal reinforcement. This inefficiency not only prolongs the construction schedule but also introduces the potential risk of structural weaknesses due to improperly placed or misplaced rebars.

On the other hand, synthetic fibers provide a more efficient and cost-effective solution for reinforcing shotcrete pools. These fibers are easily mixed into the concrete mixture, which eliminates the need for time-consuming placement of individual reinforcing bars. Once added into the mixture, the fibers uniformly distribute throughout the concrete and provide consistent reinforcement without the risk of misplacement. Additionally, using synthetic fibers reduces labor costs associated with the reinforcing bar installation and minimizes material waste, contributing to overall cost savings in the construction. Furthermore, synthetic fibers offer enhanced crack resistance and durability, providing longevity and structural integrity of the shotcrete pool shell over time. Overall, the adoption of synthetic fibers presents a practical and advantageous alternative to traditional rebar reinforcement in shotcrete pool construction.

Step 5: Pump and Filter System for Swimming Pool

A pump and filter system are installed to maintain water circulation and cleanliness. Plumbing connections are made to facilitate water flow from the pool to the filtration system and back. Additionally, provisions are made to replenish water lost through evaporation or splashing.

Step 6: Concreting in Swimming Pool Construction

The walls and floor of the pool are constructed using shotcrete placement, which will ensure uniformity and strength. Specialized finishing tools are used to shape the concrete surface to meet the design specifications. Following concrete placement, curing is performed for a period of two weeks to enhance strength, watertightness and durability.

Step 7: Plastering and Tiling of the Concrete Pool

Once the shotcreted pool shell is cured, specialty plaster coatings are often applied. These give a more uniform color and texture to the pool's inner surface. Many pools will have portions of the shotcreted pool shell tiled for a distinctive appearance and ease of cleaning.

Step 8: Construction of Coping

Coping, the perimeter around the pool edge, is constructed using materials such as concrete, marble, or tile. A waiting period of two to three days is observed after coping construction before filling the pool with water.

Step 9: Pool Start-Up

Once construction is complete, the pool undergoes a start-up phase to ensure proper functionality. This involves testing the circulation system, installing additional features, balancing water chemistry, and cleaning the pool and surrounding areas.

Step 10: Final Coating of the Deck and Landscaping Begins

The deck surrounding the pool may receive a final coating to enhance aesthetics and durability. Following deck completion, landscaping is often installed to integrate the pool seamlessly into the surrounding environment.

CONCLUSIONS

In conclusion, the integration of synthetic mesofibers into shotcrete for pool construction represents a significant advancement in the field of concrete materials and methodologies. This paradigm shift addresses one of the challenges faced by traditional concrete structures - cracking, that may be particularly evident in environments with fluctuating temperatures and moisture levels. These fibers act as reinforcements by improving the post-cracking performance of shotcrete and maintaining a significant portion of its load-carrying capacity even in the presence of cracks. Using synthetic mesofibers in shotcrete enhances the durability and performance of pool structures and offers a sustainable and practical solution.

The environmental benefits of using synthetic mesofibers are notable. The reduction in CO_2 emissions associated with producing and using these sustainable fibers presents a compelling reason for their adoption. Traditional steel reinforcement, with its significant carbon footprint and susceptibility to corrosion, can be effectively replaced by synthetic recycled mesofibers aligning with the principles of sustainability and environmental responsibility.

The study also addresses the economic aspect by demonstrating that the use of synthetic mesofibers is not only environmentally friendly but also cost-effective. The proposed dosages of synthetic mesofibers, based on the ACI 544.4-18 methodology, show promising results in terms of crack control and flexural residual strength. These dosages, when compared to traditional steel ratios, indicate a viable and economical alternative for pool construction with potential cost savings.

Additionally, the ease of handling and application of synthetic mesofibers adds to their practicality in construction, especially in scenarios where acquiring traditional materials like reinforcing steel can be challenging. The controlled dispersion of mesofibers within the concrete mix minimizes issues such as fiber balling, ensuring uniform distribution and improving the overall performance of the shotcrete.

In summary, the use of synthetic sustainable mesofibers in shotcrete for pool construction offers a holistic solution that addresses technical, environmental, and economic considerations. This innovative approach contributes to the evolving landscape of construction materials, fostering advancements that meet the demands of a dynamic and forward-thinking industry. The transition from traditional concrete reinforced with steel to shotcrete incorporating synthetic mesofibers represents a sustainable and practical evolution in the construction of modern swimming pools.

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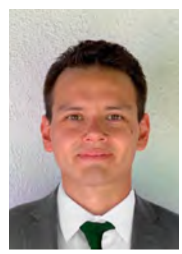

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