Course Name: Building Materials as a Cornerstone to Sustainability

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Lecture 03

Fibre Reinforced Concrete

Hello everyone. In our last class, we saw a very innovative building material that was organic and made with mycelium. In today's class we will see another interesting building material, which is fiber-reinforced concrete. We will look at its manufacturing, its types, its features, its advantages, its limitations, its applications and uses, case studies of building using this material, and the final conclusion. So, fiber-reinforced concrete can be defined as a composite material consisting of mixtures of cement, mortar, or concrete and discontinuous, discrete, uniformly dispersed suitable fibers. Fiber-reinforced concrete is of different types and properties with many advantages.

Continuous mesh, woven fabrics, and long wires or rods are not considered to be discrete fibers. Fiber is a small piece of reinforcing material possessing certain characteristics and properties. They can be circular or flat. When it comes to its manufacturing, a very important aspect of its manufacturing is in the selection of fibers.

We need to choose the type of fibers based on the specific requirements of the project. Common types include steel, glass, synthetic, which is polypropylene, polyester, or nylon, and natural fibers such as sisal and jute. If we look at the concrete mix design, we need to develop a concrete mix design that meets the structural and durability requirements of the project. This includes selecting the appropriate cement aggregates, water-cement ratio, and any additional admixtures. When it comes to fibre addition, add the fibres to the concrete mix during the batching process.

The timing of fiber addition can vary. For steel fibers, they are often added during the mixing of coarse and fine aggregates. For synthetic and glass fibers, they are usually added during the mixing of cement and aggregates. Next is the mixing. Thoroughly mix the concrete to ensure uniform distribution of fibers throughout the mixture.

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Transport the fiber-reinforced concrete to the construction site. During transportation and placement, take measures to prevent segregation of the fibers and ensure a uniform mix of the fibers. Then comes the casting and finishing. Cast the fiber-reinforced concrete into the desired forms or moulds. During the casting process, care should be taken to avoid any fibre clumping or settling.

Finish the surface as needed, depending on the application. When it comes to curing, allow the fiber-reinforced concrete to cure properly. Curing helps in achieving the desired strength and durability. The curing process may involve covering the concrete with wet burlap, applying curing compounds, or other appropriate methods. So, these are what we saw was the manufacturing process, and now we will see the type of fibers used.

Fiber-reinforced concrete incorporates various types of fibers, such as steel, glass, synthetic polymer, synthetic fiber, then natural fibers, carbon, basalt fibers, and so on. So steel fibers improve tensile strength Each has its own advantage and disadvantage, so steel will improve tensile strength and ductility, and glass fiber will offer lightweight corrosion resistance synthetic fiber will reduce the cracking and is lightweight; natural fibers produce flexibility and are biodegradable Polymer fibers offer high strength and chemical resistance. Carbon fibers provide exceptional tensile strength, and basalt fibers offer strength and fire resistance. Hybrid fibers can be combined for synergistic benefits. Let us now look at each fiber individually.

steel fibers, the properties include excellent tensile strength and ductability to the concrete. They resist cracking and improve the concrete's toughness. These are commonly used in industrial floors, pavement, shotcrete and precast concrete elements. Glass fibers glass fibers they are lightweight and provide good resistance to corrosion. They improve impact resistance and reduce shrinkage cracking.

Their applications are in architectural panels, thin-sectioned concrete elements, and for decorative applications. A look at the synthetic fibers show that Synthetic fibers include polypropylene, polyester and nylon fibers. They enhance the concrete's durability, reduce plastic shrinkage and cracking, and improve impact resistance. They can be applied or used in residential and commercial construction, slabs and overlays. Natural fibers such as sisal, jute and coconut fibers can also be used.

These natural fibers can improve the concrete's flexibility, reduce cracking and provide some environmental benefits. These are mostly used in non-structural applications and in regions where natural fibers are readily available. Let us look at the advantages and disadvantages. The advantages are increased durability, FRC exhibits enhanced resistance to cracking, impact and fatigue resulting in improved durability. These fibers are tough.

They enhance the concrete's toughness making it more resilient to dynamic loads and reducing the risk of brittle failure. They have crack control which means it reduces plastic and drying shrinkage cracking leading to improved long term performance. They are fire resistant, as certain fibers like steel and basalt contribute to improved fire resistance in the concrete. Reduced maintenance, so enhanced durability and reduced cracking results in lower maintenance costs over a period of time. There are however strong disadvantages or limitations.

First is the cost. The additions of fiber can increase material cost compared to traditional concrete. Second is the uniform distribution. Achieving uniform fiber distribution throughout the mix may pose challenges during mixing and placement. Third is the workability. Some fibers may impact the workability of the concrete mix requiring adjustments to maintain proper consistency.

The fourth limitation is the corrosive issue. So, steel fibers are now in corrosive environments; these could get susceptible to corrosion. So, impacting long term performance would be the result. Specialized knowledge. Now, proper understanding of fiber types, mix design, and construction practices is crucial, requiring specialized knowledge.

Thus, fiber-reinforced concrete offers advantages such as increased durability, improved toughness, and crack control. However, potential challenges include increased cost, the need for uniform fiber distribution, and considerations specific to certain fiber types. Careful selection and application are necessary to optimize the benefits of fiber-reinforced concrete in various construction scenarios. Now, let us look at the applications. Fiber reinforced concrete finds diverse applications across various construction projects due to its improved properties.

Here are some common applications and uses of fiber-reinforced concrete. The versatility of fiber-reinforced concrete makes it a valuable material in a wide range of construction applications, offering improved performance and longevity compared to traditional concrete. The choice of fiber type and dosage depends on the specific needs of the project. First are industrial floors. Now FRC is often used in industrial settings such as warehouses and manufacturing facilities where heavy loads and abrasion resistance are crucial.

Steel fibres are commonly employed to enhance toughness and durability. Second is pavement and highways. Fiber-reinforced concrete is utilised in the construction of pavements and highways to improve resistance to cracking caused by traffic loads and environmental factors. Synthetic fibres are commonly used in these applications.

Third are precast elements. Precast concrete elements such as panels, beams and columns benefit from the use of fibres to enhance strength and durability. Different fibre types may be chosen based on the specific requirements of the precast components. Fourth is shotcrete and tunnel lining. FRC is suitable for shotcrete applications providing increased strength and crack resistance in tunnel linings. So, in tunnel linings these fibers can help control cracking and enhance overall durability.

Next is architectural panels. So, fibre reinforced concrete is widely applied in diverse construction scenarios to enhance durability, strength and crack resistance. Common applications, as we had already seen, are industrial force, pavements. know precast elements, shotcrete, tunnel linings, bridge decks, residential construction, architectural panels, repair projects, water retaining structures, airport pavement, and so on and so forth. Let us now look at the architectural panels. Glass fibers or other lightweight fibers are often used in architectural panels to provide structural stability as well as for its aesthetic appeal.

These panels can be used in facades and other decorative elements. Next is repair and rehabilitation. Fiber reinforced concrete is employed in the repair and rehabilitation of existing structures. It helps improve the structural stability. Let us look at the architectural applications in panels.

So, glass fibers or other lightweight fibers are often used in architectural panels to provide both structural support and aesthetic appeal. These panels can be used in facades and other decorative elements. When it comes to repair and rehabilitation, fiber-reinforced concrete is employed in the repair and rehabilitation of existing structures. It helps improve the structural integrity and durability of the repaired sections. The next application is a water-retaining structure.

FRC is used in the construction of water tanks and reservoirs, providing added strength and crack resistance. Synthetic fibers are commonly used in these applications. These can also be used for slope stabilization. Fiber-reinforced concrete is utilized for slope stabilization in areas that are prone to erosion. The enhanced tensile strength of the concrete helps in stabilizing slopes and preventing soil erosion.

It is also used in high-performance structures. In high-performance structures such as stadiums, theaters, and museums, FRC is used to meet stringent requirements for durability, strength, and crack resistance. Let us now look at the case study applications of fiber-reinforced concrete. The first is the AARhus in Denmark. Using GRC parts from GRCA, full member BB5 Britain, this famous residential building on the seaside is located in Denmark's second biggest city, which is AARhus.

The project's architect set out to capture the essence of RSS architecture and personality. The structure, which resembles 2A, 2A is A as in alphabet, is designed to serve as the city's new symbol and to greet guests. The 20-story structure has over 250 units, all of which have views to the ocean. GRC was the perfect material in this project because of the building's distinctive shape and the goal of designing a contemporary structure that stands out from the rest. GRC's formability and versatility allow architects to express their creativity and offer them a great lot of design freedom.

The GRC facade elements which combine recessed holes with plugs, embedded inserts and steel brackets to provide concealed and simple installation. This produces a final product that seems monolithic and doesn't need any technical upkeep. So, in conclusion, we can see that FRC provides enhanced properties for improved performance compared to traditional concrete including increased durability, toughness and resistance to cracking. These improvements make it suitable for a wide range of applications.

It is also a very versatile material. FRC finds applications in diverse construction projects ranging from industrial floors and pavements to precast elements, bridge decks and residential construction. Its versatility allows for customization based on project requirements. The choice of fibre type depends on the specific needs of the project. Steel fibres offer high tensile strength, glass fibres provide lightweight corrosion resistance, synthetic fibres improve flexibility, and carbon fibres give exceptional strength. When we see crack control and durability, FRC effectively reduces plastic and drying shrinkage cracking, contributing to the long-term durability of the structures.

This makes it particularly beneficial in challenging environments or where resistance to dynamic loads is crucial. Fire resistance and specialized applications. Certain fiber types, such as steel and basalt, contribute to improved fire resistance, expanding the range of applications for FRC. Additionally, specialized applications, including high-performance structures and infrastructure projects, benefit from the unique properties of FRC. While FRC offers numerous advantages, there are definite challenges to consider, including increased material costs, the need for uniform fibre distribution and potential impacts on workability.

Proper mix design and construction practices are crucial for success. The formality and versatility of FRC allow architects and engineers greater design freedom. This has led to innovative and aesthetically pleasing structures as seen in architectural panels, facades and other decorative elements. Here are examples of how all FRC can be used. So, here you can see FRC, which is used in the brick-making methods with differential physical properties.

Hence, we can conclude that using FRCs will give improved performance, has versatile applications, based on the use the fiber types can be decided, crack control and durability can be decided, fire resistance and specialized applications, it has construction challenges, it has innovative design possibilities. With this, we conclude our talk on FRC and quickly move on to another building material, which is fab brick. Bricks made with fabrics. We will see the material composition, brick making method and its physical properties. So insulation properties of bricks made with cotton and textile ash waste are has shown that there is a possibility to use this material.

So, from a research paper that is based in Turkey, the surge in population has intensified the demand for novel and efficient building materials, prompting the exploration of repurposing industrial waste for construction. The unchecked accumulation of significant waste volumes poses environmental threats, emphasizing the significance of employing waste as construction materials for both economic and eco-friendly benefits. In the contemporary construction landscape, there is a pronounced inclination towards utilizing environmentally sustainable, cost-effective and lightweight materials. Researchers are actively addressing the challenge of aligning with material standards while meeting these evolving construction material preferences. Previous studies have yielded valuable insights into employing diverse industrial ways such as rubber, paper and glass powder in concrete production.

Specific investigations into textile waste including cuttings, effluent treatment plant sludge and cotton stock fibre have showcased promising outcomes. However, the unique properties of cotton waste necessitate dedicated research. The imperative to reduce fossil fuel reliance due to environmental concerns and the escalating global energy demand especially in countries like Turkey underscores the importance of doubling the electric power capacity by the year 2020. With 40 percent of Turkey's energy consumption occurring in houses, the need for sustainable insulating materials becomes critical given the rapid depletion of global energy resources. The emphasis on the growing importance of adopting eco-friendly construction materials to preserve the environment and address escalating energy demands had given rise to this research.

So, as per that research paper, the model houses were subjected to heating for 30 minutes and cooling for 115 minutes, maintaining a laboratory temperature of 15 degrees Celsius. So, in the contemporary construction industry, the prominent concern revolves around the utilization of thermal insulation materials, especially for wall construction, as a pivotal strategy for energy conservation. The cotton and textile ash waste brick house exhibited a higher temperature than a concrete brick house after the initial 30 minutes, showcasing its superior thermal performance. Despite the decrease in temperature being half compared to the concrete brick house, the improvement is noteworthy considering the significant impact of the temperature difference for the cotton and textile ash waste brick house. The thermal conductivity variation of cotton waste and textile ash waste brick exhibited a similar trend of their density variations.

The thermal conductivity coefficient of these bricks was found to be 29.3 percent lower than that of conventional bricks. Notably, different groups of these bricks displayed varied heat conductivity rates due to differing cement percentages. Therefore, practical use or application of these bricks should involve determining the cement content based on specific compressive strength and thermal conductivity requirements for each case. This underscores the need for a customized approach to ensure optimal performance of various applications.

Now, if we look at the utilization of cotton and textile waste in brick production, this is a topic of ongoing research and experimentation. The use of such waste materials in brick manufacturing is not yet widely adopted globally. However, research and development in sustainable construction materials are continually evolving. Now if we look at the steps.

First is use discarded clothes based on colours. Shred the textile to obtain fibres. You can obtain three different shapes of fibres. 7mm, 20mm and 40mm. Pick the size depending on the project or application.

Make a glue. The glue is 100% made of ecological ingredients, which is a trade secret. Mix the glue and the fibers by hand. Weigh the mixture to make sure each brick has the same density. Incorporate the mixture by hand in the patented machine. Action the machine In order to compress the mixture inside the mold, it takes about 30 minutes to shape the mixture into a brick.

The brick dries in ambient air in 10 to 15 days. Now you can use this brick to create some non-structural elements. Sometimes even small pieces of furniture and partition walls also. So, with this class, we close with two important building materials that we saw that are very innovative. So, the last one in which we saw fabric, it was again split into two. One is use of fabric ash in bricks and another is use of fabric directly as a non-structural material. We will stop our class with this and continue in the next class.