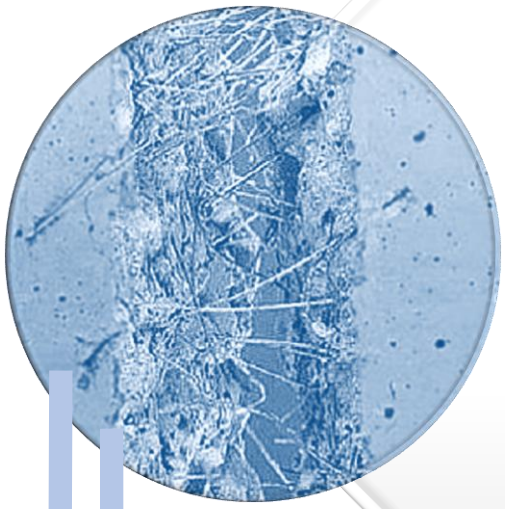

FIBER'S Types and Effects in Concrete

Research Report By

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CONTENTs:

PREFACE:

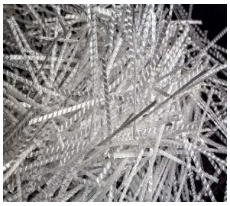
Fiber mixing with concrete and cement mortar have more than one effect, which may have positive or negative behaviors depending on the fiber's types, shapes, ratio of mixing and where it is used. A versatile mix of fiber with reinforced concrete or normal non reinforced concrete can be used for on-ground floors, pavements, slabs as well as construction parts like beams and pillars or big structure body construction like dams to decreasing the cost of using rebar, decreasing the dimension of the parts, reducing cracks and water leakage, preventing erosion and cavitation and many other purposes.

The method of using fiber in different mortars (mud, cement, water resistance paints… etc.) has been used from ancient times and it still get evolution due to the experiments of using it and the studies on the different fiber types around the world.

From ancient times humans live took the benefit of mixing grass straw or animal hair with mud mortars and bricks to increase its tensile strength to not break easily and be more durable, from thus and through the human live development, today we use different types of fibers in different mortars and paint types to increase the tensile strength and decreasing cracking due to drying and

plastic shrinkage to be more stable and more resistance to the leakage of water as well as increasing the tensile strength of different construction parts.



DEFINITIONS:

What is Fiber?

Fiber is made from many types of material (Steel, Polymer, Grass, Hair… etc.) and have different sizes and shapes but generally it looks like a macro or micro wire or steel rods or normal hair with a high tensile strength, having a heigh ratio of length to its diameter, mixing with mortars to increase its tensile strength and reducing or controlling its shrinkage and cracking during the drying prosses to reducing the leaking of water through the mortar.

Fiber Reinforced Concrete FRC

Is a mixture of distracted suitable fiber and cement concrete or mortar in a specific ratio to control the concrete cracks due to drying and plastic shrinkage during the curing prosses during the first ٢٤ hours of placement to increase its tensile strength and to be more resistance to the water leakage to be more stable and durable.

Note:

Layers of wire mesh or harp mesh made from steel, copper, aluminum or polymer used with cement or gypsum mortar with little different technique for the same purposes of using fibers.

FIBER PERFORMANCE:

Fiber performance is influenced by three characteristics;

- Tensile strength, depending on the fiber type.

- Aspect ratio (length/diameter) of the fiber.
- Anchorage (hooked, crimp, emboss, fibrillation, etc.).

Each characteristic has its effect; and all three items have to work together for optimal performance.

Fibers begin to function in a structural supportive manner when the concrete starts to crack, just like traditional reinforcement. The crack has to occur to switch from the normal concrete to the reinforcement concrete, then the fibers provide ductility and support by bridging cracks and thus providing post crack strength to the concrete.

TYPES OF FIBER:

The first step to choosing the right fiber for a structure is to understand the type of fiber required for your application. Fibers are available in different composites, sizes and shapes, given below are some different types of fiber used in construction.

١st Polymer Fiber Bars (PFB)

Polymer fiber bars (PFB) is made from Ethylene and depend on how it polymerizes, it has been widely used in civil engineering and substitutes as steel reinforcement because it has many advantages such as high strength-to-weight ratio, light weight, handling easily and no corrosion. PFB has become an economical and competitive structure material.

The bond stress transfer between PFB and concrete have three main mechanisms:

First is the chemical adhesion between the two materials at the interface. Second is the friction bond which is due to the coarseness on the surface of the bars. Third is mechanism contributing towards the bond in mechanical bearing, generate from the lugs on the bars. The third mechanical bond behavior is the main performance factor against failure mode, serviceability, crack width, deformation and structure analyses and design.

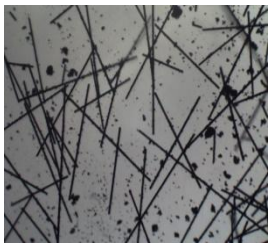
Steel rebars are relatively inexpensive, well-tested and strong but are a corrosive material for a very corrosive environment, so we sometimes use epoxy-coated rebar or even stainless steel. But the PFB which is made of basalt, remelted volcanic rock, forced through tiny nozzles to create fibers are extremely strong. The major impediment to the use of these newer material is it may cost more than steel rebar in some cases, but its positive point is it is easy to use and more durable, so that those additional costs may be offset by the increased lifespan of the concrete.

٢nd Polypropylene Fiber Bars

Polypropylene fiber which is classified as number ٥-PP (plastic polymer). Transformed from propylene, it has similar properties as polyethylene but it is harder and more heat resistant, used in a variety of applications.

Polypropylene fiber belongs to the group of polyolefins and is partially crystalline and non-polar. It is a white rugged material with high chemical resistance. Polypropylene is manufactured from propylene gas in the presence of a catalyst such as titanium chloride. Polypropylene fiber displays good heat-insulating properties and is highly resistant to acids, alkalis, and organic solvents.

٣rd Carbon fibers Bars (CFB)



Carbon fibers are fibers about ٥–١٠ micrometers in diameter and composed mostly of carbon atoms. Carbon fibers have several advantages including high stiffness, high tensile strength, low weight, high chemical resistance, high-temperature tolerance and low thermal expansion. Carbon fibers are usually combined with other materials to form a composite. When impregnated with a plastic resin and baked it forms carbon-fiber-reinforced polymer which has a very high strength-to-weight ratio and is extremely rigid although somewhat brittle. Carbon fibers also composited with graphite to form reinforced carbon composites, which have a very high heat tolerance.

٤th Polyester fibers

Polyester fibers are used in fiber-reinforced concrete for industrial and warehouse floors, pavements and overlays and precast products. Polyester micro- and macro-fibers are used in concrete to provide superior resistance to the formation of plastic shrinkage cracks versus welded wire fabric and to enhance toughness and the ability to deliver structural capacity.

٥th Steel Fiber Bars (SFB)

Steel fiber is a metal reinforcement, may be collated (glued) together in a clip, the bundles are spread throughout the concrete. Continued mixing action breaks the clips to let the individual fibers separate quickly throughout the mix. A certain amount of steel fiber in concrete can cause qualitative changes in concrete's physical property. Steel fiber bars SFB can greatly increase resistance to cracking, impact, fatigue and bending, tenacity, durability and others. For improving long-term behavior, enhancing strength, toughness and stress resistance, Steel fiber reinforced concrete SFRC is being used in heavy-duty and industrial applications where superior crack control and impact resistance is a must such as flooring, housing, precast, bridges, tunneling, heavy-duty pavement and mining. Steel fibers can help improve general structural strength and reduce the need for steel reinforcement

The types of steel fibers are defined by ASTM A٨٢٠, which are…

Type I: cold-drawn wire

Type II; cut sheet

Type III: melt-extracted

Type IV: mill cut

Type V: modified cold-drawn wire

٦th Glass Fiber

Glass fiber has roughly comparable mechanical properties to other fibers such as polymers and carbon fiber. Although not as rigid as carbon fiber, it is much cheaper and significantly less brittle when used in composites. Glass fibers are used as a reinforcing agent for many polymer products to form a very strong and relatively lightweight fiber-reinforced polymer (FRP), the composite material is called glass-reinforced plastic (GRP), also popularly known as (FIBERGLASS). This material contains little or no air or gas, is denser and is a much poorer thermal insulator than glass wool.

٧th Cellulose fibers

Cellulose fibers are made with Ethers (an organic compound of oxygen and two alkyl or aryl groups "R-O-R" such as O-CH٢-CH٣) or Esters (an organic or inorganic compound "R-C-O٢-R'" between Oxygen, Carbon, Alkyl and Alkoxy group "O-Alkyl"), which can be obtained from the bark, wood or leaves of plants or other plant-based material. In addition to cellulose, the fibers may also contain hemicellulose and lignin, with different percentages of these components altering the mechanical properties of the fibers. The main applications of cellulose fibers are in the textile industry such as chemical filters and as fiber-reinforcement composites. Due to their similar properties to other fibers its another option for bio composites and polymer composites.

٨th Natural fibers

The natural fibers such as cotton, wood, grains, felt and straw are directly obtained from an animal, vegetable or mineral source and convertible into nonwoven fabrics after spinning into yarn. A natural fiber may be further defined as an agglomeration of cells in which the diameter is negligible in comparison to the length. The use of natural fibers in making concrete is recommended since several types of these fibers are available locally and are plentiful. The idea of using such fibers to improve the strength and durability of brittle materials is not new; for example, straw and horsehair are used to make bricks and

plaster. Natural fibers are suitable for reinforcing concrete and are easily available in developing countries.

Green supply in construction industries researches and studies mainly discusses the utilization of resources in the construction industry in such a way that an eco-friendly environment can be brought in and wastes can be minimized that are detrimental to health and environment, thus leaded to the novel use of human hair as fiber in concrete. Human hair fibers (HHF) have been used extensively in concrete. Human hair has high tensile strength and friction coefficient, that is why it has been used as fiber in rural areas of Bangladesh, India, Syria and European countries.

FIBER TYPES DUE TO SIZE AND DIMETER:

١st Macro synthetic fibers

Macro synthetic fibers have a diameter greater than ٠,٣ mm, made from a blend of polymers, used as a replacement for (temperature and plastic shrinkage) reinforcement in concrete or shotcrete. Macro fibers are used where an increase in residual (post-cracking) flexural strength is required and were originally developed to provide an alternative to steel fibers in some applications such as sprayed concrete, but increased research and development showed that they had a role to play in the design and construction of ground-supported slabs and a wide range of other applications. They are particularly suitable for providing nominal reinforcement in aggressive environments such as marine and coastal structures, as they do not suffer the problems of staining and spalling that can result from the corrosion of steel fiber. Besides, because they are non-conducting, they have been used in tram and light railway developments. Macro-synthetic fibers can be added at a much higher rate per unit volume than traditional steel fibers.

٢nd Micro-synthetic fibers

Micro-synthetic has a diameter that is less than ٠,٣ mm. Provide superior resistance to the formation of plastic shrinkage cracks (cracking that occur in

the first ٢٤ hours of concrete cure) versus welded wire reinforcement or to spall protection during a fire, freeze-thaw or to improve the homogeneity of concrete during placement. They are unable to provide any resistance to further crack width openings caused by drying shrinkage, structural load or other forms of stress. In applications where the look and feel of the concrete are important, micro-synthetic or stealth fibers may be the best choice.

PURPOSE:

WHY WE USE FIBERS, HOW IT WORKS?

Fibers are usually used in concrete to control cracking due to drying and plastic shrinkage, reduce the permeability of concrete to reduce the bleeding of water, increasing its tensile strength and many other purposes, here we show some of them.

١st – Fiber increases the tensile strength of the concrete

Concrete haves a high compressive strength and low tensile strength, reinforcing it by rebars makes it a composite material having both high compressive and tensile strength. Adding different fiber types due to their "tensile strength, shape and mixing ratio" to normal or reinforced concrete increasing the concrete toughness and the tensile strength of the concrete and start working as a rebars and providing a secondary reinforcement just when the cracks appear in the concrete, this helps to minimize the rebars requirement and decreasing the required dimensions of the parts of the concrete structures specially in those which require high number of rebars.

The addition of fibers also improves the shear capacity of concrete, depending on the fiber type.

In sum experimental tests, the flexural strength was improved by ١٣,٦٤ % by using ٢٪ of human hair and an increase in compressive strength observed by ١٠,٥١ % by adding ١٪ of the human hair fiber, after ٩٠ days.

٢nd – Fiber makes the concrete more impermeable

Reinforcing concrete by adding steel bars makes it a composition with a high tensile strength but the unprotected steel bars itself has the problem of corrosion or rusting because of the oxidation, this leads rebar to be weak and loses its tensile strength. The alkaline environment of the concrete which has high PH, leads to a thin oxide layer on the steel bars and protect it from corrosion but this is not enough, when saltwater reaches the rebars they corrode and the iron oxidation layer around the rebars increase as well as the diameter of the steel bar itself decrease, this leads to weakness in the steel bars tensile strength and also cause a stress because of the thickening of the rust layer around the bars named oxide jacking stress which is one of the causes of concrete deterioration. So, we have to not let water and its contaminants such as salts finds their way to the steel bars through the CRACKs.

Cracks in a concrete appears due to drying and plastic shrinkage during the curing process (especially the first ٢٤ hours after placement) as well as expansion and contraction due to the temperature changes and also the concrete cracks under the normal expected loading conditions.
Micro cracks naturally appear in concrete and as they continue to grow, they may intertwine with one another and become larger, which can create visible cracking in the concrete, fibers counteract this by intersecting the cracks and stopping their growth.

٣RD - IMPROVE FREEZE-THAW RESISTANCE

When water freezes, it expands. Since there is water in moist concrete, it's susceptible to freezing, which creates pressure in the concrete's pores. If this pressure exceeds the concrete's tensile strength, it can rupture. When concrete is exposed to multiple freeze-thaw cycles, CRACKING, scaling and crumbling can occur. Adding fibers to the concrete will improve its freeze-thaw resistance and help keep the concrete strong.

٤th – Fiber reinforced concrete (FRC) VS high temperature or fire.

Using fibers improves the strength of structural concrete members during exposing to high temperatures or fire. The reports mentioning that FRC slabs exposed to fire are three to up to nine times more resistant than slabs without fibers.

Fibers are conducive to better mechanical properties after exposure to high temperatures. even small contents of polymer or steel fibers improve the materials behavior of concrete.

For fully compressed cross-sections, the effect of steel fibers is neglectable but adding polymer fibers improve fire resistance degradation due to concrete spalling during fire. steel fibers will improve the residual strength for normal and high-strength concretes respectively.

A combination of steel and polymer fibers in concretes accomplishes the beneficial effects of both fibers types to improve the fire resistance of the concrete.

Note:

Adding fiber to concrete have many positive effects but also have negative effects when it is added in high ratio to a concrete. Adding high ratio of fibers to concrete may lose its compression strength, this is due to decreasing of the cement ratio to surround the particle to makes high strong bond. Also, high ratio of fiber loses its workability and we will be in need to add more water to it which is not good and make the concrete lose its compression strength due to the high-water ratio content.

DISCUSSION:

To get the more benefit of adding fiber to concrete, we have to think about why you adding it, for which purpose, what type of fiber is available, how much it coasts, how you add and mix it, in which ratio you add it and what is the positive and negative effects of adding it. From these questions you should select the type of the fiber and the ratio of mixing. Some times maybe you choose a fiber due to the availability or due to the coast, here you should ask if this adding of fiber helps you or you just waste money. In some cases, and because there is not actual data, codes or equations of adding a specific ratio of a specific type of fiber to a specific structure, you should

make some library tests by yourself and then you could decide which type you will add and in any ratio.

Many workshops, committees, library tests and recommendations etc. ???

We have many types of fibers for many purposes, due to that we have many library tests and researches on them made by the producer companies, engineers or special research committees which they tried to find and define the properties of them, making equations to the best mixing ratio, giving recommendations about them and preparing standard code for this purpose.

Now we have many codes (American, Italian, Germany, Australian, French, Chinese and etc.) which we could depend on them in our constructing works but still we need more data, researches and more library tests to be on the safe side in our choices specially for using a new type of fiber or using it in a new job.

CONCLUSION:

Due the experiments, the studies and the researches, many types of fibers have been developed and will be developed in the future, and will be one of the most active part of constructing and building in the nearest future due to its high advantages comparing to its negative effects, here we collect the most advantages of fiber in concrete.

- Fibers is useful where a concrete of high tensile strength is required.
- Fibers increase the shear capacity of reinforced concrete beams.
- Fibers reduce cracking occur due to applying loads and increases its toughness and flexural strength.
- Fibers are useful when a conventional reinforcement cannot be placed due to limited dimensions of a construction parts or when we in need to decreasing the dimensions of it.
- Fibers reduce cracking occur due to drying and plastic shrinkage during the first ٢٤ hours and improve its impermeability and resisting water leakage and absorption of water throw it.

- Adding fibers to the concrete will improve its freeze-thaw resistance and help keep the concrete strong.
- Improve mix cohesion of concrete and improving pumpability over long distances.
- Reduces segregation and bleed-water.
- Fiber is good in applications where the look and feel of the concrete is important, to create a clean and good nearly invisible finish.
- It can be employed to increase the spacing of joints for structures with stringent waterproofing requirement.
- Fiber reduces erosion and cavitation activities and important for those surfaces which have high contact with water.
- Fiber helps in reducing or replacing traditional meshes and steel reinforcement and this leads to reduce the construction schedules and labor costs.
- Fiber increase safety of construction by reducing the chances of worker's mistakes or impalement that are present in traditional steel reinforcement.

And many more …

RESOURCES:

- What's Up with Fiber-Reinforced Concrete?
  By Pro Trade Craft for Residential Construction Pros November ١١،٢٠١٩

- Fiber-Reinforced Concrete Advantages, types and Applications.
  By Constro Facilitator July ٢٤،٢٠٢٠

- Fiber Reinforced Concrete: from Design to Structural Applications
  ACI-fib International Workshop. July ٤٥-٢٥, ٢٠١٤

- Fiber Reinforced Concrete.
  OZINGA Company for Concrete.

- Concrete Reinforcing Fibers.
  SIKA USA Company.

- Sustainable Composite Development:
  Novel use of human hair in concrete.
  ELSEVIER page- Case Studies in Construction Materials ٢٠٢٠

- Report on Concrete Structures Reinforced with FRP Bar
  CEP- CIVIL ENGINEERING PORTAL page October ٢٨،٢٠١٩
  By N. Bheel, P. Awoyera, O.Aluko, S. Mahro, A. Viloria

and C. Alberto Severich Sierra

- A Study on UK and Dubai Regarding Green Supply Chain Management in Construction Industry.
  CEP- CIVIL ENGINEERING PORTAL page