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USE OF POLYMER FIBERS INTO REINFORCED CONCRETE SOLUTIONS

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Abstract: Generally speaking, the fibre–reinforced concrete applications are based on the principle of improving the properties and mechanical characteristics of the concrete, most of them being based on the idea of improving the strength properties. Fibres are typically added at the batching stage and are uniformly distributed throughout the concrete giving full reinforcement to the full depth of concrete. Are produced a range of fibre reinforced concrete mixes that include the polymer fibers (polypropylene and polypropylene fibres), macro–synthetic and steel fibres. These fibres are used to enhance the concretes performance both in the fresh and hardened state. Polymer fibers, such polyethylene or polypropylene fibres, are primarily used to reduce the potential for plastic shrinkage and increasing fire resistance. They are not designed to replace structural reinforcement.
Keywords: fibre–reinforced concrete, polymer fibres, fibres relates particularities

BACKGROUND OF THE KNOWLEDGE

Many constructions require precise techniques and technologies that can utilize a number of new materials [1–5]. In this context, the use of simple concrete and reinforced concrete is somewhat restricted by specific phenomena such as: cracking, fire resistance, shrinkage, shock resistance, wear resistance, durability, etc. For this reason, various studies have been carried out and in–depth research, which has resulted in an improvement in the performance of the concrete can be obtained by adding in their mass of reinforcements dispersed in the form of fibres from different materials [1–22]. The dispersed reinforced concrete results in the inclusion of a variable amount of discontinuous fibres in the concrete mass [1–10]. These fibres can be of different types and sizes and have different properties.

Ordinary concrete is an artificial conglomerate, the preparation of which is used inorganic hydraulic binders, heavy compact aggregates (gravel or broken stone), water and, in some cases, additives (plasticizing additives, accelerators or retarders). In its simplest form, concrete is a mixture of cement paste and aggregates (different type of sands and rocks). The paste, composed of cement and water, coats the surface of the fine (sand) and coarse aggregates (rocks) and binds them together into a rock–like mass known as concrete [1–5].

A properly proportioned concrete mixture will possess the desired workability for the fresh concrete and the required durability and strength for the hardened concrete [1–5]. Typically, a mixture is by volume about 10 to 15% cement, 60 to 75% aggregates and 15 to 20% water. Entrained air bubbles in many concrete mixtures may also take up another 5 to 8% [3–5,16–18].

By mixing the binder with water, the cement paste (the active part) is formed, which, after physical–chemical processes of hydrolysis and hydration, hardens over time, transforming into a hard body that binds the aggregate particles together, conferring thus the monolithic character of the cement mixture [1–5]. The cement paste, called the matrix, represents the continuous phase, and the aggregates form the dispersed phase [1–5,21–22].

Figure 1. Solid factions of the concrete recipe

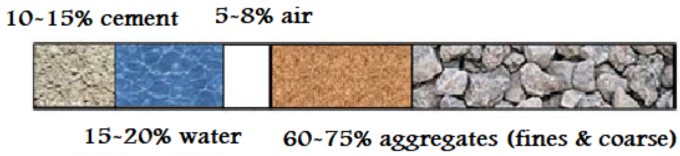

Figure 2. Typically concrete mixture

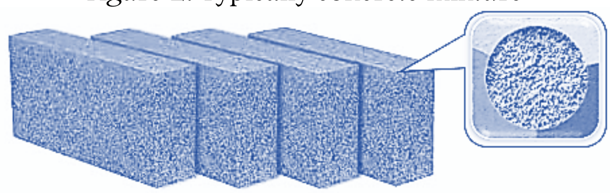

Figure 3. The concrete structure

Generally speaking, the fibre–reinforced concrete applications are based on the principle of improving the properties and mechanical characteristics of the concrete, most of them being based on the idea of improving the strength properties [1–11]. However, the role of fibre reinforcement of simple or classical reinforced concrete should not be reduced not only to this principle of improving the resistance but especially to the control of the cracking process and thereby to improving the resistance, the energy absorption properties and the impact resistance, shock, temperature variations, and fire resistance.

Fibres are typically added at the batching stage and are uniformly distributed throughout the concrete giving full reinforcement to the full depth of concrete

[1–5]. Are produced a range of fibre reinforced concrete mixes that include the polymer fibers (polypropylene and polypropylene fibres), macro–synthetic and steel fibres [4–17]. These fibres are used to enhance the concretes performance both in the fresh and hardened state [1–5].

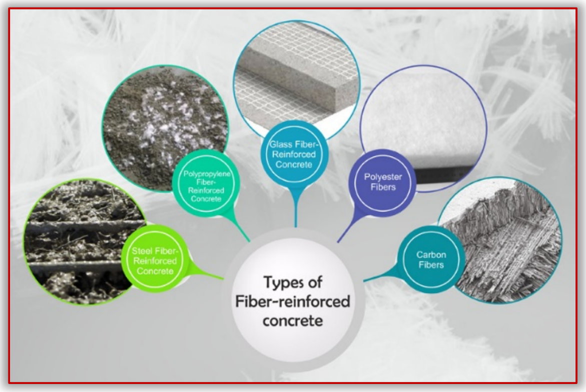

Figure 4. Fiber–reinforced concrete

Polymer fibers, such polyethylene or polypropylene fibres, are primarily used to reduce the potential for plastic shrinkage and increasing fire resistance. They are not designed to replace structural reinforcement [17–21].

FIBRES RELATED PARTICULARITIES

Fiber–reinforced concrete contain fibrous material which increases its structural integrity. It contains short discrete fibers that are uniformly distributed or randomly oriented. Fibers include steel fibers, glass fibers, synthetic fibers and natural fibers – each of which lend varying properties to the concrete. In addition, the character of fiber–reinforced concrete changes with varying concretes, fiber materials, geometries, distribution, orientation, and densities. Research into new fiber–reinforced concretes continues today [1–22].

Adding the fibrous material to concrete will increase the strength [1–22]. The basic idea is that fibers in the mix create a multi–directional, interstitial "mesh" within the concrete matrix that, when is used correctly, will make concrete stronger. But, in fact, the subject is more complex. The types and size of fibers, their distribution and orientation are a hugely complex topic. The main aspects can be summarised as follows:

— **minimum fibre length**

Based on experimental studies, it has been shown that the length of polymer fibres used for dispersed reinforcement must meet certain conditions.

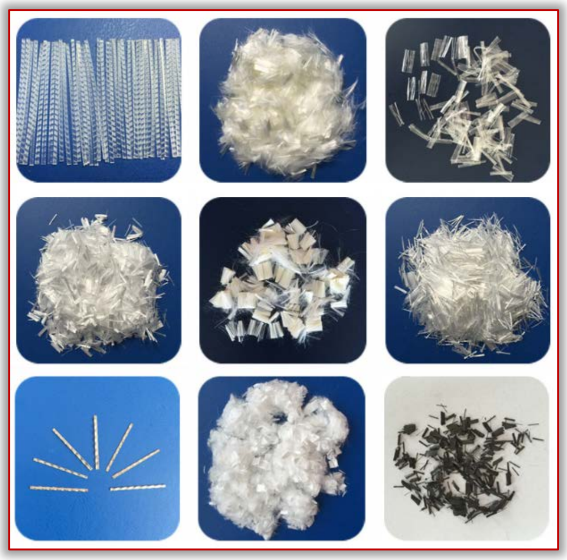

Figure 6. Various length of polymer fibres

For the determination of the minimum fibre length, it is assumed that it is oriented in the direction of the tensile stresses required by the matrix, taking into account the mechanism of transmitting the unitary efforts from the matrix to the fibres. The critical length depends on the diameter of the fibre and the unitary effort in the fibre, so the type of fibre and the average unitary effort of adhesion.

— **the ratio or geometric aspect of the fibres**

Fibers used for concrete reinforcement come in a variety of sizes and are made from an ever–increasing range of materials, including micro fibers and far larger macro fibers.

The geometric ratio or geometric aspect of the fibres is a feature that represents the ratio of the length and diameter of the circular cross–section fibres. The literature shows that there is a critical geometrical relationship, to which the fibres can be regarded as operating with maximum efficiency. There is some data that indicates that regardless of the geometric ratio (l/df) the fibre length must exceed the maximum size of the aggregates in the matrix.

Figure 7. The geometry of fibres

— **the adhesion of the fibre surface to the matrix**

In any composite system, the physical and chemical properties of the constituents and the interaction between them determine the behaviour of the material. In cement–based systems, the contact area between the fibres and the matrix is often diffuse and, instead of the distinct boundaries between the two, there is a continuous transition from one phase to the next. Often, the strength and durability of the contact area indicate a combination of physical and chemical characteristics that are due to the formation of surface reaction products. Obviously, the properties of the composite are greatly influenced by the adhesion to this surface and that, often, the contact area is the weakest link of the systems. Uniform strength of concrete slab is guaranteed by fibre maximum adhesion to concrete structure and their even distribution.

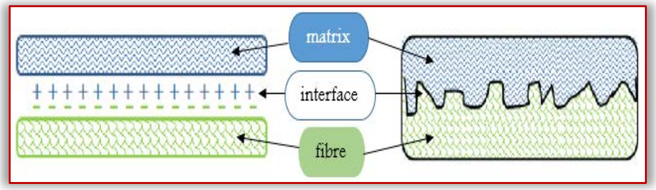

Figure 8. The fibre surface, the matrix and the interface

— **fibre distribution and orientation**

The orientation of a fibre to the plane of the crack strongly influences its ability to transmit the load through the crack. A fibre that has an orientation parallel to the crack has no favourable effect, while a fibre perpendicular to the crack has a maximum effect. The efficiency of the fibres in a matrix depends on the number of fibres that intersect a surface unit and on the tear resistance of the fibres, which is dependent on factors such as geometric ratio (l/d), surface shape and texture.

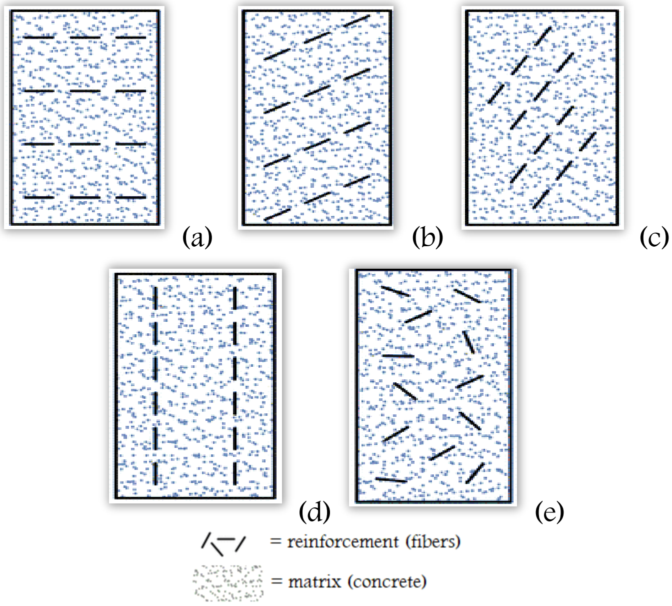

Figure 9. Fibre distribution and orientation in a cement matrix. (a)–(d) layered fibers with determined orientation (0^o, 30^o, 60^o, 90^o) (e)–randomly distributed fibers

— **fibre content**

In order to improve the properties of ordinary concrete, a minimum quantity of fibres of 1 kg/m3 is required, corresponding to about 0.04% by weight of the mixture and 0.1% of the total volume of the mixture.

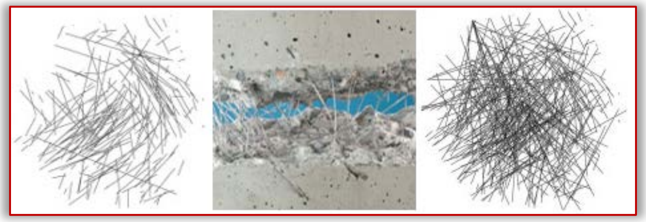

Figure 10. The fibre content

The efficiency of fibre addition increases with increasing content. Also, the fibre content influences the compactness of the dispersed reinforced concrete. Multiple dosage options let use polymer fibre for anti–cracking–during–shrink–process purpose only, as well as for structural reinforcement.

— **texture, shape and nature of fibre surface**

Any solution to increase the shear strength of the bond between the fibre surface and the matrix increases the value of the fibre resistance and improves its efficiency. Such solutions include processes for the production of fibres with deformed surfaces or asperities, deformed ends or various profiles along them.

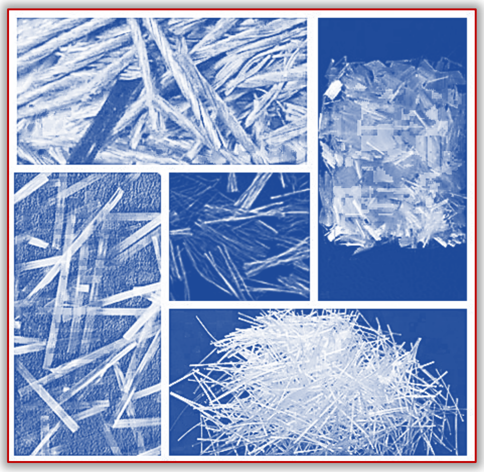

Figure 11. The shape and nature of fibre

BASIC COMPONENTS RELATED PARTICULARITIES

It is important to understand all components of concrete. But the concrete mix designs consider they purpose, rather than just the strength and cost. The mixing parameters of concrete that most influence drying shrinkage are the amount of reinforcement provided but also the size, shape, and surface area–to–volume ratio of the concrete basic components.

— **aggregates** (rock and sand)

Apart from the above mentioned factors, the size, shape and volume of the fraction of the aggregates also exert a certain influence on the properties of the concrete with dispersed reinforcement. They plays a significant role, acting as structural filler in the concrete. Aggregates are extremely important to understand in terms of how their properties affect the properties of fresh and hardened concrete. Aggregates in any particular mix of concrete are selected for their durability, strength and workability. Therefore, they properties have a significant influence on the workability, shrinkage, strength and durability of the concrete.

Natural aggregates are available in the crushed or uncrushed state such as sand and gravel or stones. Round shaped aggregates, irregular or partly round shaped aggregates, angular and flaky shaped aggregates are the shape wise classification of aggregates. Fine aggregates and coarse aggregates are the size wise classifications of aggregates. Fine aggregates are usually sand or crushed stone and its compositions are variable depending on the source. It is defined by size, being finer than gravel and coarser than silt.

Figure 12. Fine and coarse aggregates

Figure 13. Fine and coarse sand

When choosing aggregates into the concrete mixture, one must also consider their shape. Rough-textured and sharp aggregates will require more cement paste than round aggregates. The importance of using the right type and quality of aggregates cannot be overemphasized. The fine and coarse aggregates generally occupy 60% to 75% of the concrete volume (70% to 85% by mass) and strongly influence the concrete's freshly mixed and hardened properties, mixture proportions, and economy. The larger the size of the aggregates, the larger the problems of ensuring the adhesion between the fibres and the concrete. Sand cannot be an overlooked component of concrete. Although the stone will supply the strength, sand also has an important purpose – workability. Based on the experimental results, it can be stated that at a known volume of fine and coarse aggregates there is a critical fibre content, over which the compactness decreases.

— cement

Cement comprises from 10 to 15% of the concrete mix, by volume. Cement is very important, having an ability to hold the concrete structure together. It provides good strength and also helps concrete to harden early and to resist moisture. Influence the behaviour of concrete with dispersed reinforcement is proportional to the amount added. Thus, a larger amount of cement ensures better adhesion between fibres and matrices, which results in better material behaviour in terms of cracks occurrence, effect on external actions and deformations. Cement is necessary, but the strength can still be retained when using well-graded aggregates that cost significantly less.

— aggregate–cement ratio and water–cement ratio

The effect of coarse aggregate on drying shrinkage is double. First, the use of a high coarse aggregate content will minimize the total water and cement paste contents of the concrete mixture and, therefore, will minimize the drying shrinkage. Therefore, the effects of aggregate–cement ratio and water–cement ratio on drying shrinkage are important. In fact, at a given water–cement ratio, drying shrinkage is reduced as the aggregate–cement ratio is increased. Second, drying shrinkage of the cement paste is reduced by coarse aggregate because of its restraining influence. The coarse aggregate is dependent on the type and size of aggregate and its stiffness and the total amount of the aggregate used for concrete. Hard, rigid aggregates should therefore be used to produce concrete with low drying shrinkage.

Aggregates are very important for strength, thermal and elastic properties of concrete, their dimensional stability and volume stability. Including aggregate in the concrete mixture can control the shrinkage level and prevent cracking. Cement is more likely to be affected by shrinkage.

ECOLOGICAL CONTEXT

In the new context of ecological and sustainable development, the reduction of the quantities of waste is considered an important criterion and therefore the introduction in the current practice of some ecological materials is necessary. The use of waste products in concrete not only makes it economical, but also helps in reducing disposal problems. Reuse of plastic wastes is considered the best environmental alternative for solving the problem of disposal. One such waste is plastic, which could be used in various applications.

Taking into account the requirements related to environmental protection, and the construction sector (including concrete and reinforced concrete) must become more environmentally friendly, to minimize pollution. The development of new construction materials using recycled plastics is important to both the construction sector and the recycling industries. Therefore, reuse of recycled plastic materials in concrete mix as an environmental friendly construction material has drawn attention in recent times.

CONCLUSIONS & FINAL REMARKS

There are multiple reasons for adding polymer fibers in concrete. Choosing the right polymer fiber mostly depends on the type of application. Among the advantages of using polymer fibres into the concretes are the following, being perfectly aware that we can even include all:

- One of the main benefits of polymer fibers are the homogenous distribution in the concrete. Other benefits include the better cohesion of the fresh concrete;
- Thanks to extreme durability of polymers the fibre retain their full characteristics during entire concrete. The use of polymer fibres in the concrete composition increases its tensile and compressive strength. Also, the reinforced concrete dispersed with polymer fibres has an increased shock resistance;
- The polymer reinforcement fibres being neutral to corrosive chemical components, the surface of reinforced concrete dispersed with these fibres is much more resistant to the action of corrosive substances, to the action of weathering (especially frost), and to the action of degreasing materials (especially salt). Therefore, resistance to oxidization and corrosion (from chlorides, sulphates and salts) make them candidates for aggressive environments in marine industry. Also, polymer fibers are great for not chemically stable applications in the chemical industry;
- The use of polymer fibres contributes to the elimination of the degradation caused by the corrosion of the reinforcements and in this way to the prolongation of the life of the constructions;
- The addition of polymer fibres remove cracks due to stresses and contractions. Therefore, other benefits include the control and reduce crack sizes due to early-age shrinkage;
- The addition of polymer fibres increase toughness and abrasion resistance, and also increases the resistance of the concrete to wear by rubbing, thus reducing the costs of making quality industrial floors;
- The addition of polymer fibres require a lower processing costs, compared to steel reinforcements. The advantages of using reinforced concrete with polymer fibres are evident in the small prefabricated building materials, where the costs of reinforcement with bars are high;
- The use of dispersed polymer fibres determine a reduced weight of prefabricated reinforced concrete, and therefore, traditional mesh and steel fiber reinforcement may be avoided. The addition of polymer fibres replace or partially replace traditional reinforcing steel;
- The addition of polymer fibres save time in the construction process and reduce costs.

The development of the construction sector, in particular the investments in infrastructure, remain the key factors of the economic growth. This implies a strong increase in the consumption of building materials in times of economic boom, and against the background of the significant increase in demand, the needs of raw materials also increase. Concrete is one of the main materials used in construction, therefore, the consumption of concrete is determined by the state of the construction industry. Being easy to use, dosed industrial or into a simply concrete mixer, the polymer fibers save time compared to traditional mesh application.

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