

# **Multiform Systems - UltraFiber™**

## **500**

### **Introduction to UltraFiber500 Cellulose Polymer Fibres**

The term “Cellulose Fibre” represents a class of fibres that originate from wood and plant materials and they vary tremendously in size, shape, purity and fibre strength. One commonality of these fibres is that they all contain some Cellulose which is an organic polymer of glucose.

The use of unprocessed Cellulose-based fibres for reinforcement in building materials dates back well over 2000 years. Their crack control and reinforcing properties were recognized by pre-modern societies. In the modern era, processed, refined and engineered Cellulose fibres are used extensively in building materials and in concrete applications.

On a molecular level, Cellulose can vary substantially in their degree of polymerisation and in their crystalline structure so it is important to understand that all Cellulose fibres are not created equal. It is important to choose the best and strongest fibres with high polymerisation for concrete.

The most recent and productive form of Cellulose Polymer Fibres has come out of the USA from Buckeye Technologies by Multiform Systems Ltd, and was developed from a virgin purified form of Cellulose, manufactured from one of the longest, thickest Cellulose fibres found in nature. These properties make it ideal for today’s modern concrete applications. Research and independent testing has verified the performance attributes provided by this unique fibre for: improved concrete hydration, plastic shrinkage crack control, temperature crack control, increased impact resistance, improved freeze / thaw resistance, control of explosive fire spalling, improved strength properties, reduced water permeability, reduction in water absorbency, and improved concrete durability.

### **General characteristics**

Cellulose Polymer Fibres come in small discrete square tabs about 5 mm x 5 mm and 1 mm thick. Each of these tabs holds approximately 30,000 individual fibres that break up under the shearing action of the aggregate inside the concrete batching equipment. The fibre’s average length is about 2 mm and they have a diameter of about 16µm, and in 0.9 kg there is over 1.4 billion fibres per cubic metre. Their size is not much bigger than the size of the cement particles which is why they can effectively enhance the concrete’s characteristics. It is common to have bag sizes from 450 g up to 180 kg sacks. The bags may be thrown inside the batching equipment as they are dispersible and cause no issues to the final concrete product. It is common to dispense 0.9 kg per cubic metre of concrete to enhance its characteristics. Higher dosage rates can be used to further improve the concrete. The addition of the Cellulose Polymer Fibres produces a concrete that it is more creamy to use therefore enhancing finishing techniques and has no drawbacks compared to other fibre additives even in exposed aggregate finishes and polished concretes. There is no or negligible change in water usage or air content in the final mix so normal concrete properties are maintained. The concrete tends to be smoother and when colouring is added the fibres absorb the colour and provide more depth of colour or lustre in the finished concrete product.

## Theory

The Cellulose Polymer Fibre is a highly hydrophilic, that is, it will absorb moisture. They can absorb up to 85% of their weight in moisture and hold a little bit of moisture around the fibre. This hydrophilic characteristic promotes outstanding bonding between Cellulose fibres and the cement paste. As the concrete cures bonding intensifies, hardens, and the concrete becomes more fully hydrated from the internal curing provided by the moisture that has been given up by the fibre to the unhydrated cement. The release of the held moisture over time occurs as required by the concrete. Since the Cellulose Polymer Fibre is bonded and fully anchored within the concrete paste it does not require fibre lengths as long as other fibres to provide excellent performance properties, furthermore the intense bonding with the cement particles reduces microscopic voids and openings within the concrete as observed with hydrophobic fibres such as synthetic and metal fibres.

It is important that the Cellulose Polymer Fibres does not deteriorate in the highly alkaline environment found in the concrete. To test for durability in concrete there are a number of tests available, such as ICC acceptance criteria 217, which specifies that Cellulose fibres must be tested in accordance to ASTM D 6942 "Standard test method of stability of cellulose fibres in alkaline environments" these tests must show that there is no or little deterioration in the tensile strength of the fibres. The current supplier shows that they conform to the standard and that they do not deteriorate in the concrete and they will continue to work for the life of the concrete.

High levels of water absorbency, which causes permanent deterioration in reinforcing, often negatively impact long term durability of concrete. During the curing of the concrete the hydrophilic nature of Cellulose Polymer Fibres allows the cement paste to adhere and bond to the fibre so that voids and openings are not introduced within the paste. The use of Cellulose Polymer Fibres has shown through testing to be able to produce a smaller capillary radius and a considerable reduction in absorbed water caused by capillary pressure. By using the Cellulose Polymer Fibres in the concrete, the durability of the embedded reinforcing is considerably enhanced.

By using Cellulose Polymer Fibres in the concrete it has been shown through standard impact tests that they disperse and absorb impact loads, resulting in considerable increase in impact resistance. It is important to understand that it is more valuable to have concrete with a higher resistance to breaking and higher flexural strength. Than to have a concrete with normal resistance values, but once the concrete has broken for the long reinforcing fibres to hold the portions together. The loads at which these long fibres are holding the concrete together are much lower, than the levels at which first break occurs. If the load remains high, as would be expected in a service, their holding capacity will be negligible to the integrity of the concrete element. By using Cellulose Polymer Fibre higher compressive flexural strengths are gained and this will be potentially more valuable.

Cellulose Polymer Fibres also enhance the properties of concrete through interfering with the processes of micro crack propagation and cracking in concrete. This was one of the first used aspects of the fibres, to reduce plastic shrinkage cracking caused by the strains within the concrete. The same aspect has been shown to be useful by using Cellulose Polymer Fibres in otherwise new ways within the concrete. The use of Cellulose Polymer Fibres in combination with standard reinforcing steel rods has much advantage especially in seismic events due to these benefits. With a modulus of elasticity that is higher than that of concrete, the closely spaced Cellulose fibres have strong bonding to concrete to resist the

concentration of strains near crack tips and also at the edge of reinforcing bar deformations. With their close spacing, high surface area, and high tensile and bond strength, they also force a tortuous path of crack propagation and resist the widening of cracks by bridging across them. The fineness of the Cellulose fibres allows them to reinforce the mortar fraction of the concrete, which occupies the critically thin zone between reinforcing deformations. This delay in crack formation and propagation, results in higher pullout loads of reinforcing in concrete and delays the spalling from high loads applied from seismic events.

## Design

The quantity of Cellulose Polymer Fibres used varies according to the characteristic required from the concrete, and is not dependant on the designed compressive strength, though an increase will result depending on quantity of Cellulose fibre used. Cellulose Polymer Fibres combine best with the cement particles rather than fly ash, which is commonly used to replace cement. Though benefits are gained with fly ash some characteristics are not as great when using fly ash as compared to cement. Plastic shrinkage cracking is a common characteristic required in concrete, as is increased steel reinforcing pull out strength, fire resistance, reduced permeability, and impact and flexural strength. Generally the higher the quantity of Cellulose Polymer Fibres added the better the desired effect.

Reduced plastic shrinkage cracking	up to	1.8 kg / m <sup>3</sup>
Fire resistance (120 minutes fire rating, Floor slabs)	from	0.9 kg / m <sup>3</sup>
Fire resistance (90 minutes fire rating, Columns / Beams)	from	0.9 kg / m <sup>3</sup>
Reduced permeability	up to	5.5 kg / m <sup>3</sup>
Reinforcing pullout strength	up to	2.7 kg / m <sup>3</sup>
Increased compressive strength	up to	1.8 kg / m <sup>3</sup>
Impact strength	up to	2.7 kg / m <sup>3</sup>
Flexural strength	up to	3.0 kg / m <sup>3</sup>
Freeze / Thaw resistance	from	0.9 kg / m <sup>3</sup>
Slab curl resistance	up to	1.8 kg / m <sup>3</sup>
Composite Flooring Systems	up to	1.8 kg / m <sup>3</sup>

## Properties of Cellulose Polymer Fibres

Average Fibre Length	2.1mm
Diameter	0.016mm
Max. Moisture uptake	85% by weight of fibre.
Fibre Count at 0.9kg / m <sup>3</sup>	1.44 billion
Density (Water = 1.0)	1.10
Surface Area (cm <sup>2</sup> /g)	25,000
Fibre tensile strength	620 – 900 MPa
Fibre spacing in concrete (at 0.9 kg/m <sup>3</sup> )	480um avg.
Plastic crack resistance (at 0.9 kg/m <sup>3</sup> )	85.1% less than ordinary conc.
Compressive strength increase (at 0.9 kg/m <sup>3</sup> , 28days)	7 – 16%
Flexural strength increase (at 0.45kg/m <sup>3</sup> , 28days)	8%
Flexural strength increase (at 2.7kg/m <sup>3</sup> , 28days)	13%
Bond strength increase between concrete and reinf.	Over 20%

## **Mix design**

Mixing of Cellulose Polymer Fibres into the concrete mix is an easy process when done at the batching plant. It is important that aggregate is used, as the shearing action of the aggregate is needed as it tumbles through the bowl, to break open the fibre tabs. By comparison, when mixing synthetic fibres it is common to add more water as the mix dries out from the addition of those fibres, but this drying out does not occur with the use of Cellulose Polymer Fibres. The correct amount of water can be added and therefore there will be no reduction in concrete strengths due to excess water being put into the concrete, and there will be no appreciable change in the design slump.

Truck Mixing - Throw bags directly into the back of the bowl with the water and charge with the aggregate and cement then mix for a minimum of 3 minutes at full speed. Alternatively the bags may be laid on the aggregate belt as it begins to move and as the first of the aggregate and cement is added. Let the mixing truck receive all the remaining concrete ingredients, and then mix for 3 minutes at full speed.

Where an automated fibre dispensing system is installed (no bags used), turn on the dispenser during or immediately following the addition of the initial water. After all the ingredients are added to the truck mix for 3 minutes at full speed.

Central Wet Batching Systems – Add the fibres directly into the central mixer with the initial aggregate. Add the remaining concrete ingredients and allow the central mixer to mix as usual. Once the concrete is discharged from the mixer into the concrete truck it may be necessary to mix at full speed for 3 minutes. However, some mixers are very efficient and it may be unnecessary to mix any longer in the concrete truck. This **MUST** be confirmed by checking the fibre dispersion in the concrete that is discharged from the central mixer.

## **Using the Cellulose Polymer Fibres**

When the Cellulose Polymer Fibres are added to the concrete they remain unseen or virtually invisible in the concrete mix. This is what differentiates them from other fibres, as other fibres are substantially bigger and more visible. Cellulose Polymer Fibres are evenly spread throughout the concrete and are even on the surface of the finished concrete, but remain flat and unseen. Importantly, they do not ball, clump or give a hairy finish to the concrete and so can be used with confidence for all decoratively finished concretes. Because they are an integral part of the concrete and do not separate out of the concrete, the concrete can be worked as normal and no change is needed in timing or in finishing methods to that of ordinary concrete. Cellulose Polymer Fibres are compatible with normal concrete constituents and admixtures and will not affect their performance.

## **Sampling methods, testing, and quality control.**

There are two methods to check that the fibre have been evenly dispersed in the concrete mix and the tabs have been broken up.

1. Take a sample of mixed concrete from the truck and place it into a bucket. Add sufficient water to fill the bucket so that the fines separate out, then stir with a stick until the aggregate is clean and drops to the bottom and the fines remain in suspension. The Cellulose fibres remain in suspension as they are

- heavier than water and will not float to the surface. Drain the water through a sieve to capture the fibres.
2. Set aside a handful of concrete and leave to set until it reaches the plasticine stage. The fibres will not be seen in this soft sample until you break it in half to expose the fibres. The fibres will protrude from each side of the break and will be clearly seen by the naked eye.

It is recommended that all concrete should be tested using standard cylinder test methods for compressive strength at 28 days. These tests may be either wet cured or dry cured according to the appropriate standards used. A dry cylinder test more closely replicates a normal onsite pour and differences are seen easily. Any other tests may be undertaken to check the performance of the finished concrete and these test results should also be available from the supplier using recognized international testing regimes.

Manufacturing of Cellulose Polymer Fibres for use in concrete is best done in an ISO 9001 certified plant. Bags should be clearly labelled showing the weights of fibre contained within, and have the name and origin of the manufacturer and any mixing instructions required. The dry fibres must be clean and free from any deleterious materials. It is commonly preferred to have an alkaline resistant coating specially engineered to enhance the fibres qualities.

The long-term use of Cellulose Polymer Fibres have shown to have no adverse health effects apart from those that may have been caused by being in a dusty environment if large quantities of dry materials were used in an enclosed space, before being added to the concrete.

## **Applications**

A significant advantage of using Cellulose Polymer Fibres is that they can be used with confidence in virtually all concrete applications.

Common areas of use:-

Residential floor slabs on grade.

Driveways, roads, and footpath: coloured concrete, broom finishes, exposed aggregate finish, stamped concrete, swirled finishes etc.

Precast concrete, Pre-or Post-tensioned precast concrete products

Polished and decorative concrete

Swimming pools surrounds

Kerb and Channel

Toppings to precast floors

Commercial floor slabs and hardstands

High-rise buildings for beams and columns

Concrete with or without reinforcing

Suspended floors using tray deck assemblies

Fire rated products

Pervious Concretes

To reduce slab curling often found in large floor areas

Shotcreting and to improve pumpability

## **Benefits of UltraFiber500 Cellulose Polymer Fibres.**

The following benefits are obtained by using Cellulose Polymer Fibres in Concrete:

- Cellulose Polymer Fibres are used in concrete as a cost-effective method to reinforce and to enhance the concrete's characteristics or to condition the concrete to offer new performance dimensions to concrete.
- They provide enhanced curing by the gradual release of water to unhydrated cement.
- Considerable increase in the concrete strength properties from the internal curing.
- The fibres have higher surface area, higher tensile strength, higher fibre count, and closer fibre spacing than synthetic fibres.
- Better fibre dispersion throughout the concrete
- Cellulose Polymer Fibres assimilate and bond with the paste creating a tight, denser paste.
- They have minimal to no negative impacts to the plastic properties of concrete.
- Reduced water absorbency of concrete and reduced concrete permeability.
- Improved freeze / thaw durability performance
- Improved fire resistance to concrete.
- It is common to replace shrinkage control reinforcements such as steel meshes with Cellulose Polymer Fibres where there is no long-term slab instability expected.
- Enhanced seismic characteristics of reinforced concrete.
- Cellulose Polymer Fibres do not create placement or finishing problems.
- Processed Cellulose Polymer Fibres come from renewable resources.