INTRODUCTION

Many product manufacturers are facing changes in demand due to changing behaviour in society. There is a reduction of smokers, coupled with cheap imported cigarettes, both legal and illegal that have driven product manufacturers to look at other uses for their products. This research is driven by such market forces.

Elevated temperatures during curing will cause an increased reaction between the cement particles and the moisture (water) within the concrete. This reaction will cause a double problem as there will now be a higher temperature within the concrete and also within the external environment of the concrete, thus leading to rapid reaction and dehydration of the mix. As dehydration starts, the damage to the long term durability of concrete also starts to manifest. Most notably in its failure to reduce pore sizes and bleed holes, which will inevitably facilitate the ingress of fluids. Polypropylene fibres and the manufacturing process are covered by BS-EN14889 and should not be exposed to temperatures above 140°C whilst curing, which may give cigarette filter material an advantage in terms of heat resistance.

Work by Dave and Desai [1] suggest that the incorporation of Type 1 polypropylene fibres (BS-EN14889) has a beneficial effect when concrete specimens are subject to heating and cooling cycles. They conclude that "it is observed that all fibre mixes have exhibited superior performance compared to control mixes" and a "definite improvement in thermal behaviour and cracking characteristics was observed" [1]. The inclusion of concrete with polypropylene fibres has acted as a benchmark to measure the performance of other concrete types. Type 1 micro fibres are mostly used in concrete to reduce shrinkage cracking. This research utilises two types of fibres - cigarette filter and Type 1 polypropylene fibres 20mm x 19 micron diameter to evaluate the relative performance of two fibre types compared to the performance of plain concrete.

MATERIALS AND PROPERTIES

Polypropylene Fibres

Polypropylene is a large molecule built up by a repetition of a small simple chemical unit until a polymer chain is formed. It is a relatively modern product and was not manufactured until 1957 [2] following innovative work by Staudinger (1920) and Flory (1937) both receiving the Nobel Prize for their work.

Polypropylene is a hydrocarbon containing only chemical elements, in consequence of that it is always referred to as hydrocarbon polymer. Hydrocarbon polymers are composed of common chemical structures and are produced entirely from carbon and hydrogen atom. Production of polypropylene fibres is an industrial based and controlled process, dependant upon the capability of thermoplastic raisins to melt at relatively low temperatures, then to be pressurized within the screw extruder and ejected in a filament form. The type of polypropylene fibres used in this research is Type 1, 20 mm long by 19 micron diameter

Properties of polypropylene fibre reinforced concrete

Polypropylene fibre reinforced concrete (PFRC) is considered to be an effective method to improve the shrinkage cracking, strength and toughness, durability and impact of concrete materials. A considerable amount of research has been conducted to study the properties of the fibre reinforced concrete (FRC). Material properties of polypropylene fibre reinforced concrete (PFRC), depend strongly on fibre concentration and the form of the fibre reinforced [3]. Other major causes and effects of the properties of the fibre reinforcement is the bond strength of the polypropylene fibre with cement composite. The potential of the polypropylene fibre as concrete reinforcement also depends on the bond between fibre and matrix [3].

Cigarette Filter Fibre

Almost around 95% of cigarettes filters are made of cellulose acetate, a syntactic plastic like substance which is commonly used for photographic films and the remaining percentage are made from papers and rayon. A plasticizer, triacetin (glycerol triacetate), is applied to bond the fibres into a core [4].

The cellulose acetate fibres are white colour, and packed tightly together to form a filter and they look like cotton. Seeing the white faced cigarette filter with the naked eye and compression of the filter column with the fingers, would suggest that the filter is made of sponge like material. Nevertheless, opening of the cigarette filter by cutting it in lengthwise in razor shows that it consists of a fibrous mass. Teasing apart the fibre matrix would reveal more than 12,000 white fibres per cigarette filter. Microscopically these fibres are Y shaped [4] and the fibres as used in this test are shown in Figures 1 and 2.

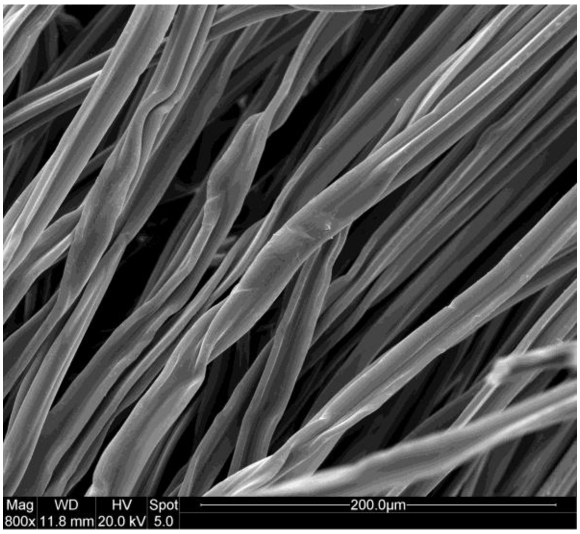

Figure 1 Cigarette filter fibre (800x magnification) – source Northumbria University laboratory

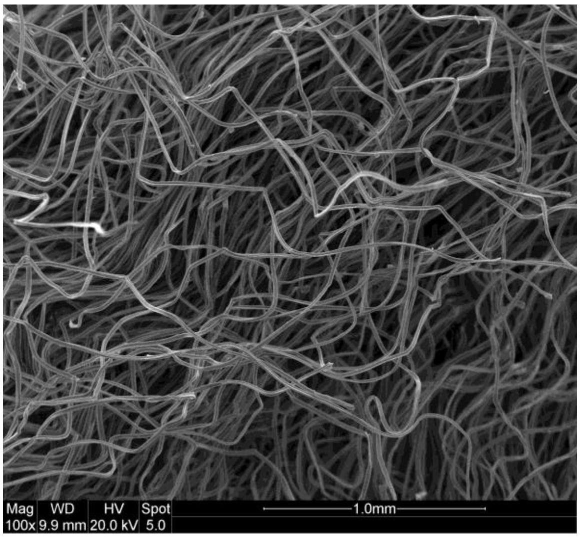

Figure 2 Cigarette filter fibre (100x magnification) – source Northumbria University laboratory.

The cigarette fibres were teased apart to separate the filter material prior to being added to the concrete mix to allow the individual stands to be coated and react with the cement paste. Fig 3 illustrates the Energy Dispersive Spectroscopy (EDS) image analysis of cigarette filter which shows the main chemical constituents as being carbon and oxygen.

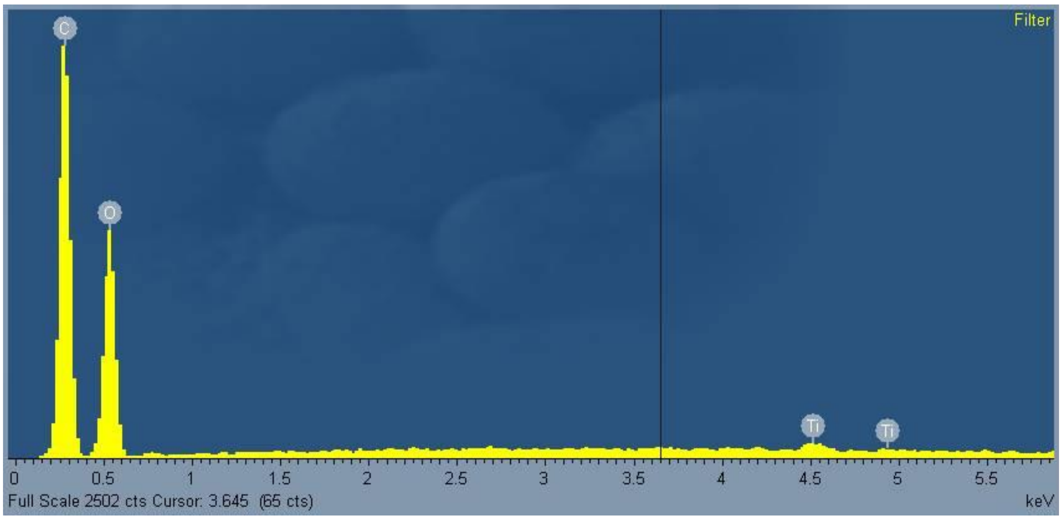

Figure 3 EDS Image of cigarette filter – source Northumbria University laboratory

Shrinkage Cracking

Shrinkage of concrete is the movement or strain due to thermal contraction or long term drying shrinkage. Some high strength concretes are prone to plastic shrinkage, which occurs in freshly placed concrete which has not set and it may result in significant cracking during the setting process. Since the bond between the plastic concrete and reinforcement has not developed, the reinforced material in the concrete would not be effective enough in controlling such cracks [5]. Where there are different moisture contents between cover and heartcrete, tensile forces will develop and produce fine cracking of the concrete with a resultant reduction in surface durability and resistance to the elements". Non fibrous concrete usually cracks when the evaporation rate is greater than 0.0681 kg/m^2, polypropylene fibres reduce cracking in the range of 90 - 100% and reduce the water permeability between 34 -

75% [6] by interfering with the normal bleed channels and capillaries that are initially formed in the plastic state. According to Vondran and Webster, [7] “Fibres apparently have a log jamming effect on the pore structure that reduces the water flow”, and this aspect is a consideration for further research to determine what fibre dosage and what fibre type have the best effect.

EXPERIMENTAL METHOD

In order to study the effect of the fibre on the concrete, three types of concrete were manufactured and tested for, surface cracking, and bleeding. The four cubes and two beams were cast and placed in front of a blown air heater. Whilst the beams and cubes were setting they were subjected to a hot air flow for 6 hours. The next day the concrete was checked for cracks with an optical microscope. The main aim of this experiment is to provide details of the early age surface shrinkage cracking.

Mix Design and Materials

A normal C40 concrete mix was chosen as it is a structural concrete that is widely used throughout the industry. The C40 design mix used is shown in Table 1.

Table 1 C40 Mix Design

MATERIAL	**QUANTITY kg /m^3**
Cement (CEM1- Ferrocrete)	403
Sand (0-4mm)	837
Aggregate (4-10mm) and (10-20mm)	336 and 621
Fibres 20 mm long (both)	2

The total of large aggregate within the mix was kept to a minimum to prevent aggregate segregation during the plastic phase. The water cement ratio was 0.45. Figure 4 illustrates the test program for this research.

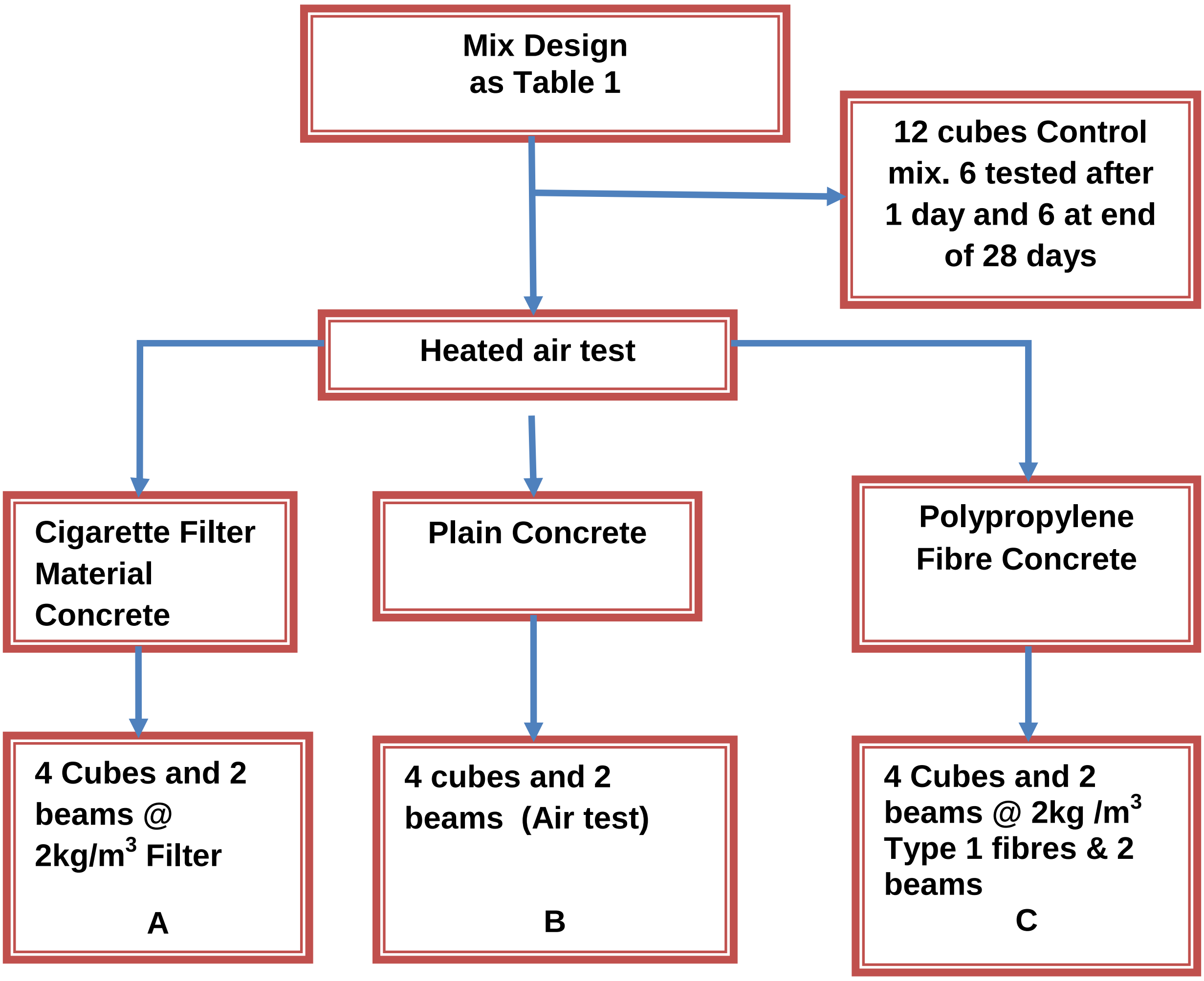

Figure 4 Test programme

Drying Shrinkage Test Method

The drying shrinkage test was conducted as described in Figure 5. Cast the beams and cubes and start heater once the slab is towelled and leave for 6 hours with the blown air heaters on. The heater was positioned 600 mm from the nearest cube. The next day the cracks were measured with an optical microscope (Surveying type). Compressive strengths were taken at 1 day and 28 days. Conclude as to the effect of fibres with regard to drying cracking compared to plain concrete.

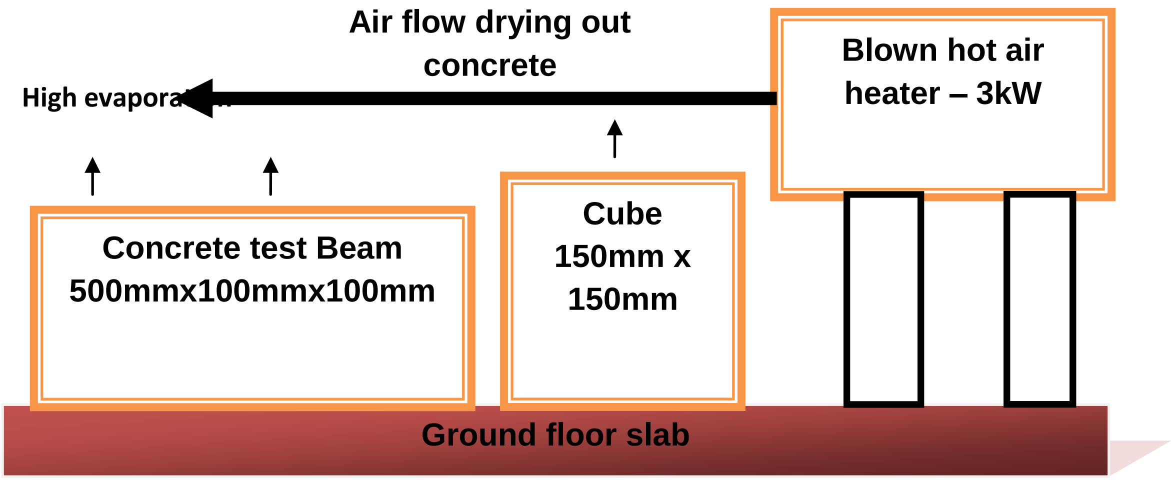

Figure 5 Test method for drying shrinkage

RESULTS

The slump for the plain concrete was 70mm whereas the fibre concrete produced a slump of 20 mm. The concrete test showed that there was not a great deal of shrinkage cracking on the surface of the concrete between 1 and 28 days. The cracking was not significant and the main reason for this was the low water cement ratio and saturated aggregates. Fig 6 – Fig 8 shows the images of shrinkage cracking which was taken with a crack detection microscope (CDM). The greatest degree of shrinkage cracking was observed mainly on plain concrete with 15% more cracks being observable when compared to the fibre concrete. The cracking was of a greater width than the fibre concrete. Shrinkage cracking which occurred was barely noticeable with the naked eye and it was only defined with crack detection microscope (CDM). This microscope is a high definition instrument which is operated with an adjustable light source. Measurement of the surface cracking was a superficial means of comparing data as no account was taken of crack area or depth, the frequency of the crack occurrence was the main characteristic measured.

Figure 6 Shrinkage cracking on cigarette filter concrete

Figure 7 Shrinkage cracking on polypropylene fibre concrete

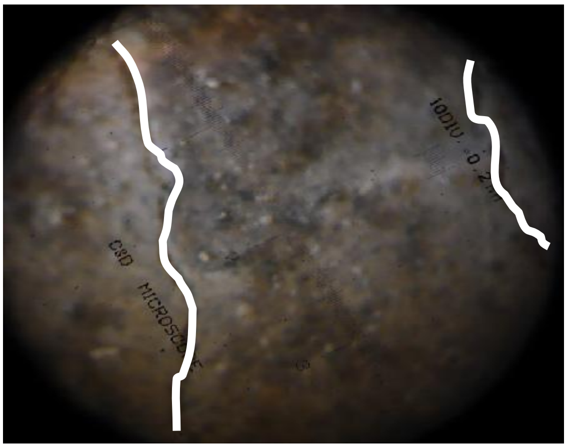

Figure 8 Shrinkage cracking occurrence on plain concrete

The compressive strength was determined at 1 day and 28 days using the control cubes and the respective strength was 6 N/mm^2 and 45 N/mm^2 which represents the early and part cured strength which was as the original design mix. The average compressive strength of the cubes subjected to the hot air flow was plain 35 N/mm^2, Type 1 polypropylene fibre 37 N/mm^2 and cigarette filter fibre 38 N/mm^2.The strength reduction compared to the control samples was 22% for plain concrete, 18% for polypropylene concrete and 16% for cigarette filter material. Given the variable nature of concrete it is not possible to say whether or not the fibres had a beneficial effect, however a 16 to 22 % strength loss shows that when concrete is subject to hot curing conditions with an air flow over the surface, measures must be taken in addition to fibre inclusion to ensure correct curing to enable the achievement the design strength.

CONCLUSION

The nature of the test was to impose severe curing/drying/setting conditions that should cause a great deal of distress to the concrete and the surface cracking created by these conditions was not found to be as great as expected. The inclusion of both polypropylene and cigarette filter fibres improved the drying shrinkage cracking performance of concrete. There was a 15% improvement in the fine drying shrinkage cracks with the use of fibres. The heat cured compressive strength results showed a strength reduction due to drying cracking that indicated internal cracking that cannot be seen. The identification of cracks only looked at the surface opening length. Depth, width and length should be quantified but this was beyond the scope of this preliminary study that may be used to inform a larger investigation. The test only considered one water cement ratio and one strength class and the concrete was batched very consistently which reduced the size and number of propagated cracks..

REFERENCES

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