UHPFRC Concrete technology

An introduction to better understanding (Ultra High-Performance Fiber Reinforced Concrete)

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Introduction

Material production in engineering fields grows day by day to fulfill the requirements of building a project, whether that project is a bridge or a skyscraper, the environment around that project determines which material is best to use to maintain durability both sufficiently and efficiently. Concrete and steel are the most used yet popular substances among engineers. Compared to other types of concrete, UHPFRC, which stands for Ultra High Performance Fiber Reinforced Concrete, is a newborn production material into the civil engineering field. UHPFRC is an effective mixture of concrete suitable for high endurance production with an extra layer of strength. The origin of UHPFRC is in the process of improving modern concrete after the mid 18 century. Major failure in concrete occurs due to the low tensile strength and ductility, which later on it was noticed that those failures could be resolved by adding new material and mixing them with concrete.

The first step toward inventing UHPFRC was adding metallic reinforcement to modern concrete due to the poor tensile strength and brittleness. Common concrete was not proper for special projects which required certain tensile strength, durability, and smaller in size. With improving technologies, new substances are added to concrete mixture focusing on improving compressive strength, adding fibers to the mixture, and optimizing particle packing density. With all the mixture produced, a new wave of concrete originated with a great tensile strength alongside compressive, shear, and bond strength. Using low water to binder ratios was the trending way of making concrete mixture alongside special selection and gradation of aggregate particles and water-reducer additives. The term HSC - HPC was used, meaning High-Strength Concrete and High-Performance Concrete. The term HSC meant a concrete with compressive strength characteristic between 50-120 MPa. While the term HPC included those HSC with improved durability properties. However, higher compressive strength meant more brittle material which was undesirable, and to solve the issue, fiber was added to concrete mixture to improve durability and ductility. The term FRC-Fiber reinforced concrete is use referring to any kind of concrete mixture using fiber reinforcement. Then, in the late 90s the term Ultra-High-Performance Concrete (UHPC) was used to refer to an optimized particle-packing material, mixing ultrafine particles which led to an increase in compressive strength above 120MPa, low porosity, high durability and self-compatibility. With the all term used and improvements done to concrete, the UHPFRC became what we have today. Along with increasing the tensile strength and compressive strength UHPFRC has a smaller size compared with normal concrete and pre-strength concrete. More about the pros of UHPFRC, UHPFRC has a lower pore size and narrower in size distribution, and the pores in the concrete is more compacted not allowing water to penetrate when tested under light and microcopy (figure 1). This will helps the concrete to last longer, with resistance of freeze and thaw simple because its self-compacting concrete and it provide a denser packed microstructure.

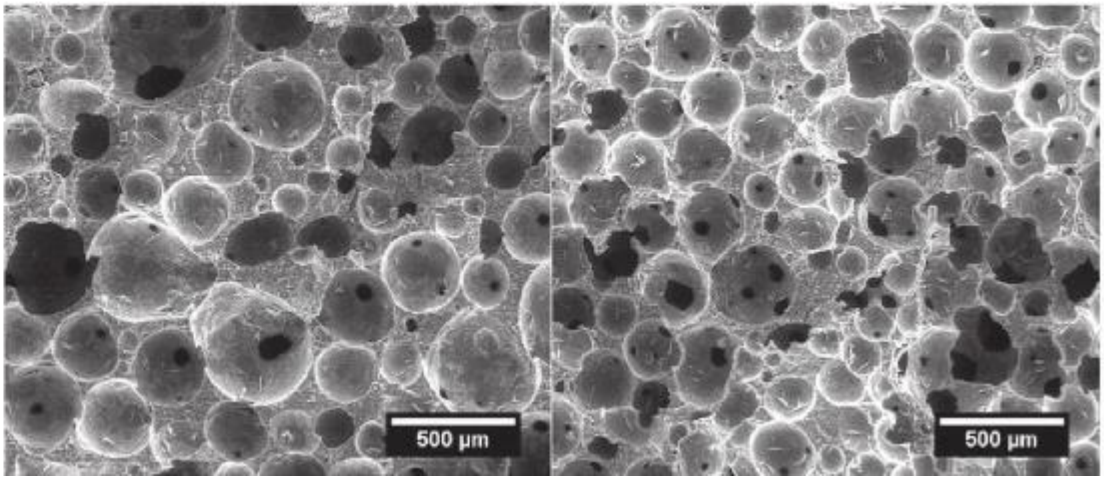

Figure 1: (left) HUPFRC fractured under 800kg/m3 compared with normal concrete under the same load (right)

Every building material has some good effects and bad effects. As we have mentioned some of the benefits of UHPFRC above, now it is time for the cons. usually client judge material based on price. Clearly, because to prepare a UHPFRC concrete there are certain add mixture that is needed such as, carbon fiber, silica fume, and silica flour, etc. According to (Federal Highway Administration) , it cost nearly $2,600 $/m^3$. Also, UHPFRC has a lower fire resistance, and it subjected to mass wasting in high temperature (during fire, NOT normal day temperature). Figure (2, 3, and 4) shows the effect of fire on UHPFRC.

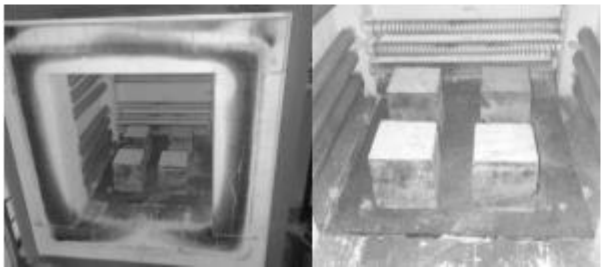

Figure 2: The sample subjected to 200C

Figure 3: The sample subjected to 400C

Figure 4: The sample subjected to 600C

Mechanical properties of UHPFRC

Ultra High Performance Fiber Reinforced Concrete (UHPFRC) is a specific type of concrete with superior mechanical and durability properties. It is different than normal concrete due to its components. It has a significant amount of cement and a smaller amount of aggregates. Thus, it makes UHPFRC perform better than the normal concrete. It has high compressive and tensile strength and a ductile behavior in tension. Since it is a new material that has some specific properties such as high ductility, low permeability, very high strength capacity in compression, and higher toughness compared to a normal concrete, it is something essential to know about both its mechanical and material properties in order to use it the best way for structural applications. It is also better to know that concretes with high levels of compressive strength will be having a greater tensile strength and the modulus of elasticity. Additionally, if you want to acquire a better response in tension, you can use more fiber in the concrete mixture. It is suggested that steel rebar should be arranged in UHPFRC in order to increase the resistance slightly and improve the structural behavior of UHPFRC, and it is all because of its dependence on fiber orientation and distribution.

Graphs and Tables

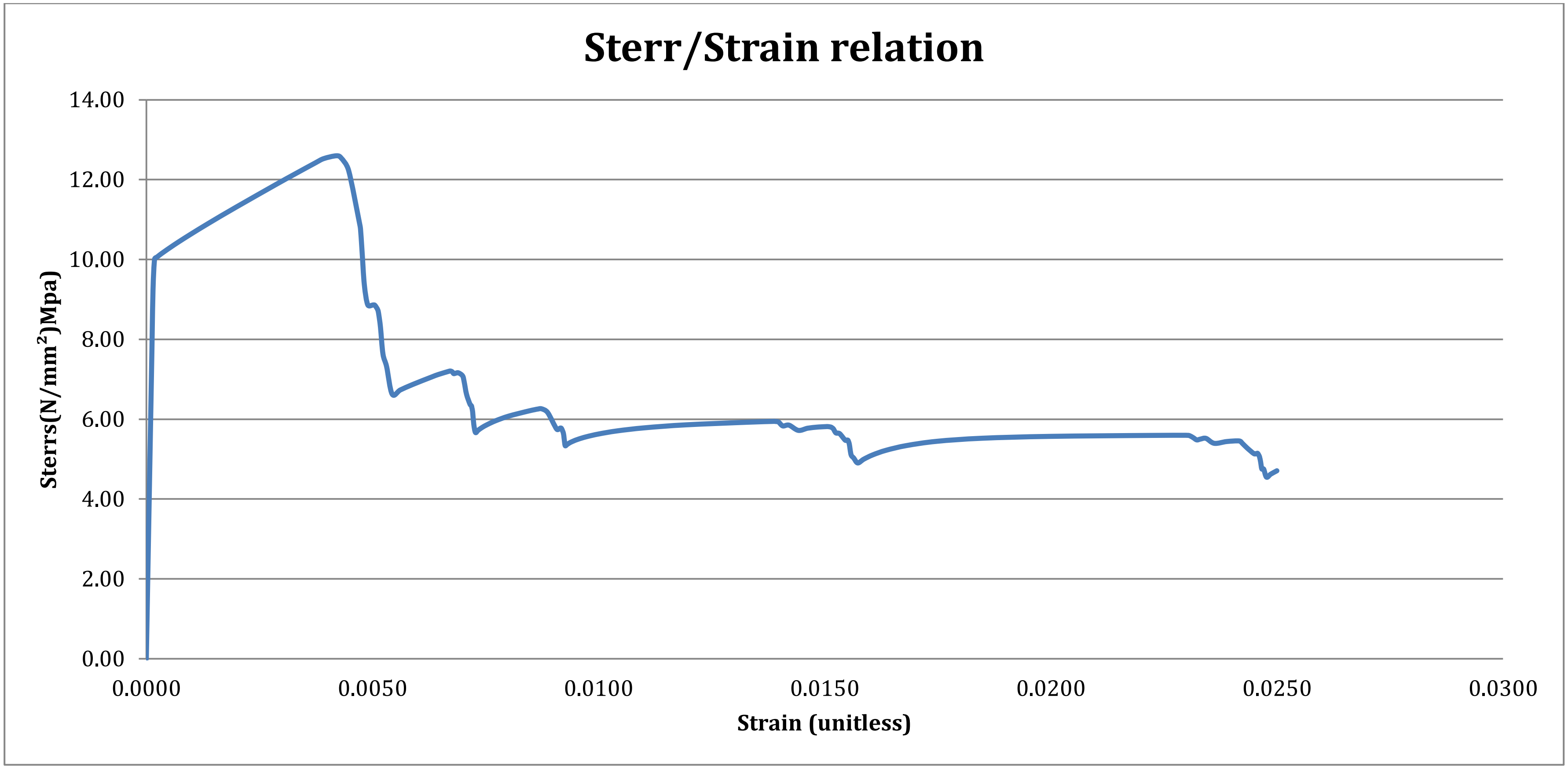

Figure 5: Stress-Strain Relation of UHPFRC

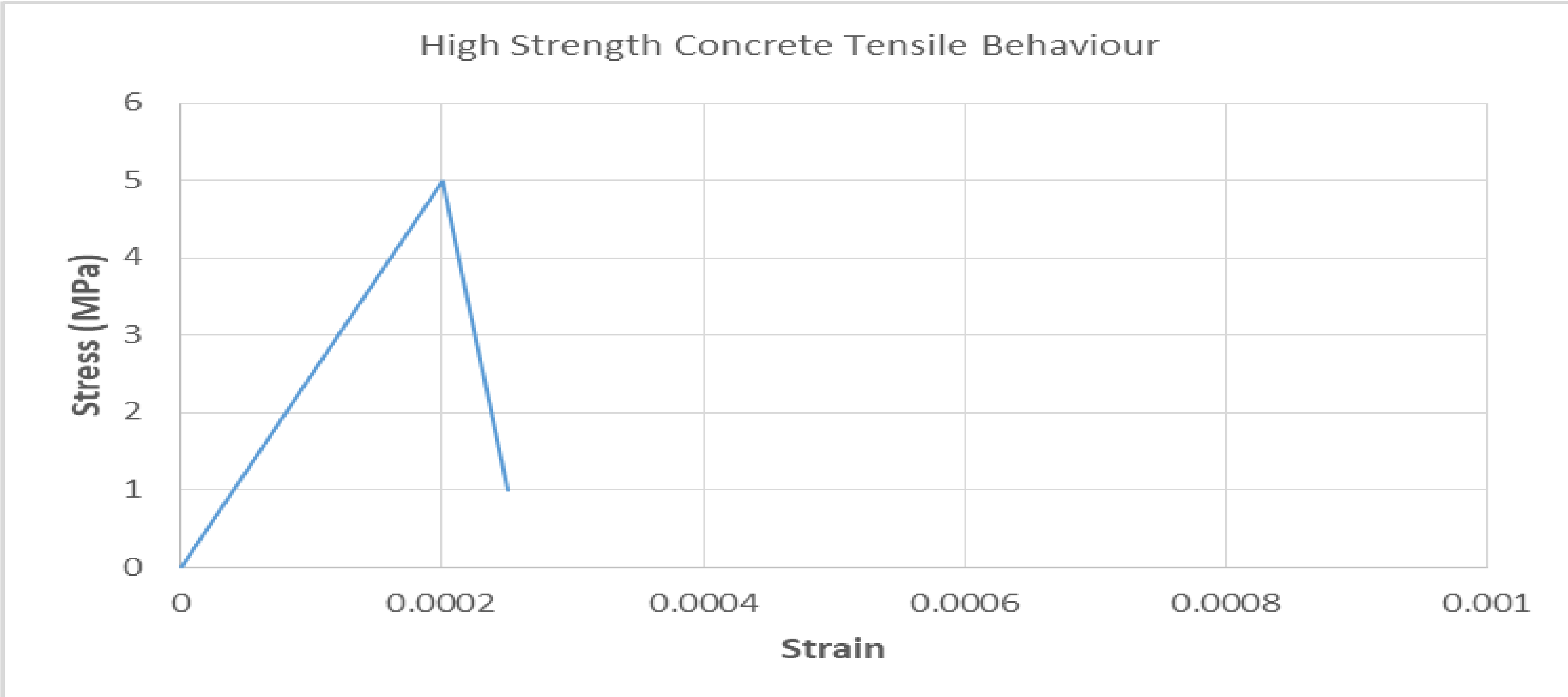

Figure 6: Stress strain relation for High Strength Concrete

Stress(Mpa)	Strain
0.00	0.00000
3.89	0.00006
7.78	0.00013
9.24	0.00015
12	0.00019

Table 1: Stress and Strain relation for UHPFRC in liner part (elastic region)

Discussion

The relation between stress and strain can give us many mechanical properties of a material. There are two main ways for finding the stress and strain relation for a concrete, either by doing a compressive test or flexural strength test. In compressive strength test (ASTM C39) the sample with subject to a vertical load. And computers will read the amount of load that this sample can handle before failure or crake. We should consider the following properties of the sample: diameter and the maximum particle (aggregate) diameter, high and diameter. The other test is Flexural strength (ASTM C78), four points. The sample will subject to a lateral load with two point load while it stands on two points. In this experiment, a tensile test had carried out and the data (force and deformation) was given to us. We did the calculation in excel sheet to find a stress stain relation, from there we find Modulus of Elasticity (E). Usually tensile test will not use for concrete because concrete is a Brittle material. A brittle material is not deforming, nor creates a necked region when pulled from its ends. Even though UHPFRC is a type of concrete but has increased in the modules of elasticity by 50%, also it achieved some ductility properties. Thus the material can deform and increase in length in the linear region (elastic region) and when the load is removed it will go back to its original shape.

In figure(5), stress and strain relation is shown for a sample of UHPFRC with a cross section of 50mm*25mm and a length of 200mm. in the first section of the figure(5) a straight line; which is represent the elastic region of the material. A sample in elastic region can absorb energy and stretch but until a certain point which is called Yield point. From that straight line we can calculate modules of elastic of the material, which is we found that for this sample of UHPFRC is to be 62.2525 Gpa As the load exceeds that limit, the material will go to another region which called plastic region. In plastic region the particle of the sample can carry more loads, but in engineering it’s the point which is called Failure the safety factor will decrease. In figure(5) it is the region after elastic region which carry more load. After mentioning this point it’s a good time to compere between normal concrete and UHPFRC. Normal concrete doesn’t have Elastic region or Plastic region, and normal concrete cannot carry too much load (Tension) not compression. But UHPFRC can carry a good amount of tension load before failure. Also, a compression between steel and UHPFRC; when stress on steel exceed the elastic region it can deform with not additional load, but in UHPFRC there is t that region, and UHPFRC will not deform until passing the ultimate strength. After the ultimate strength and when the cracks was obvious that you can see them with naked eyes. Cracks in the sample will continue to increase in number and increase in size as well without increasing in load. But unlike other materials, the stress strain relation line shows some increasing in stress after ultimate point which is mainly because of the fiber Carbone inside the component of the cement. In general, fiber Carbone and other component that is mixed this cement change a normal concrete to UHPFRC. But the fiber Carbone holds the structure (sample particles) together for a longer time. This can be useful for safety factor, the fibers will extend the time for collapsing for a longer time.

Comparison between High Strength (HSC) and Ultra High Performance Fiber Reinforced Concrete (UHPFRC), before going to talk about numbers and data, we will talk about the general difference between them. The first noticeable difference is, low water cement ration is used in High Strength Concrete this will decrease workability of the concrete and increase in strength, but admixture such as Superplasticizer is added to increase workability. Due to low water ration High Strength Concrete faces crack due to hydration, but other supplementary such as fly ash and natural pozzolonic material will be add to the cement. But both type of concrete High Strength Concrete and UHPFRC uses small aggregate size. In figure(5), stress and strain relation of UHPFRC is shown, and in figures(6) stress strain relation of High Strength Concrete. High strength concrete has a very sharp increase in stress versus strain as HSC is a brittle material and almost not deforming. HSC is better to be used for beams because of its high brittle properties which can carry lot of compression. HSC collapse faster than UHPFRC, as in the figure it collapse right after reaching ultimate strength. The modules of elasticity of HSC is (25 GPA) and the modules of elasticity of UHPFRC is (62.2525GPA). UHPFRC has twice bigger modules of elasticity than HSC. UHPFRC can handle more loads on it because of fiber Carbons inside it, but HSC rapture with fewer loads on it.

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