International Journal of Advances in Life Science and Technology
2014 Vol.1, No.2, pp. 47-53
ISSN(e): 2313-8335
ISSN(p): 2412-3803
DOI: 10.18488/journal.72/2014.1.2/72.2.47.53

SMART CONCRETES: REVIEW

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ABSTRACT

Concrete is a versatile and the most widely used material in the world. According to a recent survey, its annual production is one cubic meter per person. Historically, it is an old material, which has evolved tremendously during the passage of time. This paper envisages the most recent smart developments in this wonderful material. The smart concretes discussed in this paper include Engineering Cementitious Composites, Self cleaning concrete, self heating concretes and ultra high performance powder reactive concretes. Through modern technology, the strength of concrete has been enhanced from a few hundred pounds per square inch to more than 30000 pounds per square inch. In the same way, the utility of concrete has been tremendously broadened in many fields. Here, primarily, a brief introduction of all important recent developments is discussed. Next, the composition of these materials is narrated, followed by their applications and utilities. The main theme of this paper is to understand the importance of these concretes and to introduce it to academia and construction industry of Pakistan. It is demonstrated that the introduction of these materials will solve many problems of construction, which are not possible to solve with conventional means. Moreover, these developments could solve many energy problems and some are even quite suitable for earthquake zones of Pakistan.

Keywords: Concrete, Recent developments, Significance, Compositions, Utilization, Energy, Earthquake.

1. INTRODUCTION

Building materials are an important subject in civil engineering. The important building materials include concrete, steel, stones, bricks, plastics, timber, glass and many metals [1]. Among these, concrete is the most widely used material in the world. It is estimated that its annual production is about 20 billion tons higher than any other material on this planet earth [2, 3]. It is considered to be the backbone of civil engineering. An ordinary concrete is a mixture of cement, sand, gravel and water. Additives and admixtures are also sometimes added to achieve some special properties, which are not possible to attain with an ordinary concrete [4]. Apart from cement, all the other ingredients of concrete are easily available natural materials. Even

cement is an easily available industrial material. When the concrete fresh matrix is allowed to cure appropriately, it hardens and gains strength equal to or even more than the stone. That is why it is also known as man-made rock and this is the secret of its tremendous popularity [1]. Many supplementary cementitious materials are also sometimes added in concrete, known as additives. Among these silica fumes are very important materials. The addition of silica fumes in concrete makes it denser, enhances its bond quality and increases its resistance against chemicals [5-7]. Apart from silica fume, the other important additives are fly ash, ground granulated blast furnace slag and many other pozzolanic materials [8]. Along with additives, admixtures are another series of natural and synthetic materials added to concrete to improve its characteristics. The important admixtures include plasticizers, water reducers, accelerators, retarders and air entraining agents [9]. There are various types of concrete depending upon its composition. One important type in this regard is Fiber reinforced concrete, abbreviated as FRC. Fiber-reinforced is a special type of concrete in which short discrete fibers of synthetic or natural fibers are incorporated. The important fibers used are steel, poplypropyelene, glass and carbon [10].

Following that, it is evident that concrete is no more a sole mixture of cement, sand, gravel and water. Modern technology has made it possible to create concretes of very special characteristics by incorporating many other ingredients into the concrete. In this regard, many important breakthroughs have been made during the last few years. The purpose of this review article is to highlight the smart concretes, which made headlines in the construction industry in the last few years.

2. ENGINEERED CEMENTITIOUS MATERIALS

Engineered Cementitious Composites (ECC) are a type of fiber reinforced concrete. They are also known as bendable or flexible concrete. ECC is the invention of Dr. Victor Lee of the university of Michigan in USA [11]. It is a revolution in concrete technology, made possible through the use of nanotechnology. Conventional concrete is highly rigid and brittle and has a strain capacity of only 0.1 %. ECC is a special type of fiber reinforced concrete in which nano-slicked fibers are used, which make the concrete to have a strain capacity of more than 3%. This concrete has been claimed to bend like metal [12].

3. SELF CLEANING CONCRETE

Deicing salts are spread in snowy areas to melt down the ice on roads. But this salt is responsible for corrosion of reinforcing steel bars embedded in concrete. Another method adopted to remove ice from roads is the use of heavy machinery. But the later method also produces a lot of discomfort to the travelers. Alternatively, electrical deicing system were developed. One such electrical system incorporates Carbon Nano Fibers or CNF. CNFs are nano-sized fibers made from grapheme [13]. Carbon nano fibers have proved to possess high electrical conductivity, high heating capacity at low voltage and resistant to corrosion [14]. As such, CNF is thought as the heating element in electrical deicing systems. This suggestion first came into headlines through

Chang, et al. [15], and they put the idea of CNF-reinforced concrete also known as self-heating concrete.

Self-heating concrete is a thermally conductive concrete integrated with a CNF paper. The CNF paper is connected to an electric grid, which converts electrical energy into heat. The heat is transferred to the surface and consequently, the snow gets melted. The mechanism is also shown in Fig.1. The de-icing system eliminates the use of heavy machinery and de-icing salt for removal of snow from roads.

4. SELF CLEANING CONCRETE

Self Cleaning concrete or photocatalytic concrete is a focused concrete incorporating nano titania particles (TiO2) [16]. It is also known as smog-eating concrete. This is green Concrete due to its self cleaning properties. The applications of photocatalytic concrete include environmental pollution cleansing and self-disinfecting [17]. The advantage of using solar light and rainwater as driving force has opened a new domain for environmentally friendly building materials. TiO2 disintegrates organic pollutants into harmless CO2 and water, in the presence of light. Products of reaction are easily removed by rain or simple rinsing. Buildings stay cleaner and more beautiful. The mechanism of reaction is shown in Figure 2.

Figure-1. Mechanism of Self Heating Concrete [15]

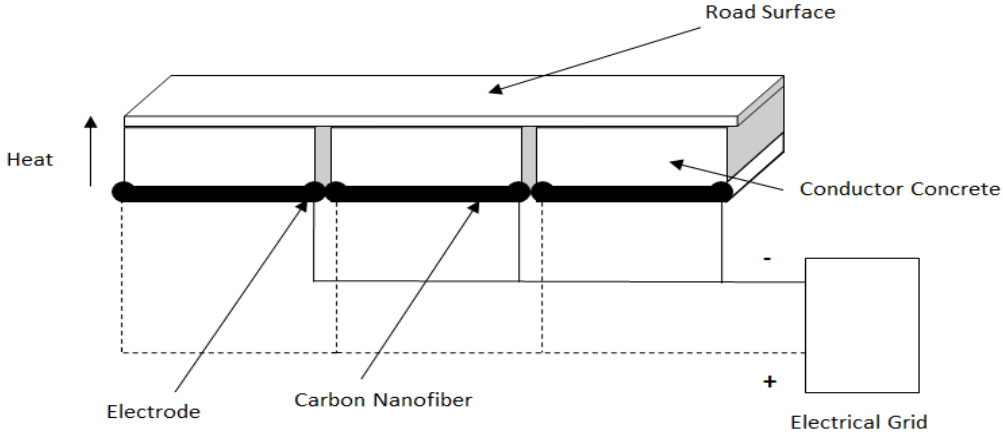
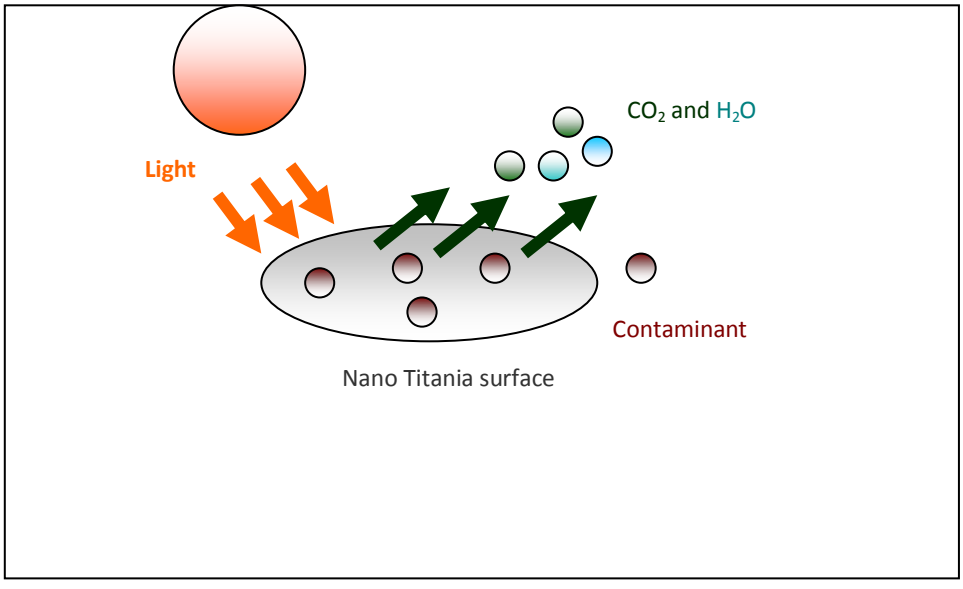


Figure-2. Mechanism of nano titania photocatalysis



Photocatalytic concrete made headlines for the first time in 2007, when an Italian company Italcementi made photocatalytic concrete at commercial scale [18]. In Figures 3 and 4, buildings made of photocatalytic concrete are shown. These building are constructed of white cement added with nano titania particles.

Figure-3. New Jubilee Church, Rome Italy [19]

Figure-4. Air France headquarters in Roissey-Charles de Gaulle airport, Paris France [20]

One major disadvantage of using TiO2 is that UV light is required to activate the photocatalysis and initiate the killing of the bacteria and viruses. In recent years, visible light absorbing photocatalysts with Ag/AgBr/TiO2 has proved to be more successful at killing the germs [21, 22].

5. POWDER REACTIVE CONCRETE

Reactive Powder concrete (RPC) is claimed to achieve compressive strengths of 200 to 800 MPa,and modulus of elasticity of 50 to 60 GPa [23]. It is reiterated here that an ordinary concrete has a compressive strength in the range of 30 to 60 MPa with modulus of elasticity of 14 to 30 GPa [24].

In an RPC, the coarse aggregates are eliminated, whereas the quantities of fine aggregates, cement and silica fumes are increased with the addition of steel fibers. Hence, the cost of RPC is about 5 to 10 times higher than that of a traditional High Performance Concrete [24]. Therefore, it is more effective to be used for concrete repair and retrofitting [25].

6. CONCLUSIONS

New concretes discussed in this review article are wonderful additions in concrete technology. ECCs impart high flexibility to a brittle concrete and converts it into a metal-like bendable material. Self cleaning concrete might solve the problem of environmental pollution in urban areas. Self heating concrete might provide high comfort to people who travel on roads in snowy regions. An RPC gives extremely high values of strength of concrete. No doubt, the cost of the concretes discussed in this work is high, yet they provide high level of durability, energy saving, clean environment and reduced structural dimensions.

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