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Study on Thermosetting Polymers and Its Application

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ABSTRACT:

Though polymers were introduced in India as late as 1980s they started to gain ground as admixtures for their various value added propositions and with the advent of nanotechnology, polymeric nanocomposites began to address many of concrete's inherent problems not addressed before. Our Paper attempts to study the comparative effects of two different polymeric types - thermosetting v/s thermoplastics Polymeric Composites & Polymeric Nano Composites made with 1.Conventional Polymers-Melamine Formaldehyde (MF) and 2.Modern Polymers- Polycarboxylate Ether (PCE) in cement mortar matrix. The Paper reports the test results for the mechanical behaviour of ordinary cement mortar composites casted with the different types of polymers with and without nano-material additions on the medium term (28 days) as per Indian standards and long term (365 days) for sustainability issues. The polymers not only helped in adequate dispersion of the water insoluble nanomaterials through ultrasonication but also resulted in better workability of the mix. The result shows that optimized addition of polymeric CNTs (dispersed in thermoplastic PCE) gives a 37% gain in strength at 28 days & increasing the CNT % also provides for latter age (1 year) strength from 38% to 69%. It may be noted that the polymeric composites of thermosetting MF influenced a strength gain of 29% at 28 days but the addition of polymeric nanocomposites (CNTs dispersed in thermosetting MF) failed to produce any satisfactory results at 28 days and showed an appreciable loss in strength at latter ages.

Key Words: Cement; Composite; Concrete; Mortar; Nanomaterials; Polymer; Strength

INTRODUCTION

Thermosetting Polymers are the type of polymers where the macromolecular chains tend to bond with one another forming the cross-linked 3D network. These polymers are also known as Thermosetting plastics or Thermosets. The definition of the word Thermosetting translates to a term which means setting permanently upon heating. Thus the Thermosetting Polymers get the hard texture after they are exposed to heating to their pre-Thermoset form.

While the first three are the most commonly used admixtures are popular all over the world but the last one insisted for special functions like to modify the mix-viscosity for pumping purposes or to reduce the shrinkage in high-rises or to stop corrosion of reinforcements in the marine climates. Water reducers with a normal water reduction range of 5-8% b.w.c are also called plasticizers and came in 1932 while the high range water reducers or superplasticizers having water reducing range between 15-25% b.w.c came in 1963.While air entrainers which is mostly used in cold countries came in 1941,Polycarboxylate Ethers came in 1990-1999.But polymers were not popular in beginning and in India they started to be used in large infrastructure projects in late 1990s but most of the concrete produced still today in developing country like ours are non-mechanized and have no polymers or admixtures in them. The advantage of using water reducing admixture is that they can reduce the amount of water needed in a mix .The reduction in water cement (w/c) ratio increases in turn the strength [14] of the mix and in turn paves the way for reduction in cement content in the mix in some cases upto 18% [5] when the w/c is kept at a constant level. Admixtures are also useful in making durable or long-lasting concrete [5] and can be used to make concrete with recyclable aggregates [17, 18] thus reducing waste and increasing the sustainability quotient. Cement production contributes about 6-8% CO2 emission around the world [15] and if this cement content can be reduced our process and product will become more sustainable. Also concrete production needs drinking water and drinking water availability is decreasing day by day and with climate change around Asian Development Bank has projected that India would have a water deficit of around 50% by 2030.So if we can reduce the water content in the mix by use of water reducers or admixtures then our use becomes more sustainable and greater sustainability could be achieved. Also conventionally, these admixtures can be of two types. The first one is known as mineral admixtures which are industrial wastes, namely fly ash and blast furnace slag whose increased use in cement concrete will lead to the path of sustainable development. The second one is chemical admixtures which were introduced in India in the late eighties to improve upon the strength and durability parameters of concrete through reduction in water-to-cement ratio.Chemical admixtures gradually gained attention mainly through its water-reduction properties apart from other properties like workability enhancement[16], increasing retention times[19], accelerating or retarding the setting times of cements etc., production of high performance concrete[19].Then as late as in 1999,its standardization got through the publication of an Indian code on admixtures-IS 9103. Fillers when added to the polymer matrix enhance its physical or chemical properties and the resultant matrix is known as polymeric composites. As compressive mechanical strength is far more popular than tensile or flexure or shear, optimizing the mechanical compressive strength w.r.to the cement or filler content is the most desired objective in cement and concrete matrix. Available literatures suggest that more less the diameter of the filler, more the reinforcing capabilities [1]. Nanomaterials as fillers are the most suitable candidate for this position as they work at the nano level (~10-9m) and have very low diameters with high surface areas and also for reducing the carbon footprint arising out of Portland cement as they can be synthesized by carbon trapping from CO2 released by various industries. Secondly, chemically, nanomaterials especially CNTs can act as nucleation agents for hydrating cement matrix crystals, whereas chemical treatments of admixtures enhance their bond to the cementitious matrix[11].Moreover, polymers filled with nanofillers can achieve better surface finish than those filled with micro filler because of their smaller size [2].But these nanofillers are nanomaterials like carbon nanotubes (CNT) which are insoluble in water and should be dispersed in an adequate medium for its functionalization. Polymers can be used for CNTs non-covalent type functionalization where a polymer molecule, is connected onto the nanotube without forming chemical bonds, by wrapping polymer molecules around the CNTs [4].However, interestingly both polymers and CNTs can be produced from CO2[13] leading to more sustainable development.

Preparation of the Thermosetting Polymers

The Thermosets or the Thermosetting Polymers are prepared using chemical reactions of a minimum of two materials. One of these reactants is the monomer that is responsible for forming the final chain of the polymer. The 2nd component is the cross-linker, also called comonomer, which acts as the substance of cross-linking. The cross-linker helps in combining two or more strands related to monomers together.

The Thermosets are generally moulded to provide them with a useful shape before they assume the hard form. The different ways in which the moulding is done includes Reaction Injection moulding (RIM), Resin transfer moulding (RTM), Extrusion moulding, Compression moulding, and Spin casting.

Properties of Thermosetting Polymers

- One of the main properties of thermoset plastics or polymers is that they harden during the moulding process and after solidifying they cannot be softened.
- Typically, when the polymers are moulded and shaped they acquire a three-dimensional cross-linked structure along with strong covalent bonds that further help them retain their strength as well as a structure even if the temperatures are set high.
- However, thermoset plastics are brittle and tend to char and burn if heat is applied for a prolonged state. Normally, thermosets decompose before melting. Meanwhile, thermoset resins are insoluble in most of the inorganic solvents.

Properties Associated with Thermosetting Polymers

The Thermosetting Polymers tend to have a cross-linked 3D structure. The chemical and physical properties of polymers are dependent on components behind the creation of polymers. Some of the fundamental properties of the Thermosetting Polymers are as follows.

- Thermosetting plastics tend to be heat resistant. However, when high intensity of heat is applied, they tend to decompose before they reach the melting point.
- The Thermosetting Polymers are brittle in nature owing to loss of elasticity when they are heated.
- Once cured or moulded, these polymers cannot be re-shaped through application of heat.
- The Thermoset density is dependent on the constituent components that are used for creating the polymer.
- Thermosets are usually resistant to chemical attacks.

The Uses of Thermosetting Polymers

Due to Thermosets having unique properties, they are highly useful for some of the daily requirements. The uses of the Thermosetting Polymers are as follows.

- They are used for manufacturing permanent parts in a wide array of industries.
- Thermosets are used for producing electrical goods as well as components such as panels and insulators.
- Thermosets are used for manufacturing construction equipment panels.
- Since they tend to be heat resistant, Thermosets are used for manufacturing heat shields.
- In automobiles, Thermosets are utilised for producing brake pistons.
- Thermosets are also used for various agricultural equipments that includes motors and feeding troughs.

Thermosetting Process

Processing thermoset polymers usually involve three stages.

- The first stage is commonly referred to as resole where during this stage the resin is an insoluble and fusible condition or state.
- In the second stage, the thermosets are only partly soluble, and they tend to display the characteristics of a thermoplastic where the changes are reversible.
- However, this is a temporary state as the molten form of thermoset lasts only for a short time because the increase in temperatures promotes cross-linking.
- The final stage is where the cross-linking reaction occurs and the final structure of thermosets is constructed. This mostly involves the moulding phase which is conducted under controlled temperature and some application of pressure.
- The final product will have a three-dimensional internal network structure consisting of highly cross-linked polymer chains. At this point, the product cannot be thermally deformed.

In addition, thermoset plastics can also be processed via a single-stage method called reaction injection moulding (RIM). While this process is similar to the method described above the only distinction here are that polymers are combined during the curing process to form a permanent chemical bond. The process basically uses polymerization in the mould instead of cooling to facilitate the formation of a solid polymer.

Some common methods of moulding thermosets include:

- Extrusion moulding which is used for making insulation for electrical cables, threads of fabric and pipes.
- Compression moulding is used to give shape to BMC and SMC thermosetting plastics.
- Spin casting which is a process mainly used for the production of figurines, fishing lures and jigs, emblems and even replacement parts.

Examples

- One of the most common examples of thermosets is bakelite which is relatively a bad conductor of electricity and heat.
- It is mainly used for making electrical switches, handles of various utensils, etc.

- Another example is Melamine which has a capacity to resist fire and heat much efficiently than other plastics.
- It is used in kitchenware and fabrics as well as floor tiles.
- Some other examples of thermoset plastic polymers include silicones, vulcanized rubber, epoxies, polyesters and phenolics.

Thermosetting Plastic Advantages and Disadvantages

1. Some **main advantages** of thermosetting plastics include – they are more resistant to high temperatures, they have high levels of dimensional stability, are cost-effective, and allow highly flexible design.
2. On the other hand, some thermosetting plastics **disadvantages** include, the products can not be recycled or reused and the products cannot be remoulded or reshaped.

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