



## CHAPTER II

### LITERATURE REVIEW

#### 2.1 Reinforced Concrete

Concrete is a construction material that consists of cement as well as other cementitious materials such as fly ash and slag cement, aggregate and chemical admixtures. There are many types of concrete available by varying the proportions of main ingredients. Concrete is most often constructed with the addition of steel or fiber reinforcement. The reinforcement can be by bar, mesh, or fiber, which provide the required tensile strength to concrete producing reinforced concrete.

##### 2.1.1 Steel Reinforcement

Steel is used as reinforcing material due to its superior qualities, in terms of strength and compatibility with concrete. Atis *et al.* (2007) studied the properties of concrete containing fly ash and steel fibers. The laboratory results showed that steel fiber addition, either into Portland cement concrete or fly ash concrete, improve the tensile strength properties, drying shrinkage and freeze–thaw resistance. However, it reduced workability and increase sorptivity coefficient. Although fly ash replacement reduces strength properties, it improves workability, reduces drying shrinkage and increases freeze–thaw resistance of steel fiber reinforced concrete. The performed experiments show that the behavior of fly ash concrete is similar to that of Portland cement concrete when fly ash is added.

Although steel reinforced concrete has high strength, deterioration of reinforced concrete due to corrosion of steel is a problem. To overcome this problem, non-metallic materials are introduced for being reinforcement in concrete instead.

##### 2.1.2 Fiber Reinforcement

There are many kinds of fiber which used as reinforcing materials in concrete. Carbon fiber reinforced polymer (CFRP) bars are mostly used in prestressing applications due to their high tensile strength, which is comparable with steel strands. Duplicate steel and CFRP reinforced beams were tested for the flexural behavior of these beams in terms of stress–strain, load–deflection, modes of failure,

load-carrying capacity, and cracking pattern. The behavior of both types of beams was found similar in many respects. (Rafi *et al.*, 2006)

Wang *et al.* (1987) conducted an experimental program on the properties of various synthesis fiber reinforced cementitious composites and the properties of the reinforcing fibers. Acrylic, polyester and aramid fibers were in uniaxial tension, both in their original state as well as after aging in cement. The properties of concrete, apparent ductility, were found to be greatly improved by the inclusion of such fiber reinforcement.

Long *et al.* (1989) reported on the bond strength between geotextile and concrete. Concrete and geotextile were bonded by placing fresh concrete on a geotextile and allowing it to cure. The influences of construction, geotextile, concrete and load on bond strength were examined using peel test. Concrete penetration into the textile was the major factor affecting bond strength. Penetration was dependent on fiber geometry, and was increased by vibration during curing. Woven geotextiles bonded least strongly unless geometric projections were provided.

Kanda *et al.* (1998) studied the characterization of fiber-matrix interfacial properties and the apparent strength of hydrophilic fibers. Single-fiber pull out test showed that these fibers had surprisingly high chemical and frictional bond strength. The chemical bond strength was relatively stable independent of a water-to-cement ratio of matrix and the fiber type tested, contrary to the friction bond strength. The pull-to-rupture strength tests revealed that the apparent of the PVA fibers in the cementitious composites was considerably lower than that in standard fiber strength tests.

## **2.2 Interfacial Interaction**

The main factor for a mechanical performance of a composite is the interfacial interaction between a matrix and a fiber. A strong interface generally leads to the best composite properties. Therefore, the adhesion between a matrix and a fiber is enhanced by both physical and chemical modifications. The physical modification is the surface roughening of the fiber by the sputtering effect, producing an enlargement of contact area that increases the friction between fiber and the

matrix. The chemical modification is the implantation of active polar groups on the fiber surface, reducing the surface energy and promoting chemical bonding between the fiber and the matrix.

The bond performance including the mode of failure and bond strength of glass-fiber-reinforced polymer (GFRP) bars in polystyrene aggregate concrete was studied with varying polystyrene aggregate content, concrete strength, embedment length, shape and surface treatment of the bars by the proposed concentric pullout test. The experiment results indicate that the sand-coated GFRP bar which its surface was coated with uniform size of quartz sand using epoxy resin gave the highest bond strength (Tang *et al.*, 2006).

### 2.3 Surface Modification

Fiber surface is modified to improve the properties of its surface (e.g. wettability) or enhance the compatibility with the matrix in composite which also improve the composite properties (mechanical properties). There are several surface modification methods such as chemical vapor deposition, plasma polymerization, physical vapor deposition, electrochemical deposition, dielectric barrier discharge and electron beam irradiation.

Plasma surface treatment of fibers is used as reinforcement in composite materials to modify the chemical and physical properties of their surfaces with tailored fiber-matrix bonding strength. Cokeliler *et al.* (2007) evaluated the effect of plasma treated E-glass fiber to improve the mechanical properties of acrylic resin denture base material, polymethylmethacrylate (PMMA). A radiofrequency generator was used to sustain plasma in a glass vacuum chamber. The results showed that plasma treatment with ethylenediamine (EDA) monomer was an effective alternative method of increasing the flexural strength of PMMA based denture base polymers through fiber reinforcement. Riccardi *et al.* (2003) considered the surface chemical and physical modifications of PET fibers induced by radio frequency air plasma treatment RF air plasma treatment of PET fibers led to an increase in their hydrophilicity. Best and more durable wettability results were obtained under high RF power and under negative polarization of treated samples, i.e. under condition in

which the implantation polar groups on the PET surface, evidenced by XPS analysis, was accompanied by extensive surface etching and possibly cross-linking between activated species.

Electron beam irradiation is one of many methods to modify surface of materials which ionizing radiation from an electron beam can induce in the irradiated material the formation of very active centers and free radicals. Pino *et al.* (2007) improved the surface properties of the carbon fiber using ionizing radiation from an electron beam to obtain better adhesion properties in the resultant composite. Experimental results showed that EB irradiation improved the tensile strength of carbon fiber samples. Ibrahim *et al.* (2005) studied electron-beam modification of textile fabrics for hydrophilic finishing. This study were carried out to modify different textile fabrics such as cotton, cotton/polyester blend nylon-6 fabrics by surface coating with a constant thickness layer of 25mm of aqueous solution of polyvinyl alcohol (PVA) and acrylic acid (AAc). This study led to obtain modified types of textile fabrics that would acquire a good hydrophilic property after being coated with different formulations. The durability of the coated layer to washing cycle was also studied. From the results, it was found that durability of the coated formulation was improved toward washing cycle. Moreover, the color strength of all fabrics toward basic and reactive dye was increased and SEM micrographs confirmed the complete adhesion between the coating formulation and all treated fabrics.

The surface modification of polyester fabric by corona discharge irradiation was investigated (Xu *et al.*, 2003). Good hydrophilic property was observed around 10 kV when the fabric was treated at speed of 5 cm/min. the hydrophilic property could be preserved for a long time. After the treatment, dye-uptake ratio and dyeing speed were also improved, these results showed that the polyester yarn could be sized with modified starch effectively. Thus, it could take a place of PVA which is widely used in the textile industry.

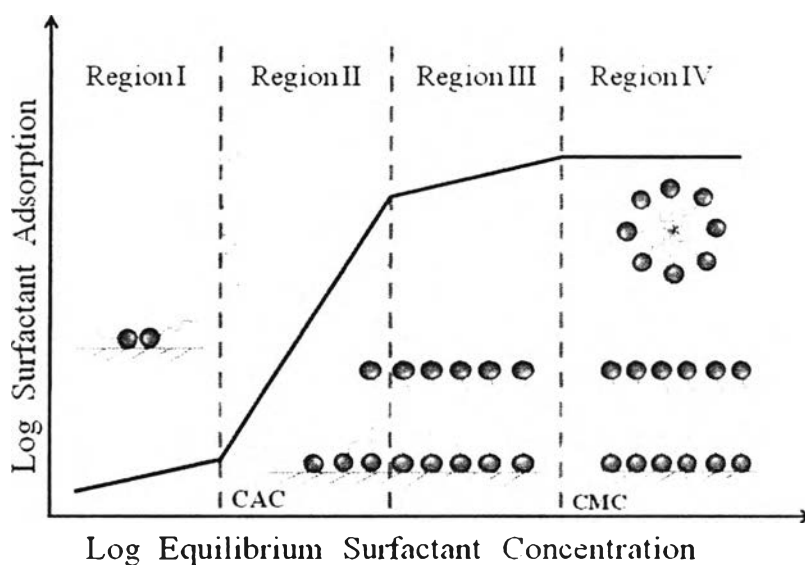
However, most of the above methods require special equipment and carried out in gas phase which is difficult to control. Admicellar polymerization is alternative method to modify the surface.

## 2.4 Admicellar Polymerization

Admicellar polymerization is a technique to create thin film on a substrate by polymerization of monomer solubilized in adsorbed surfactant bilayer at a surfactant concentration below the critical micelle concentration (CMC). The thin-film polymerization process consists of 4 steps

### Step 1: Admicellar Formation

Admicelles are formed by adsorption of a surfactant bilayer onto the surface of the substrate at a surfactant concentration below the CMC. The CMC can be considered from the adsorption isotherm graph of ionic surfactants on a substrate which is a plot between the log of adsorbed surfactant versus the log of equilibrium concentration of surfactant. The curve can be divided into four regions as shown in Figure 2.1.



**Figure 2.1** Typical adsorption isotherm of surfactant on a substrate surface.

The choice of surfactant depends on the point of zero charge (PZC), the solution pH at which the surface exhibits a net surface charge of zero. At pH values below the PZC, the surface becomes protonated and more positively charged; above the PZC, the surface is negatively charged. Consequently, anionic surfactants adsorb below the PZC and cationic surfactants above the PZC.

The electrochemical nature of the substrate, the type of surfactant molecule, the pH of solution, and addition of the counterion influence the adsorption of surfactant on the substrate surface. An electrolyte can enhance the adsorption of surfactant due to reduction the charge on the surface and repulsion between the charges on the headgroups of the on coming ions.

#### Step 2: Monomer Adsolubilization

Monomer Adsolubilization is the solubilization of monomer into the admicelle. Many organic monomers are nearly insoluble in water. Thus, at equilibrium, they preferentially partition into the hydrophobic interior of the admicelle. This process can occur either after the formation of the admicelles or simultaneously along with surfactant adsorption.

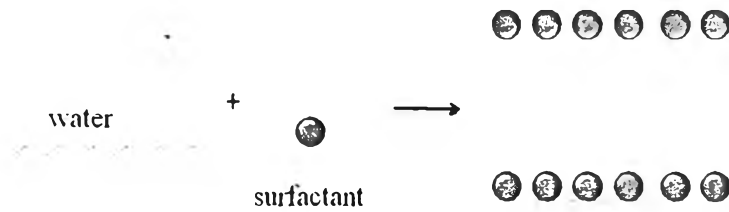
#### Step 3: Polymer Formation

In this step, the initiator is added into the system to generate polymerization of the monomer in the admicelle. For free radical polymerization, this is accomplished by the generation of radicals capable of initiating the polymerization reaction.

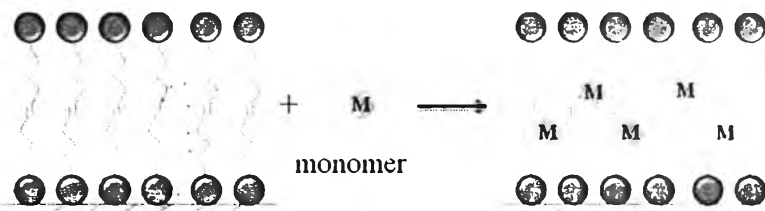
#### Step 4: Surfactant Removal

After the polymerization is completed, the upper surfactant layer is washed out in order to expose the polymer film on the substrate surface.

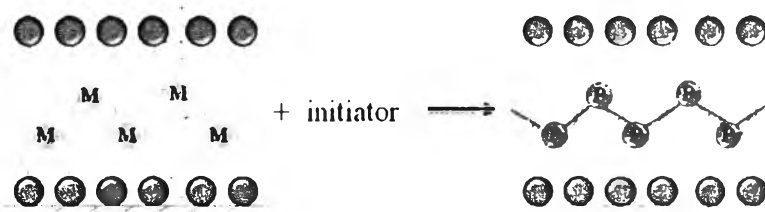
## Step 1: Admicellar Formation



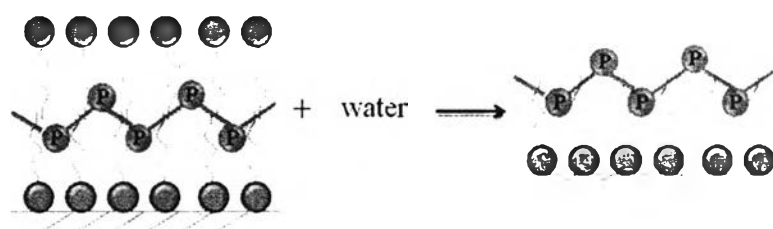
## Step 2: Monomer Adsolubilization



## Step 3: Polymer Formation



## Step 4: Surfactant Removal



**Figure 2.2** Schematic of the four steps of admicellar polymerization.

There are many applications of admicellar polymerization technique for example; to improve the surface properties such as the wettability of cotton, to increase the compatibility between the filler and the substrate in the composites which also increase the mechanical properties of the composites such as modified-silica filler. Moreover, various potential applications have been proposed for thin films formed by this technique, e.g., in the microelectronic industry, solid lubrication, corrosion inhibition, optical coatings, and surface-modified electrodes.

Sakhalkar et al. (1995) studied the formation of a polystyrene film on the surface of glass fibers via admicellar polymerization using two different cationic surfactants which are dodecyltrimethylammonium bromide (DTAB) and cetylpyridinium chloride (CPC). Treated fibers have been observed using scanning electron microscopy to evaluate the film formation. The micrographs showed a non-uniform coating on the fiber surface. Fibers were also subjected to a THF extraction process that confirmed the formation of polystyrene by UV-visible spectroscopy.

In 2002, Pongprayoon et al. improved the hydrophobicity of the cotton surface by thin-film coating of polystyrene on cotton using the admicellar polymerization process. The effects of surfactant, styrene, initiator, and electrolyte concentrations on the polymerization process were determined. The polystyrene film formed was characterized by SEM, FTIR, and GPC. From the drop test showed that the hydrophobicity of the treated cotton surface increased and depended on the LAS : monomer and monomer : initiator ratios. Results show that polystyrene thin film was successfully formed on cotton, resulting in cotton that can resist wetting by a water droplet for longer than 30 min. In 2003, they used the Wilhelmy technique to study the wettability and water transport in cotton yarn. Yarn modified with a thin film of polystyrene applied by admicellar polymerization exhibits higher contact angles and takes up much less water than the unmodified cotton. The amount of styrene and initiator used for admicellar polymerization affects the wettability of the coated fabric. In 2004, Divinylbenzene (DVB) was used as a cross-linking agent to form networked polystyrene to improve film coverage on cotton by admicellar polymerization. After the polymerization, the wettability of the treated cotton surface as determined by the Wilhelmy microbalance technique was correlated to the surface coverage of the polymer as determined by XPS. The optimum amount of DVB was around 1%.

Formation of a thin polyaniline film on hydrous zirconia ( $ZrO_2$ ) surface was carried out using a cationic surfactant, hexadecyltrimethylammonium bromide (HDTAB). The formation of the polyaniline coated  $ZrO_2$  has been confirmed by UV-visible spectroscopy, FT-IR spectroscopy, and conductivity measurements. Various parameters involved during the adsorption process such as aniline concentration on HDTAB adsorption and salt addition were studied. It was observed



that increase in aniline concentration decreased the amount of HDTAB adsorbed on  $ZrO_2$ . Addition of salt (0.05 M NaCl) in the feed solution increased HDTAB adsorption and drastically reduced the effect of aniline concentration on HDTAB adsorption. The results indicate that admicellar polymerization can be applied to the formation of a thin conducting polymer film of monomers with moderate water solubility (Salgaonkar et al., 2005).

The surface of calcium carbonate ( $CaCO_3$ ) particles was modified by admicellar polymerization to improve compatibility of its high energetic hydrophilic surface with the low-energy surface of hydrophobic polymers for enhancing composite properties. Rungruang et al. (2005) produced a thin layer of polypropylene (PP) on the surface of calcium carbonate ( $CaCO_3$ ) particles by admicellar polymerization, using sodium dodecyl sulfate (SDS) as the surfactant template and sodium persulfate ( $Na_2S_2O_8$ ) as the thermal initiator, to be used as filler for isotactic polypropylene. The admicellar-treated  $CaCO_3$  particles were characterized by Fourier-transformed infrared spectroscopy (FT-IR), gravimetric analysis, and particle size analysis. Compared to composites made from the uncoated material, composites made with stearic acid-coated and admicellar-treated  $CaCO_3$  particles had lower tensile strength, Young's modulus, and flexural strength, but higher impact strength. Observation of the fractured surfaces of the composites by scanning electron microscopy (SEM) revealed an improvement in the dispersion and distribution of the  $CaCO_3$  particles within the iPP matrix as a result of the surface treatment.