Course Name: Building Materials as a Cornerstone to Sustainability

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Lecture 03

Adhesion changing smart materials

Hello everyone. Last class we saw phase change material and it is a case study example of how it is used in architecture, what are its advantages and disadvantages. Today we will look at adhesion changing smart materials and photo adhesive smart materials. The next two classes will focus primarily on titanium dioxide and its uses and applications in architecture. In this class, we will see what smart materials are. What are adhesion-changing smart materials? What are photoadhesive smart materials? titanium dioxide, ceramic slabs with titanium dioxide, construction membranes with titanium dioxide, glass panes with titanium dioxide, and we will see a case study.

Now, adhesion-changing smart materials include materials and products that are able to change reversibly the attraction forces of adsorption or absorption of an atom or molecule of a solid, liquid, or gaseous component in response to stimuli. This may take place due to the effect of light, temperature, an electric field, or a liquid and a biological component, or maybe just a biological component. Adsorption is the attachment of an atom or molecule of a component to the inner surface of a material or product. Hydroceramic, for example, is proved to be effective in reducing the internal temperature of a room by 5 degrees Celsius.

So, if we look at smart materials, which are intelligent and responsive materials, these are materials that are designed to have one or more properties that can be significantly changed in a controlled fashion by external stimuli such as stress, moisture, electric or magnetic fields, light, temperature, humidity, pH, chemical compounds, etc. Hydroceramic is a combination of hydrogels evaporative property with thermal mass and the ceramic clay and fabric property of humidity control. If we look at hydromembranes. then hydromembrane is a passive self-regulating composite material operating on the principles of biomimetic ventilation and cooling systems. Its shape memory actuation adapts to the environment, where regulating the interior's temperature, air flow, and humidity becomes important.

Hydromorph being permanently durable becomes cost-effective in the long term. It can be used on a micro and macro scale as a textile and building skin, respectively. Let us look at adhesion changing smart materials. These include materials and products that are able to change reversibly the attraction forces of adsorption or absorption of an atom or molecule of a solid, liquid, or gaseous component as a response to some stimuli. This may take place due to the effect of any stimuli which could be light or temperature or electric field or due to a living organism, biocomponent, etc.

Now, the process can be generally classified as physical adhesion, chemical adhesion, or mechanical adhesion. Depending on the stimulus that changes the attraction forces of adsorption or absorption of atoms or molecules of solid, liquid or gaseous components of adhesion-changing smart materials, they can be differentiated as the main attraction forces are due to the adsorption, secondary bonding, Van der Waals forces, electrostatic bonding, dipolar bonding and secondary valency bonding between different components. There can be based on the stimulus that changes the attraction forces of absorption. These can be differentiated as photoadhesive smart materials. The second one is chemical adhesion.

The processes can be generally differentiated as physical adhesion, chemical adhesion and mechanical adhesion. Now what is physical adhesion? The main attraction forces are due to adsorption, secondary bonding, Van der Waals forces, electrostatic bonding, dipolar bonding, and secondary valency bonding between different components. Chemical adhesion. So, chemical bonding provides the main attraction forces between different components. If we consider mechanical adhesion, these attraction forces arise mainly from interlocking, anchoring, or intermeshing between different components.

Under this, we have photoadhesive smart materials. These change the attraction forces of adsorption or absorption of atoms or molecules of solid, liquid or gaseous component as a response to light. Second are the thermoadhesive smart materials. These change the attraction forces of adsorption or absorption of atoms or molecules of solid, liquid, or gaseous components in response to temperature. Thermoplastics are one example of smart materials that have strong thermal adhesive properties.

They create a temperature-dependent bond between different components. Next is electroadhesive smart materials. These change the attraction forces of adsorption or absorption of atoms or molecules of solid, liquid, or gaseous components as a response to an electrical field. Then we have hydroadhesive smart materials. These change the attraction forces of adsorption or absorption of atoms or molecules of solid, liquid, or gaseous components in response to liquid components.

Then we have the bioadhesive smart materials. These change the attraction forces of adsorption or absorption of atoms or molecules of solid, liquid, or gaseous components in response to biological components. Say, for example, bacteria. Their inherent properties allow products based on photoadhesive materials to change reversibly their adhesion in response to light. Photoadhesive smart materials are of particular relevance in the field of architecture.

Photoadhesive smart materials change. For example, the wetting angle of liquid components applied to solid components in response to light. In architecture, the prominent photoadhesive material interest is titanium dioxide. Now, titanium dioxide was first used as a white pigment. This pigment was made in the USA and sold from 1909 under the name Kronos Titanium White.

In Germany, it was manufactured in 1924 as a DGA Titan Veil. At first at the antis modification and then from 1938 in another rutile form. Since 1917, titanium dioxide has been produced from ilmenite, which is titanium iron ore, using the sulfate process with the addition of sulfuric acid. From 1958 also the chloride process has been in use. Here chlorine is added to the ore.

Since 1968, titanium dioxide has been used as a food additive. After its photocatalytic effect was discovered, the Japanese were successful in 1995 in using titanium dioxide in ceramic surface coatings. In recent years, Japan has also developed paper and building membranes with photocatalytic effects. In the year 2002, it saw the first self-cleaning glass with titanium dioxide appear in the European market. So, the raw materials for production of a titanium iron ore which is called ilmenite is a shiny black mineral It is a rutile, a less iron rich titanium ore.

Both of these are obtained from open-cast mines. Titanium dioxide is currently the most technically important compound of titanium and it occurs naturally as a crystal lattice structure. Titanium dioxide is insoluble in water. insoluble in organic solvents, diluted acids, and alkalis. It is lightfast and temperature stable because its melting point is 1855 degrees centigrade.

Ceramic slabs with a surface coating of baked on titanium dioxide, preferably the anatase modification, are currently available as facade slabs. and also for wall and floor tiles. These can be handled easily and used like conventional facade slab and tiles. They are intended for use where their self-cleaning properties and their ability to improve the air quality by breaking down organic pollutants are important. They are applicable in conjunction with conventional façade substructures, largely maintenance-free.

They have long replacement life. They are fire-resistant. They are relatively inexpensive compared with conventional ceramic slabs. Let us look at the construction membranes. Textile membranes which are fully coated with plastic such as PVC, PTFE with a titanium dioxide surface coating are available in rolls in various dimensions depending upon the manufacturer.

Extensive cutting to shape is required. These can also be prefabricated to suit the customer's requirements as conventional construction membranes. They are best suited for use where self-cleaning is desirable and integrated into various membrane construction types with largely maintenance free and long replacement life. Let us look at glass panes with titanium dioxide. These can be integrated into framed and frameless construction types.

Reactivation happens by additional cleaning, which is required where there is severe dirt contamination, such as bird droppings or tar. So, conventional glass paints with titanium dioxide surface coating are best suited for use where self-cleaning and air quality improvement by breaking down organic pollutants is desirable. A self-cleaning glass comprised of a clear sheet of glass onto which a transparent hydrophilic and photocatalytic mineral coating is deposited. The light decomposes any organic matter while water, for example, rain, washes it away as it sluices over the surface. So this can be combined in order to provide solutions incorporating enhanced thermal insulation, solar control, acoustic insulation, or even security.

So the self-cleaning glass is composed of a clean sheet of glass. There is a clean sheet of glass onto which a transparent hydrophilic and photocatalytic mineral coating is deposited. So this is the mineral coating. The light decomposes any organic matter, and when rain falls over it, over the dust and the grime, it slides over, the dirt slides over, and gets washed away, resulting in what we call self-cleansing glass. So, the glass cleans itself automatically.

Let us look at a case study example. So these membranes can be formed into technically and geometrically complex textile structures, which can possess a special aesthetic charm. The Garden Chapel has a photocatalytic self-cleaning membrane skin in Japan. So, in January 2001, in the garden of a luxury hotel in Osaka, Japan, a chapel was built which incorporates a white construction membrane. The surface that is exposed to rain was given a self-cleaning coating containing titanium dioxide.

The double curved load bearing structure of the chapel is open on two sides and has four supports. It is clad externally with numerous rows of tied filigree rhomboids on which about 50 meter square of the membrane were applied. The shape, surface structure and permanent self-cleaning white colour of the structure suggests a lightweight bridal gown moving in the wind. The earlier disadvantage was that if maintenance was neglected or cleaning was not carried out or was inadequate, then the membrane would become unsightly after a few years. Now with this self-cleaning mechanism of titanium dioxide, it helps in easy maintenance because once the membrane comes in contact with moisture or any water like rain, it cleans itself.

This is not a large structure but imagine multi-story buildings and skyscrapers They spend a huge amount of money on cleaning the external glass if it is done manually. But with the self-cleaning glass, it saves time and energy and is also economic in the long run. So, with this introduction, adhesion-changing smart materials, we will stop the class and we will continue our next class, wherein we will be looking at titanium dioxide in much greater detail. We will stop here and continue next class. Thank you.