Course Name: Building Materials as a Cornerstone to Sustainability

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Lecture 01

Introduction   to   smart   materials

Hello everyone. So with the last class where we saw permeable concrete, we have completed some of the materials that we called or classified as advanced building materials. So we have seen traditional building materials and alternate building materials. We have also seen innovative building materials. We have seen advanced building materials. Now, we look at smart building materials.

Now, what are smart building materials? So, this lecture on the introduction of smart building materials is organized to provide a comprehensive exploration of building materials in this innovative field. The introduction section sets the stage by defining and outlining the significance of smart materials in the construction industry. Subsequently, a detailed examination of the characteristics of smart materials will be presented, drawing a clear comparison with common architectural materials. The classification section categorizes smart materials based on their properties and types, offering insights into the diverse   range   within   this   category.

The application segment dwells on the integration of smart materials in various building components, with a focus on facade systems, lighting, and energy systems. Advantages are explored, emphasizing the superior properties of these materials and the associated cost and efficiency benefits. The challenges section critically addresses both technical and implementation challenges as well as environmental considerations. Building examples provide case studies showcasing the real-world application and impact of smart materials in architecture. The lecture concludes with a summary recapping key points and hinting at future trends and development in the dynamic field of smart building materials.

Now, the advent of smart materials represents a substantial response to the evolving technological needs of the 21st century as emphasized by researchers. Described as highly engineered materials that respond intelligently to the environment, smart materials have become an integral consideration in contemporary architecture. These materials exhibit the ability to remember configurations and adapt to them based on specific

stimuli. They may possess intrinsic quick response capabilities or be intentionally designed to undergo significant property changes in a controlled manner under external influences such as stress, temperature or electric fields. In essence, smart materials encompass a diverse range of entities including molecules, composites, assemblies or systems all characterized by specific behavior.

These behaviors include immediate, transient, self-actuated, selective, and direct responses, making smart materials a versatile and dynamic class of materials. Let us look at the characteristics of smart materials. Smart materials, in contrast to common architectural materials, exhibit distinct characteristics that set them apart. One key feature is their real-time responsiveness, enabling them to adapt dynamically to changing conditions. Unlike conventional materials, smart materials can react to multiple environmental states showcasing their versatility.

Importantly, intelligence is embedded within the material itself, allowing it to autonomously respond to stimuli. The response of smart materials is both district, discrete and predictable, providing a controlled and reliable outcome. The specificity extends to the activating event, ensuring that the material's reaction is directly tied to the stimulus it receives. The fundamental characteristics that distinguishes smart materials in architecture include their capability for property change, facilitating adaptability. They also possess the ability for energy exchange, contributing to their interactive nature.

Moreover, smart materials exhibit discrete size and location in their responses allowing for targeted effects. Reversibility is another crucial trait ensuring that the material can return to its original state after undergoing a change. These unique characteristics offer the potential for optimizing behavior to maintain steady state conditions in the environment, making smart materials valuable assets in architecture applications. In a gist, the characteristics of smart materials is that they respond in real time They respond in more than one environmental state. Their intelligence is inherent in the material.

Their response is discrete and predictable and their response is specific to the activating event. Also, smart materials show reversibility They show energy exchange, they undergo property change and they have discrete size and location. Let us look at the broad classification of smart materials. Now smart materials are divided into two types. This is according to their behavior of energy stimulus from surrounding environment.

The first type comprises materials that have the capability to change their chemical, mechanical, electrical, magnetic, or thermal properties, including thermochromic, phototrophic, shape-changing, mechanochromic, chemochromic, electrochromic, phase-changing materials, and adhesion-changing materials. Now, the energy input to a material

affects the internal energy of the material by altering the material's microstructure, and the input results in the property change of the material. Now, this type of material reacts through changes in color and temperature. The second type of material are those that have the capability to transform the energy from one form to another. These could be photovoltaic.

They can be light emitting materials. We have already seen photoluminescent and electroluminescent. These can be chemoluminescent, piezoelectric, or thermoelectric. electrostrictors, magnetostrictors, light emitting diodes and shape memory alloys. The energy input to a material changes the energy state of the material composition but does not alter the material.

While the state of the material remains the same, the internal energy undergoes a change. Some examples we have already seen. There are one or two that are common to both types. Let us broadly look at the shape-changing smart materials. Shape-changing materials represent a remarkable class of substances that undergo reversible transformations in response to external stimuli encompassing light, pressure, heat, electricity, or magnetism.

The alteration in their form is intricately linked to the distribution and arrangement of sensitive components within the material, ultimately resulting in changes in dimensions. Ritter's classification system categorizes shape-changing smart materials into six distinct types, each responsive to specific stimuli. These are photostrictive, thermostrictive, piezostrictive, electroactive, magnetostrictive, and chemostrictive. Furthermore, subcategories within shape-changing materials are identified based on the specific alterations they exhibit, ranging from bending, straightening, twisting, and untwisting to constricting, loosening, swelling, or shrinking. This classification system not only facilitates a comprehensive understanding of the diverse behavior of shape-changing materials but also provides a structural framework for their exploration and application across various fields.

Next, let's look at the energy-generating smart materials. Energy-generating smart materials represent a remarkable advancement in the field of material science. These materials possess the capability to generate diverse forms of energy, usually achieved through the conversion of one energy type to another culminating in the production of electric energy. The systematic examination of these materials employs two categories, distinguishing them based on their inputs and outputs. Energy exchange and electricity generation.

The materials under scrutiny are intricate compositions combining various elements to

fulfill specific functions. These amalgamated materials can be likened to simple devices, meticulously designed and structured based on their conceptualization and intended applications. This innovative approach to energy generation holds promise for more efficient and sustainable energy solutions marking a significant stride in the realm of smart materials and their diverse applications. Now let us look at self-maintaining smart materials. Material science is a multifaceted domain that wells into both the exploration of smart materials and the experimentation with cutting-edge technologies to augment the properties of existing materials.

A notable recent development in this field is the advent of self-healing technology, marking a substantial advancement. Unlike conventional material science approaches, certain emerging technologies within the realm focus on material research to fabricate entirely new materials endowed with distinct properties. This approach diverges from naturally occurring smart materials that exhibit characteristics like self-maintenance. The property of self-healing inherent in smart materials is further amplified through these novel technologies, representing a significant stride toward more resilient and adaptable materials with enhanced capabilities in self-repair. Another group is high-insulating smart materials.

Aerogel and ETFE, which is ethylene tetrafluoroethylene, stand out as two noteworthy smart materials renowned for their exceptional insulation capabilities. Their distinctive feature lies in their capacity to deliver high levels of isolation, making them pivotal in diverse applications where efficient thermal insulation is paramount. Aerogel, acknowledged for its impressive insulation properties, is particularly esteemed for its effective thermal insulation. On the other hand, Ethylene tetrafluoroethylene, a material derived from Teflon, is recognized as another smart material celebrated for its superior insulation performance. These materials not only provide effective thermal insulation but also showcase versatility finding application in various contexts where maintaining temperature control is crucial.

Let us look briefly at the applications. Several building components and systems stand to benefit from the integration of smart materials. Facade systems, particularly smart windows, offer enhanced control over thermal conduction and solar radiation, contributing to the optimization of a building's energy efficiency. Lighting systems whether utilizing optical fiber or light emitting diodes can be improved through the application of smart materials to optimize lighting conditions. Energy systems encompassing photovoltaics and micro or meso energy systems can benefit from smart materials in areas such as energy transmission, internal heating control, and the optimization of HVAC systems.

Architects play a very crucial role in leveraging these advancements. Understanding how materials behave in relation to environmental phenomena is essential. Applying advanced technologies based on smart materials has the potential to significantly enhance the sustainability of buildings. By focusing on phenomena rather than solely on material artifacts, architects can strategically reduce energy consumption by acting discreetly where necessary and operating at a local level. This approach allows a broader range of designs for both new and existing buildings to harness the advantages offered by these technologies, thereby promoting sustainability in the built environment.

Let us now look at the advantages of smart materials. Smart materials and their production processes have the potential to bring significant benefits to the construction industry. These materials offer improved strength, toughness, and flexibility, making structures more robust. They also contribute to extended durability, reducing the need for frequent repairs or replacements. Smart materials are resistant to wear, corrosion, chemicals, and fatigue, ensuring a longer lifespan for constructed elements.

Importantly, they bring about cost savings not only during construction but also over the entire life of a structure. Additionally, these materials enhance a building's ability to withstand extreme events like natural disasters and fires, providing increased safety. Their manufacturing and application are straightforward, making the construction process more efficient. Smart materials also consider aesthetics and environmental compatibility, ensuring structures are both functional and visually pleasing. Moreover, these materials have unique features like self-diagnosis and self-healing, allowing for early problem detection and automatic repair.

In essence, incorporating smart materials in construction presents a range of advantages making buildings stronger, more durable, cost effective and adaptive. In a crux, we see that the advantages of smart materials are their enhanced strength, toughness and ductility. They show improved durability and extended life service. Third, they show heightened resistance to abrasions, corrosion chemicals and fatigue. Fourth is they have cost efficiency both in the initial stages and throughout the building's life cycle.

Fifth, they show better responsiveness to extreme events such as natural disasters, fires, earthquakes, cyclones, etc. Sixth, there is ease of manufacturing as well as installation. Seventh is the considerations for aesthetics and environmental compatibility is high. Eighth is they show capability for self-diagnosis, self-healing and structural control. What are the challenges of smart materials? Now, while smart materials hold the potential to effectively address environmental crises, their widespread utilization in building construction remains limited.

This lack of prevalence can be attributed to factors in both theoretical and applied domains. In the theoretical realm, the scarcity of knowledge and raw materials typically hinders the widespread adoption of new technologies. However, in the case of smart materials, diverse types are readily available, eliminating these theoretical obstacles. The impediments are thus rooted in the applied field, where concerns like the fear of risk, limited awareness, and high costs hinder their incorporation. Overcoming these barriers requires proactive measures starting with the introduction of smart materials through effective advertising to enhance public awareness.

Subsequently, their implementation in prominent and visible location becomes crucial for familiarizing people with these materials and encouraging their usage. The ultimate goal is to achieve widespread acceptance resulting in a surge in demand and also subsequent mass production ultimately driving down costs. Recognizing this, the initial step in both theoretical and applied development is fostering awareness and understanding. This complex challenge necessitates meticulous observation to analyze obstacles and devise effective solutions. In short, smart materials, while being very effective for environmental crises, have certain limitations in building construction.

Barriers to widespread usage exist. as theoretical, which is like limited knowledge and limited raw materials, and applied, which is in the applied domain, fear of risk, lack of awareness, all of which comes with a new material usage. The overcoming barriers requires strategic introduction through awareness, propaganda, advertising, etc. Implementing these in public places is crucial, as that itself serves as broadcasting, or that itself serves more as advertising for people and encourages use. Widespread acceptance leads to increased demand. This will enable production and cost reduction.

Recognition is a primary step in both theoretical and applied development, requiring careful observation and solution-oriented analysis. We will now look at a few building examples. This is the Dutch biotope pavilion spanning an area of about 3727 meters square and situated in Dubai. It stands as an innovative architectural endeavor by V8 architects. This project goes beyond its physical dimensions, serving as a response to pressing global challenges such as water scarcity, energy transition, and food shortage.

At its core, it's a distinctive chimney-like structure forming a cone within the pavilion. This element plays a pivotal role in the exhibit, effectively regulating temperature and moisture levels and addressing the critical issue of water scarcity. The pavilion implements a sustainable solution by harvesting 800 litres of water every day from the humidity of the air, subsequently utilized for plant irrigation. Impressively, the entire process is powered by renewable energy with lightweight, organic, transparent solar cells, which is integrated into the design, and it showcases the artistic touch of Marjan van

Oubel. The next building example we will take is the one that is situated in Yakushima, Japan.

This is a hospitality project covering an area of 162 meters square. It showcases the innovative design expertise of architect Tsukasa Ono. The focal point of the design involves incorporating burned wood beneath the foundations of each building, facilitating mycelium growth in the forest soil network. Mycelium, recognized as an eco-smart material, plays a crucial role in fostering tree root growth under the structures. This contributes significantly to soil strengthening.

As part of its commitment to sustainability, the project embraces a regenerative architecture methodology developed by SUMU. This approach seeks to enrich nature through thoughtful building interventions. Additionally, the architectural features in the project prioritize self-sufficiency, achieving 100% off-grid energy utilization through a combination of solar power, storage batteries, and locally sourced firewood. This harmonious blend of ecological considerations and architectural innovation defines the unique character of the hospitality venture in Yakushima. In summary, smart materials engineered for intelligent responses to environmental stimuli are reshaping the landscape of architecture by providing adaptability and enhanced functionality.

These materials find application in various components such as facades, lighting, and energy systems, capitalizing on their versatile and responsive properties. With traits that are changeable and reversible, smart materials contribute significantly to sustainable construction practices. The integration of these materials is exemplified in innovative projects like pavilions and hospitality structures showcasing their practical applications in addressing contemporary challenges. Notably, shape-changing and piezoelectric materials offer adaptability to external stimuli, introducing new dimensions of versatility. Regenerative architecture takes the concept further by integrating burned wood and mycelium, promoting self-sufficiency and comfort.

In conclusion, the adoption of smart materials signifies a transformative shift in construction practices, introducing strength, resilience, and sustainability across diverse applications, paving the way for a more adaptive and efficient built environment. With this, we have stopped or we will conclude. the introduction of smart materials in architecture. In the forthcoming classes, we will see every smart material one by one in detail. Until then, goodbye from me. Thank you.