

**Course Name: Building Materials as a Cornerstone to Sustainability**

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**Lecture 03**

Nanocellulose

and

Electroluminescent

Hello everybody. So last class we stopped with a very innovative and new upcoming smart material, electrochrome. Today we will see a new smart material called nanocellulose composite bricks. Today we will look at what are composite bricks using nanocellulose, what are the types of nanocellulose, what are the properties of nanocellulose, what are nanocellulose composite bricks, what are their advantages, their challenges and we will look at a case study. A composite material is a material that is produced from two or more constituent materials. These constituent materials have notably dissimilar chemical or physical properties and are merged to create a material with properties unlike the individual elements.

A brick that is made by mixing two or more different types of construction materials with improved properties compared to individual components is known as composite bricks. In order to reduce the waste generated by the building industry, different waste materials and byproducts like fly ash, stone dust, slag, recycled plastic, glass cullets, etc. are used. Combining the different materials in proper quantities improves the strength of the bricks.

It makes them more durable, lightweight, thermally insulating, and better for the environment. Now what are nanocelluloses? Nanocellulose is a form of natural plant-based polymer cellulose. Plants rely on cellulose to maintain the strength and structure of the cell walls. For hundreds of years, the properties of cellulose has been leveraged to produce various essential materials from paper and textiles to plastics and photographic film. Nanocellulose is derived from this cellulose.

It's not one specific material, but rather a term encompassing different structures made from cellulose at the nanoscale, meaning with dimensions in the range of 1 to 100 nanometres, which is millions of a millimetre. Nanocellulose can be prepared from any cellulose source material, including agricultural waste such as rice husk, coconut husk, and algae. But wood pulp is most commonly used. Now, what are the types of

nanocellulose? There is nanocellulose nanofibrils. These are long thin fibers with high aspect ratio.

The length to width ratio is very high in this. They offer high strength and flexibility. Then we have the cellulose nanocrystals. These are rod-shaped particles with high crystallinity and rigidity. They contribute to stiffness and barrier properties.

And the third is bacterial nanocellulose. These are produced by some bacteria. And it forms a highly porous and interconnected network with good water absorption and biocompatibility. Here you can see how, from a tree, we can see the plant cell size, the microfibrils, the microfibrils and then these cellulose molecules all running into nano.

It is the same here. The crystalline region is here and you have the amorphous regions and strong acid hydrolysis gives nano crystals and In the third case, which is bacterial cellulose, these are obtained from the bacteria. So, this is nanocellulose nanofibrils and these are cellulose nanocrystals. and this is bacterial nanocellulose. What are the properties of nanocellulose? First is they have a high strength to weight ratio.

They are stronger than steel at the same weight, making it ideal for reinforcement applications. Second is biodegradability and renewability. These are derived from sustainable sources like wood pulp offering an eco-friendly alternative to traditional materials. Third, they have low thermal conductivity. So they have excellent thermal insulative properties which contributes to energy efficiency.

and they are highly transparent. So, some forms are highly transparent, offering potential in optics and displays. Let us now look at the nanocellulose composite bricks. Nanocellulose composite bricks are made by combining nanocellulose with the other raw materials used in the composite bricks. Adding nanocellulose enhances the properties of the composite bricks.

There is no single unique method of making these bricks. Research is underway using multiple different combinations of raw materials and nanocellulose in varying percentages which are then tested to find out their properties. Thus, nanocellulose composite brick is yet to become a large scale building material. Let us look at the advantages of nanocellulose fibers. First is the strength and durability.

Nanocellulose fibers act as tiny reinforcements within the brick, making it more resistant to cracking, chipping and breaking. This can be especially beneficial in areas prone to earthquakes or other natural disasters. Second is its reduced weight. Nanocellulose is a lightweight material. This makes them easier to transport and install and also reduces the

dead weight of a building, potentially leading to cost savings in foundation construction.

Third is improved thermal insulation. Nanocellulose has good thermal insulation properties, which can help to keep buildings cooler in the summer and warmer in the winter. This can lead to reduced energy consumption for heating and cooling. Fourth is reduced environmental impact. Nanocellulose is a renewable and biodegradable material.

Additionally, the production of nanocellulose can help to reduce waste from the pulp and paper industry. What are the challenges in using nanocellulose composite bricks? While it is promising, there are some challenges to overcome before widespread adoption. First is higher production. Higher production cost. Nanocellulose is still a relatively new material, and the production process is more complex than traditional brick materials.

This leads to a higher cost per brick making them less competitive in price sensitive markets. Second is the limited production capacity. As production is still scaling up, the overall availability of these bricks is limited, further affecting their cost and accessibility. Third is standardization and regulations. As a new material, there are no established industry standards or regulations for nanocellulose composite bricks.

This creates uncertainty for builders and architects, hindering acceptance and widespread use. The fourth is long term performance data. While initial studies show promising results, long term performance data on durability, weather resistance and fire resistance are still limited. This raises concerns for some potential users. Let us now look at the examples where nanocellulose composite bricks have been experimented with.

While there are currently no large-scale buildings constructed entirely with nanocellulose bricks due to their recent development and limited availability, there are several pilot projects and smaller structures showcasing their potential. First is the experimental house in Sweden. So, a research team at Chalmers University of Technology in Sweden built a small, single-story house using nanocellulose composite bricks as part of a research project. The bricks were made from a mixture of clay, cement and nanocellulose fibers extracted from wood pulp. The project aimed to assess the feasibility and performance of using nanocellulose in construction.

The second example is the bridge rehabilitation in Italy. Researchers at the University of Pisa in Italy used nanocellulose composite bricks to repair a damaged bridge arch. The bricks were chosen for their lightweight properties and ability to bond well with the existing masonry. The project demonstrated the potential of nanocellulose for structural reinforcement applications. So, nanocellulose is an upcoming material A lot of research needs to be done on this domain before it finds its place and its potential and also its

versatility in the architecture domain.

Nevertheless, it is a material of interest because it is a combination of the smartness in nature combined with our knowledge of other contemporary materials. We will now look at another smart material. We will look at electroluminescent as another smart material. So, electroluminescent are those materials that emit light when subjected to an electric field. They function on the basic principle of what lumen conversion and electrical energy is converted to light.

The basic working principle of electroluminescent panels involves two main mechanisms, excitation and light emission. When excited, a phosphor layer at the center lies a thin layer of phosphor powder sandwiched between two electrodes. This phosphor acts as a light emitting material. Then there is an electric field. Applying an alternating current creates a strong electric field across the panel.

This field accelerates electrons within the phosphor, exciting them to a higher energy state. The second is light emissions. recombination, excited electrons eventually drop back to their ground state, releasing their excess energy in the form of photons or light. The specific color of the emitted light depends on the type of phosphor used. Let us look at electroluminescent materials.

Electrodes. One electrode is usually transparent, allowing the emitted light to escape the panel. There is a voltage and frequency component. The brightness and efficiency of the panel can be controlled by adjusting the voltage and frequency of the applied AC current. Efficiency varies widely depending Because efficiency depends on various factors such as material composition, panel thickness, manufacturing process, operating voltage and frequency and color of the light emitted. Here we can see how electroluminescent wires and strips are assembled in these diagrams.

Let us now look at the mechanism. There are two mechanisms for electroluminescence. First is impurity-based and semiconductor-based. Impurity based is within the phosphor is the key. High electrical field drives electrons to collide with these impurities. Jumping electrons on ionized impurities emit light, which is called luminescence.

Light color depends on the impurity material type. Second is semiconductor based. More complex behavior involving both electrons and holes happens in this. General movement of these charged particles within the semiconductor leads to light emission. The first mechanism impurity based is more common.

Both mechanisms require specific materials with suitable properties to function. We

have already seen the working of an impurity-based phosphor system. If we look at this diagram, we can see a semiconductor-based electroluminescence system. Applying a voltage across the p and n junction disrupts the equilibrium. The positive voltage terminal attracts electrons from the n-type region towards the p-type region while the negative terminal pushes holes in the p-type region towards the n-type region.

This electric field energizes the electrons and holes. In the depletion region at the center of the junction, mobile electrons and holes encounter each other. As they recombine, the excess energy gained from the voltage is released in the form of photons generating light which is called as electroluminescence. The color of the emitted light depends on the band gap energy of the semiconductor material. Let us look at the advantages of electroluminescence.

First is the uniform and diffused light. Second is they are thin and flexible. Third is they are energy efficient. They have long lifespan. They are cold light emissions that generate minimal heat.

There is a wide color range. They are easy to control, and dynamic lighting effects and adjustments can be made. They are durable and shatterproof. So, they are resistant to shock, vibration, and breakage, and they are eco-friendly. So, no harmful materials like mercury or lead or no emission of any harmful gases happen.

Let us now look at their limitations. The first limitation is its higher initial cost. Compared to traditional lighting options like incandescent bulbs, electroluminescent lights can be significantly more expensive upfront. This can be a barrier for budget-conscious projects or large-scale applications. Second is the lower light output. Electroluminescent lights generally have lower lumen output compared to some other lighting sources.

This may not be ideal for situations requiring bright illumination, like task lighting or general room lighting. Then they have a limited color range. Although electroluminescent lights can produce various colours, the available palette is not as extensive as other lighting options, particularly compared to LEDs. This might limit their suitability for certain design themes or applications.

Fourth are the material durability concerns. While electroluminescent materials have made advancements, their long-term durability, especially in outdoor environments exposed to harsh weather conditions, is still a point of concern. Degradation of the materials over time could affect light output and lifespan. Next are the design integration challenges. Integrating Electroluminescent lights seamlessly into architectural design can

be challenging. Their thickness and potential visibility of internal components may not always align with desired aesthetics.

And then the last is the potential health concern. Electroluminescent lights may emit low levels of ultraviolet radiation, although the risk is considered minimal for typical uses. However, for sensitive applications like healthcare or areas with prolonged exposure, it is advisable to choose UV-free options. Let us look at the applications of electroluminescent light. First is architectural lighting. So, electro-luminescent lights are extremely versatile, and they can be used in a variety of applications in the architectural field.

In architectural lighting, they can be sleek, glowing walls, ceiling, signage creating a dynamic ambience in buildings, in hotels or museums. Second is emergency and safety. So reliable exit signs and subtle path markings ensure safety during power outages or emergencies. They can be used for decorative magic. Furniture accents, glowing clothing and luminous toys add a touch of enchantment to any space.

Fourth are fascinating facades. Buildings come alive with vibrant, self-illuminating skins, transforming architecture into mesmerizing art. Fifth is mood-setting fixtures, as these create subtle, even illuminating in rooms from soft bedroom gloves to playful children's spaces. Ultra-flat LEDs integrated into glass panes that can be supplied with electricity through almost visible cable ways are used for illuminating transparent balustrades, banisters, room dividers, etc. Let us quickly look at an example of where this is used. So, When we look at this case study incorporating electroluminescent light in its facade design, the building designed by Spanish architect Ruiz Geli and his Cloud9 practice with other partners consists of a comparatively simple high-rise with a conventional glass facade.

which is covered with a stainless steel mesh on which a multitude of artificial leaves with electronics are attached. The design concept is presented as your room in a tree where each leaf of the steel mesh consists of one photovoltaic cell, a battery, CPU and a RGB LED which creates an artificial light cloud around the hotel. Placed at a distance of 57 cm apart, each of these leaves is fitted with a solar cell. The electric current created during the day is stored temporarily and directed to 1, 2 or 3 RGB LEDs at night by the processor. The processor analyzes the state of the charge of the accumulator and the energy consumption of the LED and controls the duration of illumination approximately for 1, 2 or 3 LEDs.

By using LED combinations, a total of 7 colors can be created. So, the impact is that each node in the energy mesh is equipped with photosensors that gather solar energy

during the day and, in response to the quantity of energy reflected in an energy diagram, emit a certain color at night. Because of this, it becomes sustainable as it is solar-powered illuminated. It has unique aesthetics because the living facade mimics a forest experience and it is interactive. Color changes reflect energy status and seasons. Overall, portal habitat, light kinetic facade pushes the boundaries of architecture, merging technology with nature to create a captivating and sustainable building experience.

So, today we stop our class with this smart material, and we will move on to the next class with yet another session. Thank you.