Course Name: Building Materials as a Cornerstone to Sustainability

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Lecture 01

Phase Change Materials - Part 1

Hello everyone. So today we continue with yet another smart material, and today we will look at phase-changing materials. So today we will look at phase-changing materials. What are the types of phase-changing materials? What are the products of phase-changing materials? And we will have a look at case studies of buildings that have used this smart material. Now, in the construction and architecture industries, the term PCM has been generally applicable to materials and products that can be used as temperature-regulating media. For example, latent heat storage media for the regulation of temperature.

Increasing the thermal storage capacity of building can increase human comfort by decreasing the frequency of internal air temperature swings so that indoor air temperature is closer to the desired temperature for a longer period of time. This system provides a valuable solution for correcting the difference between supply and demand energy. A phase change material is a substance that absorbs and releases thermal energy over a period of time. PCMs work by undergoing the process of melting and solidifying to store and dispense heat.

In the process of having to store and release thermal energy, the PCM material undergoes a change in state. Thermal energy storage in the walls, ceiling, and floor of the building may be enhanced by encapsulating or embedding suitable PCMs within these surfaces. They can either capture solar energy directly or thermal energy through natural convection. The use of phase change materials as latent heat storage materials is an efficient way of storing thermal energy. Materials that can absorb or release energy in the form of heat at specific temperatures are known as phase change materials, sometimes known as latent heat storage materials.

material undergoes a physical state transition from solid to liquid or vice versa as it absorbs or releases heat respectively. One of the most common examples that we quote of TCM is water. because it has the capacity to transition between the solid state, which is ice, and the liquid state, which is water, releasing and storing energy as it does so. Therefore, we can say that from here in this picture you can see that PCM is a material that is in a solid state. As the temperature rises, it stores the heat.

In this process of storing the heat, it melts and turns into liquid. During this time, the temperature remains constant. Now let us look at what happens in the vice versa situation. When the PCM is in the liquid form, the PCM is in its liquid form, and as the temperature drops, the PCM begins to solidify and becomes crystalline, and eventually it becomes a solid. This is the process in which phase change occurs.

So, the phase change materials, or PCMs, can give out latent heat at a wide range of temperatures, from subzero to several hundred degrees. The heat-on-demand requirement is satisfied by phase-change materials that work at specified temperatures. The phase change from a solid to a liquid or liquid to a gas and vice versa occurs at precise temperature. Thus, when energy is absorbed or released, it can be predicted based on the composition of the material. So, these phase change materials are latent energy storage materials.

They use chemical bonds to store and release heat. The thermal energy transfer occurs when a material changes from a solid to a liquid or from a liquid to a solid state. This is called in state or phase. Phase change processes invariably involve the absorbing, storing, and releasing of large amounts of energy in the form of latent heat. Phase-changing materials such as inorganic hydrated salts absorb and release large amounts of heat energy.

These processes are reversible, and phase-changing materials can undergo an unlimited number of cycles without degradation. Phase-changing materials can be crystalline, amorphous, or intermediate. This picture shows the microscopic photos of crystals of hydrated salts before and after heating. Now, PCMs absorb and emit heat while maintaining a nearly constant temperature. Within the human comfort and electronic equipment tolerance range of 20 degree Celsius to 35 degree Celsius, latent thermal storage materials are very effective.

These solid liquid phase change materials perform like conventional storage materials. Their temperature rises as they absorb solar heat. Unlike conventional heat storage materials, when phase-change materials reach the temperature at which they change phase, their melting point is the point where they change their phase. At that time, they absorb large amounts of heat without getting hotter. When the ambient temperature in the space around the phase change material drops, the phase change material solidifies releasing its stored latent heat.

So, these solid liquid phase change materials perform like conventional storage materials and their temperature rises as they absorb solar heat. So, unlike many other regular conventional heat storage materials, when phase change materials reach their melting point, which is when they change their phase,. They tend to absorb a large amount of heat, but they do not get hotter or warmer. So, when PCM is in a solid state as the temperature increases as the temperature increases the PCM melts absorbing the heat energy from the environment and becomes into a liquid. As the temperature drops, this liquid-state PCM gets solidified, and at that time it releases the stored heat.

whereas here it absorbs heat. So, the phase-changing material becomes a liquid when it has to store the heat and it manages to have the temperature as a constant. When heat is released, the phase-change material becomes solid or crystalline, but it manages to have a constant temperature. So, based on chemical composition, a phase change material can be classified as an organic, inorganic, or eutectic. So, there are three types of phase change materials.

Eutectic is a mixture or combination of organic and inorganic. Organic materials in turn can be classified as paraffin and non paraffin. They can change their state several times without displaying any degradation. Inorganic they can be classified as salt hydrates and metals These two belong to inorganic materials. The eutectic mixture results from the combination of two or more organic and inorganic compounds or organic or inorganic compounds with the transition temperature that can meet the specific demands.

So eutectic could be a combination of inorganic and organic or inorganic and inorganic or organic and organic. So these are the three classifications of phase change materials. We will look at each of it in detail. So, if we look at the organic phase change material, let us look at its advantages and disadvantages. The organic phase change material is available in a large temperature range.

It can withhold large temperature range. Organic phase change materials are chemically inert. They do not cause issues such as corrosion or any other issues. They do not undergo phase segregation. They are thermally stable for repeated freeze and melt cycles which means these can undergo phase change several times say from solid to liquid and liquid to solid back and yet they are thermally stable.

have low vapour pressure in the melt form. When they are melted, when they store heat, they have low vapour pressure. They have relatively small melting heat. Then they are non-corrosive or mildly corrosive when they have fatty acids, but they can undergo the process of freezing and melting several times without causing any issues. They are compatible with construction materials.

They have small volume change when they transit the phase. So when they become from solid to liquid and liquid to solid, their volume does not change drastically but it is very mild. They have little or no super cooling effect during freezing. Then they are innocuous. which means they are non-toxic, non-irritant and the non-paraffin type may have various levels of toxicity.

But anyways, we are not going to eat the phase change materials, but they are not, usually they are not corrosive, irritants and toxic. They are stable below 500 degree centigrade. The non paraffin type shows instability at larger or very high temperatures but otherwise they are stable below 500 degree centigrade. And they are recyclable, making them a sustainable material. They also come with certain disadvantages and that is they have low thermal conductivity around 0.

2 watts per meter Kelvin. They are moderately flammable. One needs to be careful when you handle them and they are non-compatible with plastic containers. So, they should not be used with in combination with plastics. Let us now look at the inorganic phase change materials, their advantages and disadvantages. So, the inorganic phase change materials have high volumetric storage heat.

They have high melting point. They can store a lot of energy before they change their state. They have high thermal conductivity. They are more sensitive. It is about 0.

5 watts per meter Kelvin. And most important they are cheap and readily available. Inorganic phase change materials are non-flammable, inflammable. They are compatible with plastic containers. This was a disadvantage with organic PCNs.

They have a sharp phase change. They have low environmental impact and they are potentially recyclable making them a sustainable or a environmentally positive material. Let us look at their disadvantages of inorganic phase change materials. So, inorganic phase change materials are super cooling during freezing, the phase segregation during transitions, they are corrosive to metals, whereas organic was corrosive to plastics or it could not hold in plastics. It is an irritant unlike organic. They have high vapor pressure inducing water loss and progressive changes in thermal behavior during thermal cycles.

They have low durability that is possible long term degradation when exposed to environmental agents. They are moderate chemically stable and they undergo high volume change. So, organic phase change materials have certain disadvantages which are actually advantages when we use organic phase change materials. Let us look at eutectic phase change materials. Now, these based on the combination of organic, inorganic or organic organic or inorganic inorganic can make the best case scenario the advantages of both and also eliminate the disadvantages of both.

Their advantages are they have sharp melting temperature and they have high volumetric thermal storage capability that is slightly lower than organic phase change materials. if we look at their disadvantage, there is very limited data available on their thermophysical properties because of the numerous combinations we can have on phase change materials which are eutectic in type. So, in today's class, we saw what are phase change materials, and what do they actually do? So, a phase change materials when it gets heated it absorbs the heat and changes itself from solid to liquid form at the same temperature holding the heat When this material gives away the heat, when the heat gets dissipated the material changes from liquid to solid again. This change of phase can happen multiple times and it is reversible. We also saw that there are three types of phase change materials organic, inorganic and eutectic which is nothing but a combination of organic and inorganic.

So, with this learning we will stop our class today and continue our next class with phase change material. So, our next class will be a continuation of the same topic. Thank you.