Course Name: Building Materials as a Cornerstone to Sustainability

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Lecture 02

Phase Change Materials- Part 2

Hello everybody. So, last class we saw what are phase change materials. As a recap phase change materials are materials that have the capacity to change their phase, meaning they become solid to liquid and liquid to solid depending upon energy absorption or energy release. So, when a phase-change material absorbs heat, it transits itself from solid to liquid. It holds the heat in a liquid phase, and when it holds the heat and when the heat gets dissipated, it changes itself from liquid to solid. And this process keeps continuing again and again through and through.

And we also saw that there are three types of phase change materials. One is organic. We saw its advantages and disadvantages. The second one is inorganic.

We also saw its advantages and disadvantages. The third one is the eutectic, which is a combination of organic and inorganic. So, this is what we saw in the last class. Today, we will look at the characteristics of PCM. Not all existing phase change materials can be used for thermal storage in building applications.

In order to be suitable for this use, at least two important requirements must be fulfilled. And what are these requirements? So, in order to be applicable in the building industry, the phase change material must have melting temperature and it should also have appropriate melting heat. Appropriate melting temperature is the temperature when the phase change actually occurs. Melting heat is a measure of the thermal energy that a material absorbs when it changes its state from solid to liquid. The thermal storage capacity of a phase change material is strictly correlated to its melting heat.

I will repeat melting heat is a measure of the thermal energy that a material absorbs when it changes its state from solid to liquid. Okay, I will even write it melting heat, which is an important criteria for a phase change material to be used in architecture and building construction. So, melting heat is a measure; it is a measure of the thermal energy that a material absorbs when it changes its state from solid to liquid. So, in order for any phase change material to be used in architecture, the material must have these two important characteristics. Generally, an ideal phase change material to be used for storage of thermal energy should, number one, undergo small volume changes.

So, it cannot expand itself too much; otherwise, it will be unsuitable for building use. Within that particular space it should be able to expand and contract and accommodate itself within that space. It should be non-toxic. After all, it is a place where humans live. So, it should be non-toxic.

It should be non-corrosive. It should be non-corrosive because it is embedded inside a material. If it is corrosive, then we would not have a proper material to hold it and also handling the PCM will become very difficult. It should have high thermal conductivity and specific heat capacity, so it should be worth the effort that is made to use the material in terms of holding the heat. It must not super cool and it must not decompose.

So, we should be able to recycle it again and again, and it should not decompose. and also the thermal storage capacity of a phase change material is strictly correlated with melting heat, and that is an important characteristic and a criteria. Now, let us look at the types of phase change material in detail. So, organic compounds like paraffin and paraffin mixtures, which are waxes, whose melting temperature depends on the particular paraffin used and any added constituents. They can be made in large quantities and can be used over a relatively large temperature range, approximately minus 12 degrees Celsius to plus 180 degrees Celsius.

They have a wide range of applications and are insensitive to mechanical vibrations. They must be maintenance free. should have long replacement lives, but they are highly combustible. The volume change at phase change is relatively expensive compared to salt-hydrate-based phase change materials. So paraffin and paraffin waxes have their own characteristics, their own advantages and disadvantages.

They are insensitive to mechanical vibrations, but they are maintenance-free. Their replacement life is long, which means we can use the material for a longer period of time They are highly combustible, so you have to be very careful when you handle this material. Their volume changes at phase change, and they are relatively inexpensive and cheaper compared with salt hydrate, PCMs, or inorganic compound phase change materials. So, we are looking at types of PCMs and their characteristics. Let us look at the characteristics of inorganic compounds.

Inorganic compounds are in the form of salt hydrates. Salt hydrate or salt hydrate mixtures, like eutectic mixtures or water and water mixtures, whose melting temperature depends on the particular salt hydrate used and any added constituents. They are non-combustible and can be used over a relatively large temperature range, say approximately minus 70 degrees Celsius to plus 120 degrees Celsius. They are relatively inexpensive as compared to the organic or paraffin-based phase change materials. The organic inorganic compounds, which are paraffin salt hydrate mixtures and water mixtures, will depend on what is the paraffin used and what is the salt hydrate used.

Now, the following phase change materials are most commonly used. Materials and components for the manufacture of phase change materials must be able to function over a comparatively high number of charging and discharging cycles and, depending on the application, undergo relatively little change in volume. For example, if we take paraffins and paraffin mixtures, the melting temperature depends on the particular paraffin used and any added constituents. Market presence can be made in large quantities. So, these paraffin and paraffin mixtures are available easily They can be used in large quantities and have many years of practical use.

So, no, what shall we say, longevity, as they can be used for many cycles, many years. They can be used over a temperature range of minus 12 degrees Celsius to 180 degrees Celsius, which is quite wide. They have a wider range of applications. So, they have a wider range of applications. They are insensitive to mechanical vibrations.

They are maintenance-free. They have long replacement life. Then they have the disadvantage of being highly combustible. You have to be very careful when you handle this material. They have a volume change.

There is a volume change during phase change. They are relatively inexpensive. compared to water-based phase change material and still expensive compared to salt-hydrate mixture. So, these are the advantages, limitations, and characteristics of paraffins and paraffin mixtures. Let us look at the salt hydrate and salt hydrate mixtures.

So, salt-hydrate mixture. The melting temperature depends on the particular salt hydrate used and any added constituents. So, depending on the type of salt, only the melting temperature, but then the advantages, we will be able to identify the one that has the best melting temperature needed for that condition. They are non-combustible unlike paraffin. So, these are non-combustible. They can be used over a relatively large temperature range, minus 70 degrees Celsius to plus 120 degrees Celsius, including negative melting, which is like a salt water eutectic.

They are relatively inexpensive compared to organic, compared to the paraffin and the paraffin-based PCMs. Otherwise, they could become expensive. They have a tendency to be super cool when used for cold storage. So, the tendency to segregate volume change at phase change and they also have a tendency to promote corrosion which is an important criteria for us to consider. Then let us look at the water and water mixture type of PCM.

So, the melting point of water is 0 degrees centigrade. So, the melting point of water, as we all know, is 0 degrees Celsius. Now, leaks are not hazardous to groundwater. So, they are non-toxic during leakage, if any. They can be used over a relatively large temperature change.

They can be used between minus 40 degree centigrade to plus 100 degree centigrade. Of course, they are not; the salt hydrates have; they can be used for even a wider range, minus 70 to 120, but this is minus 40 degrees Celsius to plus 100 degrees Celsius. There is no tendency to segregate. So, this is nothing like anything getting segregated within the mixture.

They are relatively inexpensive. They are cheaper compared to paraffin and salt-hydrate-based phase change materials. They have relatively poor thermal conductivity. So, their thermal conductivity is a compromising characteristic. That is with respect to paraffin and salt hydrate based PCMs. they do undergo a volume change at phase change.

At the time of phase change they do undergo a volume change. Next let us look at the silicate. Silicates they are used in the form of powder as a carrier element. So, silicates are used as a powder as a carrier medium for embedding various phase change materials. Proportion of composite material is approximately 40 percent.

In powder form, one of its suitable uses is for filling containers and they undergo relatively little volume change at phase change. Let us look at the PCM products. Phase change materials, PCMs have a wide range of uses. For example, in clothing textiles, in motor vehicles as external panels and partitions and in refrigerations and heating system. In recent years, a relatively large number of products of PCM has been used in architecture and these are developed and brought to the market.

They are mainly used for passive climatization, for example wall and ceiling components. Some more ambitious applications are now being tried following a phase of observation and testing in smaller projects. The products are now available that can be used in existing and new buildings. Their solid walls enable many old buildings to buffer temperature peaks so that, for example, their rooms stay comfortably cool for longer period of time in summer months. But new buildings usually lack these thermal storage masses.

Compact external walls with highly heat insulative and heat storing components can be constructed by the intelligent incorporation of latent heat storing products based on phase change materials, such as appropriately designed gypsum plaster board, plaster or even complex facade systems. Existing buildings can be improved by increasing the storage mass by retrofitting waste change containing products. Today we will see microencapsulated waste change material. Now it has market presence, so it is available.

These can be made in large quantities. They can be incorporated into different construction materials. They are available as various end products such as phase change material, plaster resistant to mechanical damage like cutting. What is a mechanical damage? Something like cutting. Otherwise, as for paraffins and paraffin mixtures which do not support this. They are not universally available but only approved end products can be used.

They cannot be used alone because of inadequate fire resistance or fire safety. Otherwise, as for paraffin and paraffin mixtures, they can be used. Let us look at plasters with phase change materials. Now include microencapsulated paraffin based phase change materials for passive climatization of internal walls and ceiling. These can be handled and applied as conventional plaster.

They do have a market presence and they can be made in large quantities. They can be colored by the application of paint or the addition of pigments. They are easy to apply. Otherwise, as for paraffin mixtures, they are not universally available. They are relatively expensive compared with conventional plasters because they are not easily available.

Let us look at gypsum plaster board with phase change materials. Now, these are currently available as 2000 mm, 2 meters by 1.25 meter by 15 mm board. They can be handled and fixed as conventional plaster board or fiber cement boards.

They have PCMs embedded in it. The thermal conductivity is comparable with that of conventional plasterboard. They are relatively expensive compared with conventional plasterboard. Then the fourth is aluminium foil bags with phase change materials. Now, aluminum foil bags with salt hydrates or salt hydrate mixtures for passive climatization of say ceilings. For example, ceilings will improve thermal conductivity if placed adjacent to components with good conductivity that is made from metal.

And this can be an example to be applied to suspended ceilings. Let us look at light directing insulation glazing systems with microencapsulated phase change materials. These can be made in large quantities and can be incorporated alongside conventional glazing allowing the detailing to be simple. They are relatively easy to install, and they can indicate charge state. Otherwise, as for salt hydrate and salt hydrate mixture, they can be used.

Higher replacement costs of defective panes and phase-change containers make it expensive. They are relatively heavy, which has a consequence on the installation cost and also handling the material. The high manufacturing and installation cost compared with conventional insulation glazing makes it a deterrent to use it. So, the insulation glazing system comprises four panes positioned one behind the other with external integrated light-directing prismatic plastic panels and internal integrated transparent plastic containers filled with salt hydrate. This system provides passive climatization of the facade and can be used in almost the same way as conventional insulation glazing systems.

Now, let us look at case studies where PCM has been applied. So, Swiss architect Dietrich Schwarz has shown in several of his buildings how, in addition to their latent heat-storing properties, the ability of PCMs to change their optical appearance can also be used in a facade. The initial solution involves pure paraffin in transparent hollow plastic blocks used as latent heat storage facade elements in the south facade of a zero-energy house in Switzerland. In contrast, for this project, a salt hydrate was used as a PCM.

for fire safety reasons. The architect has placed a brand new 148-square-meter latent heat-storing insulating glazing system on the south side of the complex. This is filled with the salthydrate. A 78-mm-wide glass crystal system is built similarly to a standard triple-insulated glazing unit. But it has a PCM panel inside and a light directing prism panel outside. The PCM panel is made of polycarbonate containers that are filled with a salt hydrate mixture which retains heat at 26 degree centigrade to 28 degree centigrade.

During the winter, the lower sun angle allows the solar radiation to pass almost unimpeded into the facade construction where it hits the PCM panel. It gets converted into thermal radiation and stored in the melting of the salt hydrate. If the room temperature falls below 26 degrees Celsius, perhaps at night or on cloudy days, the salt hydrate crystallizes and releases its stored heat energy into the room. If the facade looks opaque as seen from outside through the prismatic panels or from the inside, then the salthydrate is uncharged. If it appears translucent seen from the outside through the prismatic panels or transparent from the inside with no printed pattern, the salt hydrate is being charged or fully charged.

So, with this, we have covered the entire phase change materials. We have seen the different types of phase change materials, what makes them useful in architecture, what are the qualities, what are the characteristics, their advantages, disadvantages, applications, and uses. With this I will stop today's class and we will meet again with yet another smart material.