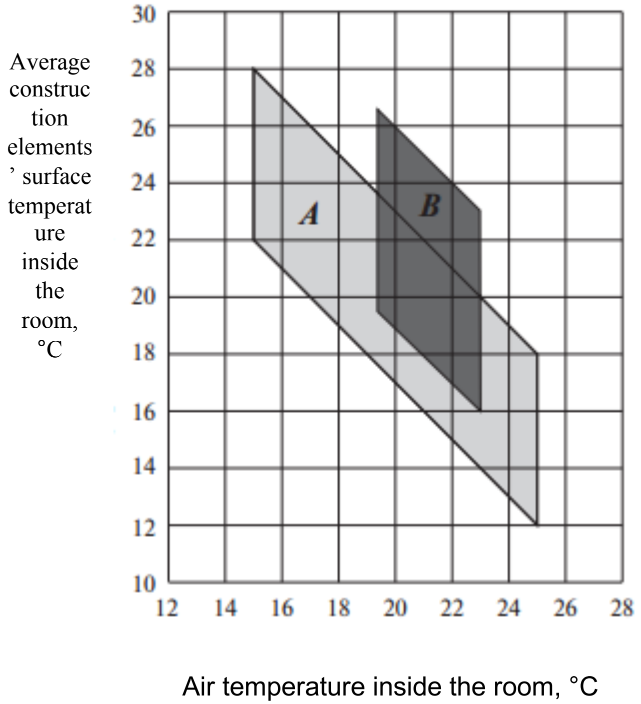
Lifecycle analysis of finishing products enhanced with phase changing materials

Petr Zhuk
Moscow Institute of Architecture (State Academy)

Main goals of summer heat insulation

- primary energy savings
- greenhouse gas emissions reduction
- Provision of thermal comfort in rooms
- avoidance of pathogens accumulation in air conditioning systems’ philters
- reduction of air conditioning system installation and energy utilization costs

Room comfort indicators



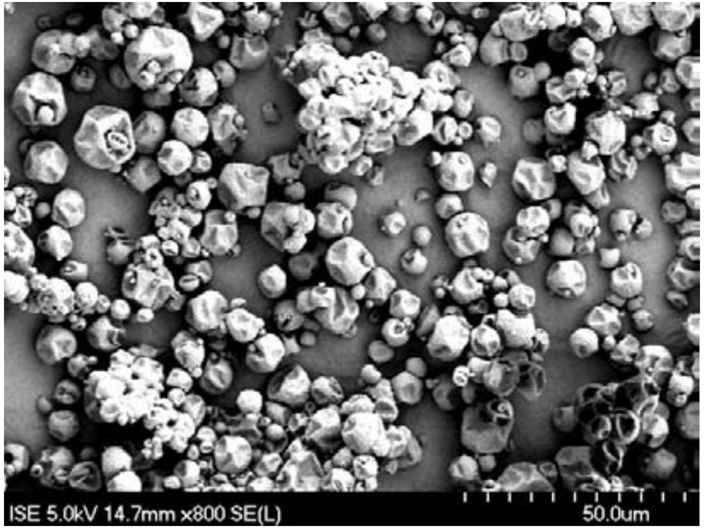
- Air temperature
- Inside temperature of closing surfaces
- Air circulation
- Relative humidity

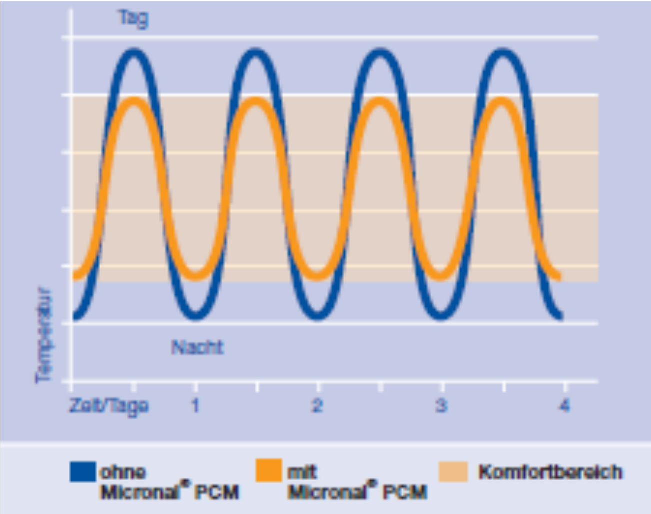
Within a certain range it is possible to align room air temperature through adjustment of average temperature in construction elements’ inner surfaces so that it would not cause sense of discomfort from a thermal point of view

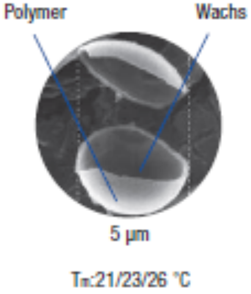
Comfort areas within the room depending on air and surface temperature:
A – comfort area for rooms with low humidity; B – comfort area for damp rooms

W.-H. Pohl Belueftete Daecher mit Metalldeckung, 1991

PCM in gypsum materials' structure







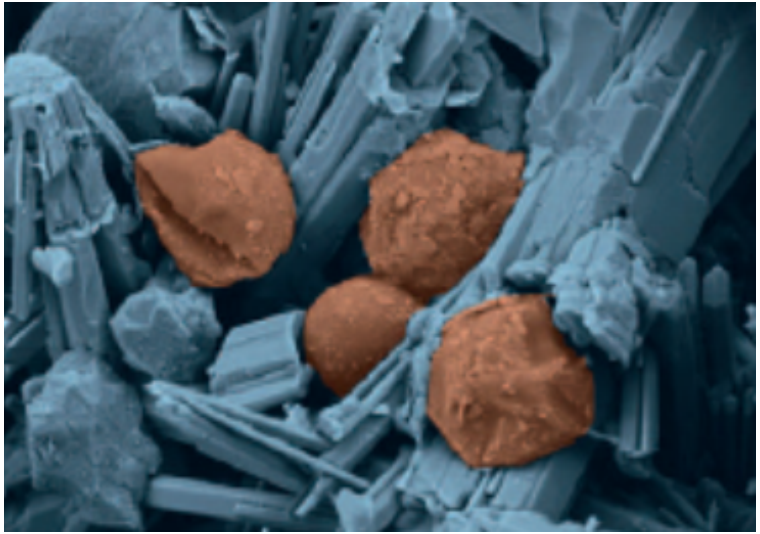


Photo: Marco F. Schmidt Temperaturmanagement – in seiner leichtesten Form Micronal PCM der BASF

Incorporation of PCM in gypsum materials' structure

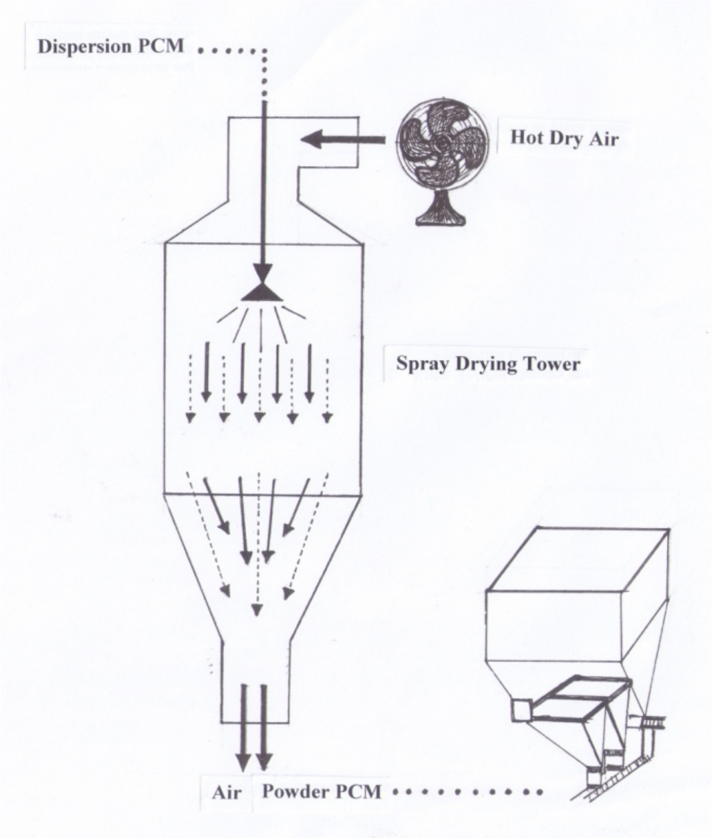
Microcapsules are dispersed in water. Dispersion is injected along with gauged water

Powder is being made through drying during air-spraying process

Photo: Marco F. Schmidt Temperaturmanagement – in seiner leichtesten Form Micronal PCM der BASF

Production of finishing materials with PCM

Incorporation of microcapsules was performed in two ways: (1) through microcapsules' dispersion in tempering water as well as (2) in form of powdered substance, which is mixed with binding agent in form of dry plaster mortar. The amount of granule particles incorporated was similar for both materials. This amount was 3 kg per square meter of finishing's surface.



Production scheme for plaster with PCM in form of powder

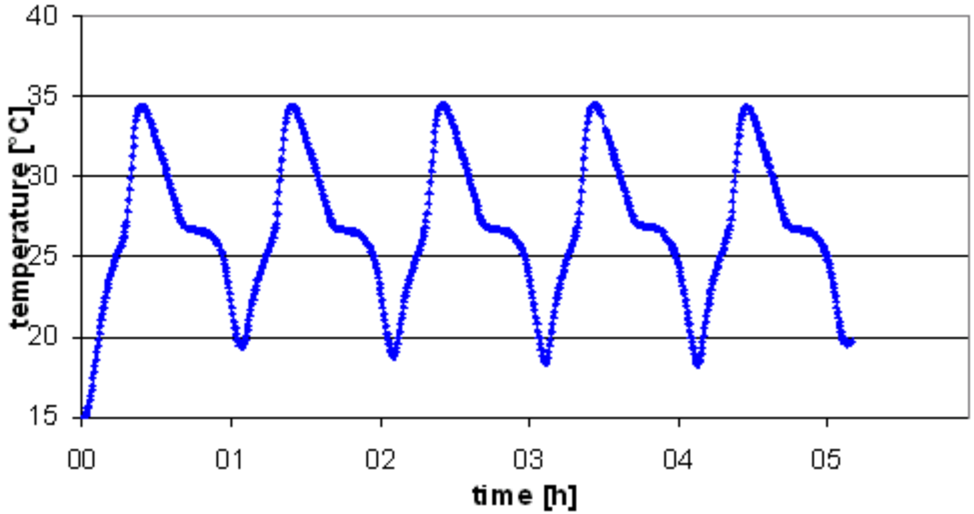
Longevity tests of finishing materials with PCM

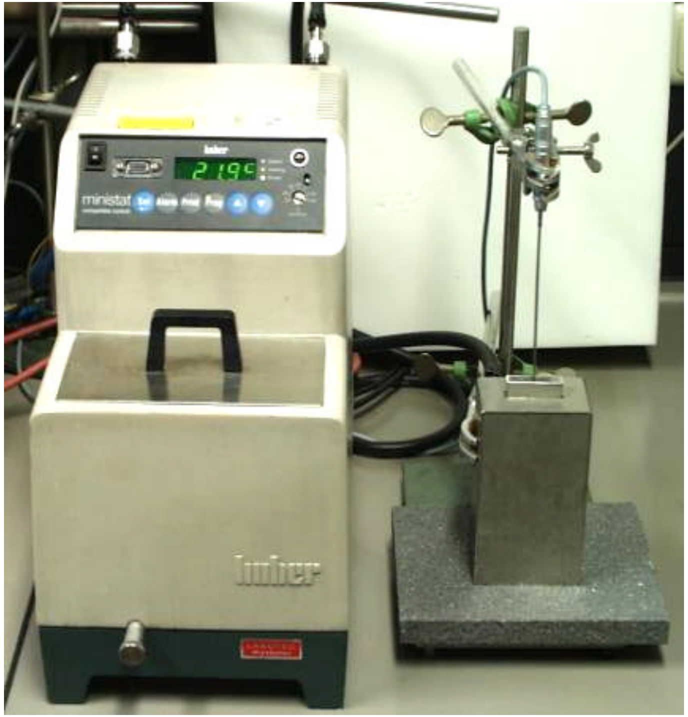
One of the most important lifecycle aspects in current research is Phase Changing Materials (PCM) operating longevity as components of finishing materials. To assess the longevity, methods harmonized with the Quality Assurance RAL-GZ 896
were used
During the test it is necessary to exercise control over PCM's functional criteria such as the range of phase-changing temperature and the amount of saved thermal energy.

Name of material with PCM components	Result of test for PCM incorporation as a powder, number of cycles	Result of test for PCM incorporation as a dispersion, number of cycles
Gypsum-based plaster		
Sample 1	12.450	9.500
Sample 2	14.250	7.450
Sample 3	15.150	5.450
Sample 4	20.050	5.500
Sample 5	18.450	8.150
Gypsum board fragment		
Sample 1	22.450	10.650
Sample 2	27.550	12.450
Sample 3	25.350	11.350
Sample 4	23.150	10.600
Sample 5	21.000	11.450


RAL GÜTEZEICHEN
RAL QUALITY MARK
Phase Change Materials
(Phasenwechselmaterial)
Gütesicherung
Quality Assurance
RAL-GZ 896
Ausgabe März 2018
Edition March 2018
RAL
DEUTSCHES INSTITUT FÜR GÜTESICHERUNG UND KENNZEICHNUNG E.V.

Longevity tests of finishing materials with PCM

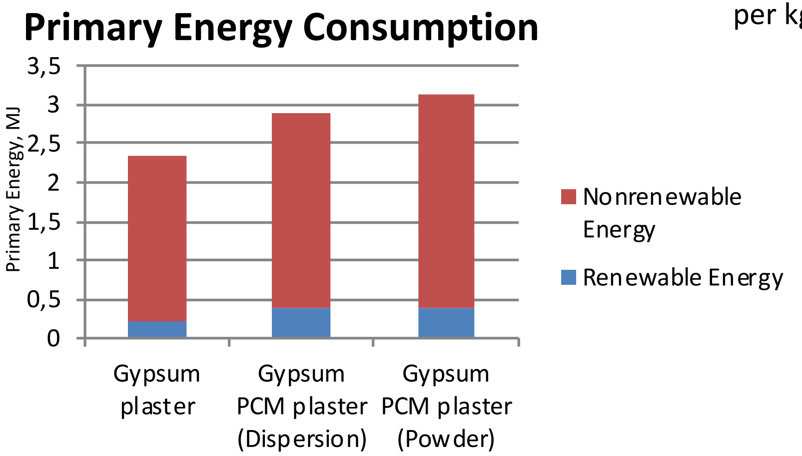


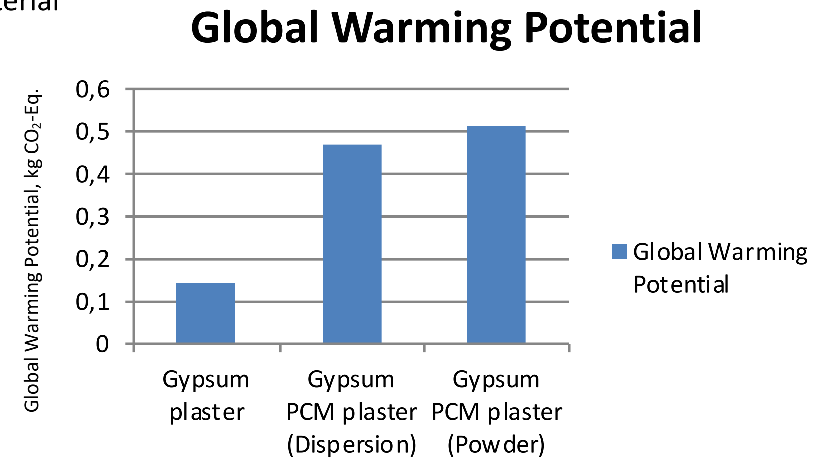


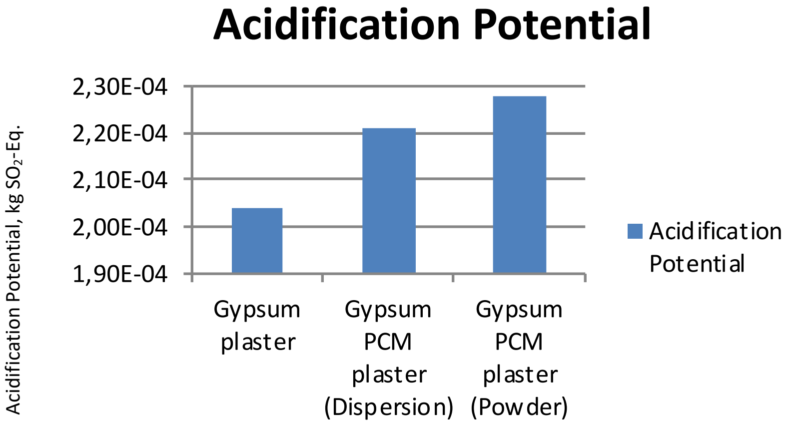
Specification of studies resides in testing of materials, not only PCM components. Thus being said, gypsum-fiber sheet with injection of powder showed the best results

Comparison of three types of plaster based on three environmental indicators

All figures represent the production stage only and are expressed per kg of material







Considering the need for production of PCM themselves and their considerable amount in coating a moderate increase of environmental impact on PE, GWP, AP indicators can be seen This increase can be considered insignificant

Comparison of primary energy consumption per life cycle stage for gypsum plasterboard with and without PCM

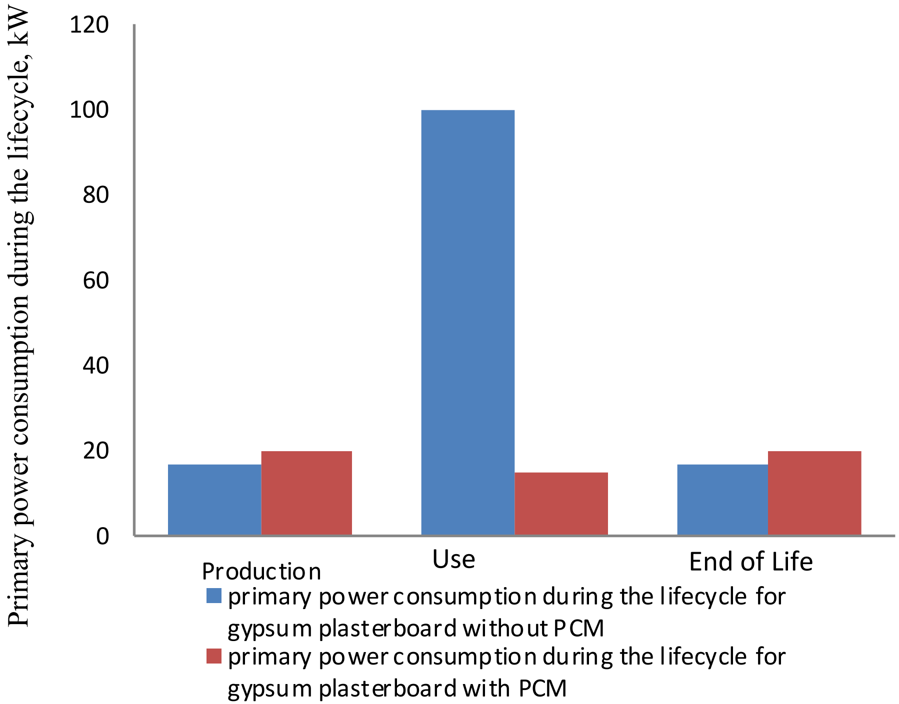


Figure shows the scale of energy consumption that occurs during the lifecycle stages of the plaster, i.e. production, operation and end of life. In addition, it was taken into account that during the operation stage climate control equipment in rooms with the use of PCM can be waived. The figure is a qualitative display of comparative power consumption scales during materials' lifecycles and can be interpreted in such a way that slight increase of expenditures during materials' production and recycling stages a significant effect at the operation stage can be achieved

Examples of buildings with the use of PCM latent heat insulation

Solar-Decathlon Haus

Goal: constant inside air temperature around 23 Celcius. Building is powered by solar energy

School in Diekirch. Luxembourg

Goal: achieving thermal comfort in a building of light container type without active cooling

Discussion

- Indicator results of environmental impact during the full lifecycle of finishing materials with the use of PCM are generally comparable to indicator results of similar materials without these components. This proves the insignificant environmental impact of PCM production and operation.
- Increase of environmental impact can be observed during raw materials preparation (PCM granule production), production of finishing materials with the use of PC components and at the stage of recycling at the end of their operating life. Separation of mineral constituent and granule with organic components provides for higher level of finishing material components recycling.
- Considerable environmental impacts can be achieved at all times during the useful life of a building due to significant saving on climate control equipment, because PCM longevity allows calculating for such a long period.

Conclusion

- one of the most important parameters of finishing materials utilizing PCM is their cycling stability, which, depending on the way of granule incorporation, amounts for decades under given design operation condition and provides for working life of phase changing component comparable to working life of finishing coating as a whole;
- preparation of raw materials (including production of the phase-changing component itself and granule with it), as well as gypsum board and plaster mortars with PCM granule, are associated with a slightly larger environmental impact compared to regular finishing materials;
- at the operation stage due to creation of comfortable conditions in a room without the use of air conditioners and other climate control equipment energy consumption effect is achieved as well as reduction of greenhouse gas emission, expressed as GWP and acidification;
- recycling of finishing materials with PCM requires a higher energy consumption compared to similar regular finishing materials, but this effect is insignificant and does not have a crucial impact on general positive evaluation of finishing materials with PCM lifecycle;
- calculating amount of PCM granule being incorporated in finishing material structure as well as special aspects of their distribution along layers from surface to depths of coating play an important role which allow achieving the most effective heat-insulation during summer.