Abstract: The aim of development was to combine the advantages of the well known and efficient system of pre-mixed machine plaster with a new function to tone down the room temperature in summer. The joint research project with the Fraunhofer Institute for Solar Power Systems in Freiburg started in 1999. The team of Laboratory for R&D at maxit in Merdingen, Germany developed and improved the properties continuously. In 2004 the multi functional plaster clima has been ready for marketing.

1. INTRODUCTION

Protection from the cold in winter by good insulation of construction is essential and prevents heat losses. Less energy is needed for heating. In summer insulation also reduces the heat, which penetrate through the walls but most of the heat enters the building through the windows in the form of solar radiation. Good insulation actually prevents the interior of rooms from cooling down at night.

What are the factors and interactions on which the interior temperature depends?

- Surface area of windows
- Shading arrangement
- Direction of building faces
- Current weather conditions
- Insulation and internal energy sources
- And the Weight of the building

The building mass is a major factor in determining the temperature. A heavy building is able to smooth out temperature peaks. For example, there is palpable difference between
temperatures in heavy building like cathedrals and mobile homes. In churches its cool all year round, in mobile homes e.g. on construction site you are living in barrack climate.

2. THE PHYSICAL EFFECT

2.1 Heat storage: Two types

2.1.1 Change in temperature
The heat energy in liquid hot water is stored as a palpable increase of temperature.

2.1.2 Change in state
By contrast, storage of latent heat takes place only when the water changes state. Water is a good example for the amount of energy which can be stored when substances change state. The energy required to melt 1 kg of ice at 0°C to form of water is about 333 kJ/kg. The same amount of heat energy can be used to heat 1 kg liquid water from 0°C to 80°C (change of temperature).

2.2 Mass or PCM?
The only way to maintain a comfortable temperature inside a building in summer without installing active air conditioning is to increase thermal mass. You can do it in traditionally manner with heavy building materials, or by introducing latent heat storage in construction.

![Figure 1: Comparison between some construction materials which provide the same heat accumulation](image)

The intelligent application is based technically on waxes with an appropriate melting point, enclosed in microscopically small polymer capsules, which are incorporated into machine plaster. As a phase-change material (PCM), the capsulated wax buffers the interior temperature just when the room is starting to overheat. The wax has a melting point of 26°C and it begins to absorb excess heat from the room at this temperature, preventing it from heating up any further.
The ability of the paraffin to store heat over a period of several hot summer days depends on the amount present. When storage capacity reaches saturation no more heat can be extracted from the room. The latent heat contained in the liquid wax has to be released at some stage. A room with phase-change materials is therefore ventilated at night when temperature is lower in order to disperse the stored energy. In this respect, there is no difference between a building containing PCMs and one with massive conventional construction materials.
3. PCM MICROCAPSULES

How can we take that wax in modern and established machine fit dry mixed mortars and other construction materials? Material science and chemical engineering was in demand. The core of solution was created by BASF.

The process of micro encapsulation is the safely way to incorporate phase change materials in several types of building products. Microscopic wax droplets with a diameter of 5 to 20 microns are enclosed in a very strong plastic coat. These tiny capsules are completely impervious and safe to process. They are far too small to be damaged by sanding, drilling or cutting.

Figure 4: Microcapsules latent heat stores at work  Figure 5: Polymer coating

The durability of PCM microcapsules must be guaranteed. The material was put through its paces in long-term cycle tests. After 10,000 cycles it showed no change at all. The microcapsules were undamaged and the PCM had the same latent heat of fusion as at the beginning of the test. Assuming 300 phase changes per year, 10,000 cycles correspond to a minimum life expectancy of more than 30 years.

Figure 6: Certification mark of quality (voluntary agreement of durability and tech. features by leading manufacturers)
The encapsulation also protects the integrity of the pure wax, ensuring that it retains its maximum heat storage of 110 J/g.

4. APPLICATION IN PRACTICE

4.1 Gypsum machine plaster as heat accumulator

4.1.1 The idea
The aim of development was to combine the advantages of the well known and efficient system of pre-mixed machine plaster with a new function to tone down the room temperature in summer.
To offer an interior machine plaster for one layer indoor applications with a temperature regulation effect sounds attractive to planer, architect, qualified skilled worker and dry mixed mortar industry.
The joint research project with the Fraunhofer Institute for Solar Power Systems in Freiburg started in 1999. The team of Laboratory for R&D at maxit in Merdingen, Germany developed and improved the properties continuously. In 2004 the product has been ready for marketing.

4.1.2 The product
The functional plaster consists of gypsum, mineral aggregates, admixtures for improvement of application properties and a powder of micro capsulated latent heat store named “Micronal® PCM” produced by the BASF.
Hundreds of recipes were tested. The hardening curve, strength and heat capacity of each mixture were measured. Dozens of application tests were driven for the successful formulation.

4.1.3 The reproducible effect
The comparison PCM plaster maxit clima with a common gypsum plaster is significant. Probe was made in identical test rooms except of plastering with or without PCM.

Fig. 7: only 30 h instead of 160 h temperature above 26° C (cumulated 27° C and 28 °C)
Figure 8: Comparison of the two systems: common gypsum plaster and PCM plaster
The temperature on wall in PCM room was reduced in maximum at 4 K [1]

Figure 9: exterior photo of the two almost identical test rooms on roof of ISE Freiburg
5. PLANNING, APPLICATION AND LIMITS

Incorporated PCM in construction material is limited. To support optimum function, the inflow of solar energy has to be restricted. The effect of clima plaster is supported with:

- Shading arrangements
- Low-E-glasses for windows
- Night ventilation refreshing rate higher than 1 per hour
- Large area of coated and activated wall and ceiling
- Thin top surface coatings in order to get a good heat transmission

5.1 Computer aided planning

5.1.1 PCM for more comfort

The energy software “PCM express” is been testing in recent summer. It will be able to calculate and simulate the impact on room temperature by PCM construction materials. Also a calculation of amortisation is possible, directly compared with costs of air condition. The planers can play with versatile possibilities e.g. shade varieties, construction design, number and type of windows, relocation etc. We will get a tool to decide, which rooms should provided effectively with PCM. The BETA Version is planned to be released in autumn 2007.
5.1.2 PCM for cost reducing

Example:
A detached house with an area of approx. 120 m² PCM containing ceiling areas with 3 kg PCM per m². The 360 kg PCM corresponds to 360 kg x 110 KJ / kg about 40,000 kJ. This 40,000 kJ corresponds to more or less than 11 kWh.

Figure 11: The PCM will have paid for itself in 5 years

11 kWh are equivalent to the cooling performance of an air-conditioning unit with an input power rating of 4 kW used at full capacity for 1 hour a day (Energy efficiency ratio is 2.75). Predicted working process: PCM works for five hours a day 10 weeks of significant hot weather periods a year. That would have the same effect as using air conditioning unit for 300 hours. The present costs are 300h x 0.76 EUR = 228 EUR.
Assuming an energy price rise of 5.00 % per annum, the PCM will have paid for itself within 5 years.

6. EXAMPLES OF SUCCESSFUL APPLICATIONS

6.1 First commercial object with passive cooling concept
Office building in Offenburg, Germany
- About 5000 m² usable space
- Improved insulation
- Pure night ventilation for cool down
- No air conditioning
Figure 12: Stahl und Weiß, Büro für Sonnenenergie, Freiburg, Germany
Lehmann Architekten, Offenburg, Germany

Figure 13: Low-tech building with good thermal comfort at low energy demand

Only 22 hours per year out of comfort zone
6.2 PCM plaster, PCM plasterboard, PCM Aircrete

7. CONCLUSION

The PCM machine plaster is a pioneer for a new class of building products. It provides architects and planners with a tool that gives them more freedom in construction design and results in better energy efficiency and more comfort.

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a) Institut für Gebäude- und Solartechnik (IGS)
TU Braunschweig, Mühlenpfordtstraße, 23, D-38106 Braunschweig
kuehl@igs.bau.tu-bs.de, www.igs.bau.tu-bs.de
b) EGS-Plan Ingenieurgesellschaft mbH,
Heßbrühlstraße 15, D-70565 Stuttgart
thilo.duelger@egs-plan.de, www.egs-plan.de
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