THERMAL STORAGE FOR SUSTAINABLE DWELLINGS

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INTRODUCTION

In the UK residential buildings account for 27% of the final energy consumption (Department of Trade and Industry, 1999). It can therefore be argued that the use of solar energy in this sector has great potential for reducing energy consumption and CO_2 emissions. The main problem with utilising solar energy is that its availability is often intermittent, variable and unpredictable. These problems can be addressed by an active solar combisystem using phase change material for thermal storage. This paper focuses on the potential that such a system presents in reducing winter space heating demand.

THERMAL STORAGE

Thermal storage can either take the form of sensible heat storage (SHS) or latent heat storage (LHS). Latent heat storage is accomplished by changing a material's physical state whereas SHS is accomplished by increasing a material's temperature. To store the same amount of energy smaller quantities of material are required for LHS than for SHS. This can be illustrated by using a common building material such as concrete, which has a sensible heat capacity of approximately 1.0 kJ/kg (CIBSE, 1986b) whereas a phase change material (PCM) such as calcium chloride hexahydrate can store/release 193 kJ/kg of heat on phase transition (Lane, 1983). A further advantage of LHS is that heat storage and delivery occurs at a constant temperature, which makes it ideal for reducing temperature fluctuation in space heating applications.

PHASE CHANGE MATERIALS

An ideal PCM should fulfil a number of criteria such as high heat of fusion, high heat capacity, high thermal conductivity, small volume change at phase transition, be non corrosive, non toxic, non flammable and exhibit little or no decomposition or supercooling (Ghoneim et al., 1991). Organic and inorganic compounds are the two most common groups of PCMs. Inorganic compounds have a high latent heat per unit mass and volume, are low in cost in comparison to organic compounds and are non-flammable. However they can suffer from decomposition and supercooling which can affect their phase change properties. Most organic PCMs are non-corrosive, chemically stable, compatible with most building materials and have a high latent heat per unit weight. Based on the selection criteria established two PCMs namely calcium chloride hexahydrate and sodium sulphate decahydrate are being considered for use in the current research.

STORAGE SYSTEMS

Phase change materials need some form of containerisation in order for them to be used for thermal storage in buildings. This presents a challenge to the choice of PCM and the method of containerisation. A number of proposed systems encapsulate the PCMs in building materials such as plasterboard (Feustel, 1995) (Salyer and Sircar, 1997), building blocks and concrete (Chahroudi, 1978) (Salyer et al., 1995). Other systems rely on bulk storage, where large amounts of PCM are stored in tanks or cylinders, in these systems a secondary medium is required to 'transport' the heat. In 1998 Ip proposed a system for solar energy storage and space heating. It comprised of an array of solar collectors and lengths of double walled metal tubing in which the PCM (calcium chloride) was encapsulated between the pipe walls. Computer modelling showed that this system had the potential to reduce energy savings between 18–34% (Ip, 1998).

However the sustainability of the above systems can be questioned in that some of them store heat that is generated from electricity and the system components and the PCMs are not recyclable. Some other disadvantages of these systems are that they can take up a considerable amount of space and building layout can restrict their use. The proposed system in the current research attempts to address these issues which include: sustainability, service life, ability of the components to be recycled, ability to be installed in both new build and retrofit applications and the ability to maintain internal design temperature.

SYSTEM CONFIGURATION

The proposed system is a combisystem that will be able to contribute to both space heating and hot water demand. The system consists of evacuated tube collectors with heated water being stored in a highly insulated tank. A number of panels that are filled with PCM are interconnected as illustrated in Fig. 1. The panels are made from recycled plastic with small-bore recycled plastic pipework running through them. Once filled with PCM the panels will be sealed but provision is made to allow the PCM to be emptied from the panel. A series of PCM panels can be joined through pipe connections at either end. These panels can be installed either between or on top of floor joists or on a concrete slab. The panels are 1 – 1.5 m long to ease handling and 400 – 600 mm wide to facilitate fitment between floor joists. Water heated by the solar panel will be used to charge the panels and during the summer when space-heating demand is low, this water will only be used to meet hot water demands. Back up heating will be provided by a combination gas boiler or a wood stove. Electricity generated by photovoltaic cells (PVs) will be used to drive the circulation pump in the solar collector’s closed water circuit.

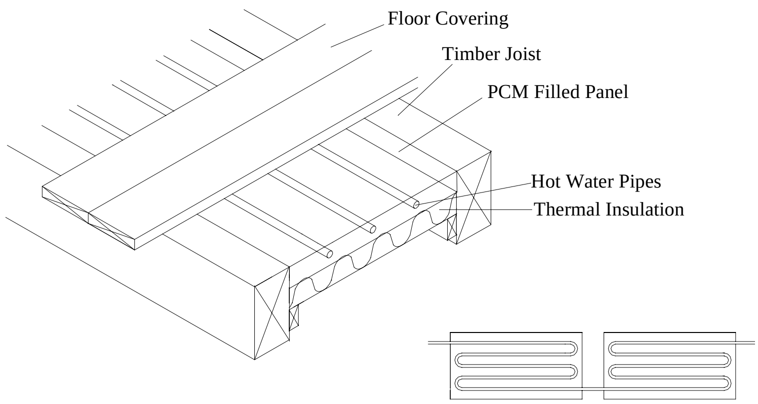

Fig. 1. Proposed System Diagram

ENERGY SAVING POTENTIAL

The energy saving potential of the system is dependent on solar availability and the efficiency of the thermal storage system. Solar availability in the SE England is amongst the highest in the UK. A south-facing surface inclined at 30° to the horizontal in SE England would receive an annual mean daily solar irradiation of approximately 9.8 MJ/m^2 (CIBSE, 1986a). An initial estimation of the solar energy captured, using a collector efficiency of 70% and system efficiency between 25% - 50%, shows the system has the potential to capture between 1.7 MJ/m^2 – 3.4 MJ/m^2 of solar energy.

Applying this in conjunction with previous work (Ip, 1998), for a two storey 3 bedroom house with a total floor area of 100 m^2 and a heating load of 1.6 MJ/ m^2, using a collector area of 6 m^2 , would produce energy savings in the range of 6% - 12.5%. This figure excludes additional energy savings attributed to the ability of the system to meet domestic hot water demand. It must also be noted that further reductions can be expected if the system is used in a low energy building incorporating passive solar architecture. The use of a PV powered water pump not only saves energy but also maintains the system efficiency, by automatically adjusting the water flow rate in response to the solar availability.

EXPERIMENTAL DESIGN

The next phase of the research involves setting up an experimental model of the proposed system to evaluate its thermal performance and compare it with the computer simulation predictions. This experimental work aims to establish relationships between the solar energy, phase change heat storage and heat contribution to space heating. It is anticipated that the results can be used for practical design purposes.

CONCLUSION

The use of an active solar combisystem incorporating PCM has tremendous potential for reducing the impact of residential buildings on the environment and can help in the long overdue move to dwellings that are more sustainable. A combisystem offers the possibility of providing all year round reductions in energy use and CO_2 emissions. The proposed system uses solar energy, which is renewable, and the components are either from recycled materials or designed to be recyclable. This paper has identified the potential of the proposed system to reduce space heating requirements and the need to establish design data for practical and wider applications.

REFERENCES

Chahroudi, D. (1978) In *Proceedings Of The International Solar Energy Congress*, Vol. 1 New Delhi, India.

CIBSE. (1986a) *Guide A2 Weather and Solar Data,* The Chartered Institution of Building Services Engineers, London.

CIBSE. (1986b) *Guide A3 Thermal properties of building structures,* The Chartered Institution of Building Services Engineers, London.

Department of Trade and Industry (1999) *Digest of United Kingdom Energy Statistics 1999,* The Stationary Office, London.

Feustel, H. E. (1995) In *Indoor environmental program energy and environment division Lawrence Berkely Laboratory University of California.*

Ghoneim, A. A., Klein, S. A. and Duffie, J. A. (1991) *Solar Energy,* 47, 237-242.

Ip, K. C. W. (1998) In *CIB World Congress* Gavle, Sweden, pp. 1265-1272.

Lane, G. A. (1983) *Solar heat storage: latent heat materials Volume II: technology,* CRC Press Inc, Florida.

Salyer, I. O. and Sircar, A. K. (1997) *Int Journal of Global Energy Issues,* 9, 183-198.

Salyer, I. O., Sircar, A. K. and Kumar, A. (1995) In *IECEC,* pp. 217-224.