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Internship Report

Combination of Phase Change Material with Concrete for Foundation Uses

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LWA	Light Weight Aggregate
PCM	Phase Change Material

ABSTRACT

Globally, energy demand has increased each year due to increasing economic activity. In four season's countries, a lot of energy is spent for heating purposes. The heating process for buildings is not always efficient because there are heat losses through the foundation, walls, and windows. This is most often the case in old houses. This study focuses on introducing phase change material (PCM) in renovated foundations of old houses.

The heating system from an old house will possibly have to be renewed while the house is being renovated. One of the methods is adding phase change material (PCM) in concrete, in this study, the PCM will be paraffin. Through literature study, it is found several ways to combine PCM with concrete, but the best way is using macro-encapsulation. Porous lightweight aggregate (LWA) is used as a medium to store PCM in its pores and prevent direct contact between PCM and the concrete mix. Direct contact between PCM and the concrete mix could significantly reduce the strength of concrete. To prevent leakages of PCM while it is melting, LWA that is filled with PCM is sealed with epoxy, graphite powder, and silica fume.

It is possible to improve the conductivity of concrete by adding a small amount of fiber in the concrete mix. Adding 0.5% of the fiber in the mix will not reduce the mechanical properties of the concrete. To improve the insulation level of concrete, rubber can be added as an extra layer in the bottom of concrete. The addition of rubber as an extra layer can improve the insulation level by 18.5%. The combination of rubber and fiber in concrete mix theoretically can reduce the amount of heat losses to the soil and increase the heat transfer through the concrete. A small house must be built to study the effect of a combination between PCM, fiber, and rubber in the real situation.

The amount of heat can be stored in the foundation depend on many variable. In this study to estimate how much energy can be stored in the foundation, several assumptions are used. The LWA has a porosity of 78%. The Paraffin-LWA used in this study has melting and freezing temperatures at 25°C and 28°C respectively. A typical foundation thickness in a house is 30 cm. The percentage of PCM in the concrete in this study is 26% and the heat capacity of PCM is 149 kJ/kg. If a room has a size of 4 m x 4 m, it will have a total foundation volume of 4.8 m^3 and 300MJ of heat can be stored during the phase change period (melting) of PCM. This amount of energy is capable of holding the room temperature stable at 20°C for 36.5 hours while the average outside temperature is 5°C and assuming that the losses only occur from the wall. Extra cost of €21,060 is needed to install this system.

Through the study above, it is found that combine PCM with concrete is possible and the best method is macro-encapsulate PCM. Additional study by created a prototype is necessary to prove if the calculation correct or not.

1. INTRODUCTION

1.1. Introduction

The demands in energy usage increase each year due to increasing activities in economic development. However, the availability of conventional energy in terms of fossil fuel is limited and becomes more expensive. It also produces emissions that are harmful to the environment. Therefore, for a better future, it is important to find sustainable and renewable energy sources to fulfill the needs of energy.

In four season's countries, the majority of energy is spent in heat terms to heat up the houses and buildings. Many old houses lose heat through the wall or foundation because of the bad heat insulation. Old houses also have a problem with their foundation because most of them still use wood as their foundation and after a dozen years, its performance will decrease significantly due to weathering. While the foundation of the old house is being renewed, it is possible to improve the insulation in the foundation and floor by adding some material that can store heat or reduce the heat conductivity of the concrete.

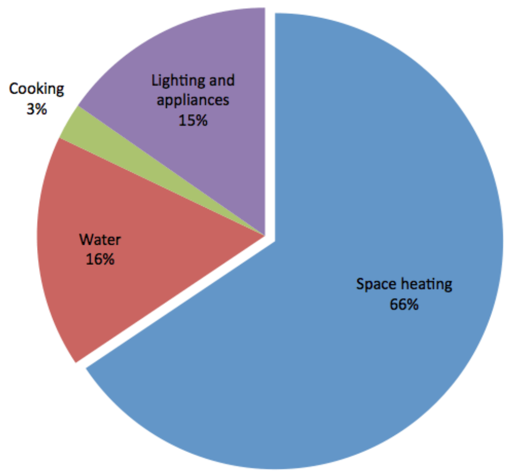

Figure 1.1 UK domestic energy consumption by end use, 2012 (Natural Scotland)

There are several ways to prevent the heat losses through the wall and/or foundation. First, to improve the insulation in the floor or foundation by putting some insulation materials between or inside the concrete. Second, putting some material that can store energy in terms of heat in the concrete. In order to store the energy in terms of heat, there are two methods that are available to be used, sensible and latent thermal energy storage. Sensible heat storage is a method of heat storage. When the heat has stored the temperature of the substance increases. Latent thermal energy storage is a way to store energy when substances change their phase from solid to liquid or from liquid to gas. In this condition, the temperature of the substance is relatively constant. The substance which is used for the latent heat storage is called phase change materials (PCMs).

1.2. Objective of the Project

While replacing the foundation of an old house, it is also possible to increase the energy efficiency of the house itself. Creating a good configuration between phase change materials or any other possible substances and the concrete for the foundation will increase the efficiency of the house energy level and reduces the use of gas to heat the house. Combined heat collectors and heat storage system will help to keep the temperature inside the houses more stable during the day.

The following research questions are determined.

1. What are possible options to combine PCM and concrete in a house foundation to decrease heat losses in the floor by storing heat?
2. How much energy can be stored in floor or foundation?
3. How much does the investment cost to build the system?

1.3. Framework of the Project

This project is done during an internship in Envita-Almelo. Envita-Almelo is a company that part of Ortageo Group. The detail about this company can be found in the Appendix section. This project will emphasize in literature study with some calculation based on data provided in the source.

2. SYSTEM ANALYSIS

2.1. Combination PCM in Concrete

Phase change materials are substances that can adsorb or release heat while the material changes the phase from solid to liquid or the other way around. Phase change materials have a certain range temperature of melting and solidifying. The temperature range differs per chemical component and structure in the material. Some materials also change their temperature a little bit during phase change. Phase change material can adsorb a lot of heat during the melting process and it is possible to release all of the heat that it adsorb during the melting process.

Phase change material can be combined in the concrete in three common ways. The first is direct incorporation and immersion, the second is form-stable composite PCM, and the third is encapsulation. The direct incorporation and immersion technique is the most economical and practicable way to mix the concrete with PCM. But the problem of this technique is the leakage issue of PCM after a large number of thermal cycling (being melted and frozen for hundreds of times). This issue will affect the mechanical and durability properties of the concrete and also interfere the hydration products. To prevent the leakage, the second method is used. PCM is confined to the porous media and utilized to produce thermal energy storage of concrete. But this method does not work well because it affects the mechanical properties of cement base composites. The form-stable composite PCM may interfere with the hydration product because it sticks to the surface. To improve the second method, some researchers introduce and build microencapsulation PCM.

Microencapsulation is a process that creates a small capsule fill with solid particles or liquid droplets. The process is coating the droplets or particles. This process creates a barrier between a core material and other components where it placed. There are two categories of microencapsulation (Konuklu, et al., 2015). The first is physical methods, which mainly include spray drying of centrifugal and fluidized bed processes. The second is chemical methods, which mainly include interfacial polymerization, in-situ polymerization, and other fabrication methods. The benefit of putting the PCM in the capsulated material is to prevent a leakage of the PCM from the surface, a change in the number of hydrates in the salt, and diffusion of low viscous liquids of melted hydrocarbons throughout the building material (Konuklu, et al., 2015). The combination between microencapsulated PCM and concrete improves the thermal performance significantly, but it also reduces the mechanical performance of the concrete significantly. The first reason why microencapsulated PCM reduces the compressive strength of the concrete are leakage of PCM and subsequent interferes with the surrounding matrix is because the microcapsule was damaged during mixing. The second reason is because the microcapsules and the concrete have a significant disparity in intrinsic strength.

Macro encapsulated PCM can solve the problem that appears when using microencapsulated PCM mix with concrete to store energy in terms of heat. Macro encapsulated PCM can be created by combining lightweight material (LWA) and PCM, for example, paraffin. PCM that used in (Memon, et al., 2015) is paraffin that has a latent heat storage capacity of 149.1 J/g. LWA that is used in (Memon, et al., 2015) has a density of 600 kg/m^3 and a porosity (MIP) of 77.75%. The composition of the LWA can be seen in Table 2.1.

Table 2.1 Physical properties and chemical composition of LWA (Memon, et al., 2015)

Density	600 kg/m^3
Porosity (MIP)	77.75%
Water absorbing capacity by simple immersion (1 h)	18%
Water absorbing capacity by vacuum immersion (1 h)	73.85%
Chemical composition	(%)
Silicon dioxide (SiO_2)	53.39
Aluminum oxide (Al_2O_3)	21.50
Iron oxide (Fe_2O_3)	15.84
Potassium oxide (K_2O)	2.56
Calcium oxide (CaO)	2.30
Magnesium oxide (MgO)	1.42
Titanium dioxide (TiO_2)	1.17
Manganese oxide (MnO)	0.80
Sulfate as SO_3	0.58
Sodium oxide (Na_2O)	0.43

The paraffin-LWA is created with the following steps. A beaker is placed inside a vacuum chamber for 60 min at 0.1 MPa. This beaker has been filled with a LWA and a melted PCM. This method is known as vacuum impregnation technique. The test results showed that the porous aggregates can absorb up to 68 wt% of PCM (Memon, et al., 2015). After PCM and LWA have been combined, the next process is putting the paraffin-LWA in the epoxy and graphite powder mixture and finally coat it with silica fume. Graphite powder is used to increase the thermal conductivity of Paraffin-LWA and silica fume is used to separate the Paraffin-LWA that has been coated. Memon, et al., 2015 shows that the melting and freezing temperature for Paraffin-LWA is 25.39°C and 28.17°C respectively. Paraffin-LWA has a latent heat of 102.5 J/g. Memon, et al., 2015 compared the compressive strength between a concrete made out of LWA and Paraffin-LWA. The composition of a control concrete (that contain LWA) and concrete that contain PCM-LWA is mentioned in Table 2.2.

Table 2.2 Composition of concrete (Memon, et al., 2015)

	Cement (kg/m^3)	Water (kg/m^3)	Sand (kg/m^3)	LWA (kg/m^3)	Paraffin-LWA (kg/m^3)
Control	400	140	507	316	
PCM-LWA	400	140	507		600

According to (Memon, et al., 2015), after 28 days of drying, compared to the concrete that only contains LWA, the compressive strength of Paraffin-LWA concrete is 13% higher reaching 17 MPa. The sample concrete is prepared for wall usage. There is no steel structure contained in the sample concrete. When the steel structure is installed in the top and bottom of concrete as it usually done for foundation purposes, the compressive strength of the Paraffin-LWA will increase and meet the requirement of minimum strengths of concrete for building.

2.2. Combination Concrete with Rubber and Fibers

Tire rubber and carpet fibers are wasted materials that can be easily found everywhere. All vehicles use rubber for their tires. Every day, many new tires are produced and many used tires are replaced. These used tire rubbers become a large problem (to reuse or recycle every few years). Each year, the amount of old rubber will increase along with the increase in cars being produced. Most of them are burned and this harms the environment. Only a small portion is burned for electricity production or used in asphalt concrete to reduce noise.

Rubber from tire can be used to improve the insulation in concrete without changing the concrete's strength because it does not mix in the concrete hot mix. In the experiment done in (Yesilata, et al., 2009), the tire rubber is scrapped into small pieces before it is put on the concrete. They did not mix the scrap tire rubber in the hot mix, but lined up in the top layer of the fresh concrete. The density of tire rubber is 0.84 g/cm^3. In the experiment, 80 ± 1.5 cm^3 of square shape rubber is put on the fresh concrete before it starts to harden. An added rubber tire layer in the top of the concrete surface leads to increase of the insulation performance by 18.52%.

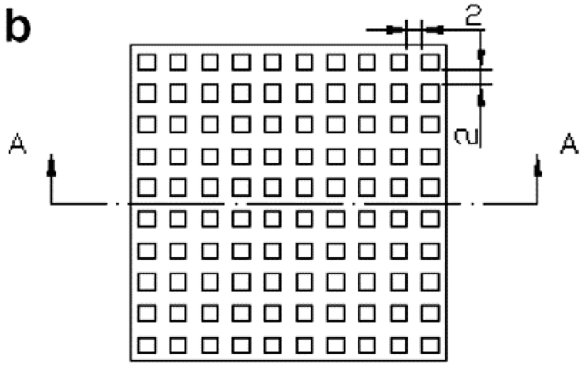

Figure 2.1 Geometric spesification of concrete with square rubber pieces (Yesilata, et al., 2009)

Fiber has already been known as a substance that can reduce the spalling risk and that increases the permeability of concrete when it is added to the mixture. Fiber in fresh concrete helps to prevent plastic shrinkage crack formation and prevent micro cracks growth in hardened concrete. In an experiment (Ozger, et al., 2013) post-consumer textile carpet waste is applied. The carpet fiber was made of poly-amide (PA66).

Table 2.3 Experiment components (Ozger, et al., 2013)

Component	Control Concrete	Concrete with Fiber
Water	97 kg/m^3	97 kg/m^3
Cement	280 kg/m^3	280 kg/m^3
Gravel (12/25)	400 kg/m^3	400 kg/m^3
Fine Gravel	200 kg/m^3	200 kg/m^3
Sand	1000 kg/m^3	995 kg/m^3
Fiber	-	5 kg/m^3
w/c ration	0.35	0.35
Specific weight	2451 kg/m^3	2440 kg/m^3
Slump	0 cm	0 cm

An experiment with mixture in Table 2.3 was done to understand the change of mechanical aspect when fibers added to the hot mix replace a small amount of sand. The hot mix has been dried for 28 days before it was tested. The test result is shown in Table 2.4.

Table 2.4 Mechanical test result comparison between concrete with and without nylon fiber (Ozger, et al., 2013)

	FC	C
R_{cm} (MPa)	57 ± 2	57 ± 1
f_{cm} (MPa)	39 ± 2	38 ± 1
E_m (GPa)	36 ± 3	37 ± 1
f_{ctm} (MPa)	3.9 ± 0.2	4.4 ± 0.4

FC is for concrete with fiber and C is for control concrete.

Table 2.4 shows that there is small improvement for f_{cm} (compressive strength for cylinders) due to the lower w/c ratio of the cement paste because the fiber adsorbs some water. Fibers increase the lateral tensile strength of the concrete and help to postpone or prevent crack enlargement. The debonding at the fiber-matrix interface causes the micro cracks to growth further when the compressive loading begins and slowly increase. The fiber-reinforced concrete becomes more ductile than plain concrete.

This experiment also measured the heat capacity and conductivity of the concrete with and without fiber at 300°C. The heat capacity for FC is 0.63 J/g.K while for C it is 0.81 J/g.K. The heat conductivity of FC is 1.16 W/m.K while for C is 1.02 W/m.K. The data above shows that adding fiber from carpets can reduce the capacity of the concrete to store heat. In the other hand, the ability of the concrete to transfer heat increases. The hygroscopic nature of the fibers improves the thermal behavior. Ozger, et al., 2013 also found that fiber-reinforced concrete is more durable than plain concrete because it suffered less from drying shrinkage and coincides with a more limited formation of micro cracks.

2.3. Solar Water Heater combination with Phase Change Material

PCM in floors cannot be very effective if there is no heat transfer from heat sources to the PCM to heat it up and heat up the room. The PCM in the concrete in the floor or foundation will be more useful if a heat source is also attached to the floor. A combination between PCM concrete and a floor heating system is one idea to make the PCM function more useful than just as insulation, preventing heat loss to the ground through the concrete floor.

There is an experiment that combines the floor heating system and PCM to heat up the room. The resource heat to fulfill the heat needed during the whole day is an electric heating device that is located under the PCM layer. This system harnesses the low price of electricity during night time to heat up the room and PCM layer until the temperature is high enough to heat up the room for the entire day when the price of electricity is high. But there is a weakness of this system. The total efficiency can be lower because the amount of energy losses during conversion from electricity that produce from heat. For example, a power plant that use coal as the fuel. Coal will produce heat to warm up the water until it becomes a high pressure vapor to turn the turbine. This system will only have an efficiency up to 40%. When the electricity is converted to heat, there will be another loss. In overall, from coal to heat for heating up a room, the total efficiency will be very low and will not reach 30%. So, why we do not extract heat to heat the room directly from the primary heat sources?

Instead of using electricity for heating up a room, a sustainable way can be used to fulfill the needs of heat. It is possible to extract heat from the sun. Sunlight is one of the most reliable and unlimited energy source for the earth. The most important is that it is free and available every day in a year, however the duration differs in each location of the earth due to the inclination angle of the earth rotation. There are several ways to collect energy from the sun, one of them is collect in terms of heat. Heat from the sun can be transfer to a storage material inside the building using water as the medium. Why use water? Because water is easy to find in the earth (2/3 of the earth surface composition is water) and it is the best substance in liquid form to store heat. This is shown by its specific heat capacities (4200 kJ/kg.K). Water can be corrosive for some materials, such as iron, but it is safe for daily usage because it is non-poisonous and easy to change and replace when the system is being maintained.

Figure 2.2 Solar water heater with vacuum tube (15Ch)

To collect heat from the sun, the water needs to flow in solar heat collector. One of the well-known hot water collector, is an all-glass vacuum tube. It is combined with a pump, water tank, and for areas that have 4 seasons, it is also equipped with anti-freeze heating wire. A hot water collector with all-glass vacuum tube is preferable to use in the 4 season. The vacuum area helps to insulate the hot water tube from environment temperature. It will help the water that can heat up until its maximum temperature without being cooling because the different temperature with the environment.

Water will be stored in big water tank. Inside the tank, the temperature gradient will lead to natural convection and move the higher water temperature above (it has lower density) and colder water temperature to the bottom (the density is higher than hot water). One exit pipe to the solar water heater located in the bottom of the water tank and the return water from the solar water heater enter the tank from above. On the other hand, an exit pipe to the floor heating system is located in the top side of the tank and the cold water that recovers from the heating system enters the tanks from the bottom. The heat water heating system use a capillaries water pipe to make the contact area between the hot water and concrete, PCM, or floor can be higher with lower flow rate. The distance between each capillaries pipe can be small to create a more uniform temperature in the floor and PCM that is located under floor. It is also necessary to install a water distribution device to make the amount of water flow in each pipe uniform. The schematic of system describe above can be seen in Figure 2.3. While the sun shines, it can heat up the water up to 60°C but the ideal temperature for a room is about 20-23°C. To achieve a room temperature between 20-23°C, the temperature of a floor heating system is preferably in the range of 22-26°C. Thus, it is preferable to use PCM that has a melting and solidification temperature of 26-32°C. The PCM will absorb the extra heat emitted from the heat water while it changes its phase during the heat absorption period.

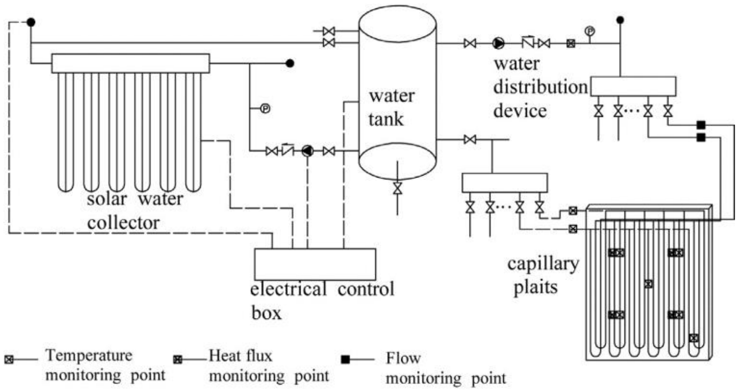

Figure 2.3 Scheme of water circulating system (Huang, et al., 2014)

2.4. Concrete Strengthens Standard

Every building shall meet the standard when it is built. There are a lot of standard for every part of the building and it is differ depends on the government regulation. In the Dutch building regulation, the minimum strength of concrete for a foundation must meet the requirement of C28/35. After 28 days of drying, the minimum characteristic cylinder strength is 28 MPa and minimum characteristic cube strength is 35 MPa. This minimum requirement is also for concrete that contains PCM or the product is not available to use as a foundation because it cannot handle minimum weight of the house.

3. METHODS

3.1. Storage Energy Calculation

The amount of energy that can be stored in the floor or foundation depends on the size of the room. For this study, five assumption are used to estimate of how much energy can be stored in a foundation.

1. The dimension of the room will be 4 m of width, 4 m of length, and 2.5 m of height. The thickness of concrete for the foundation is 0.3 m. By multiply length, height and thickness, it is given total concrete volume in the foundation is 4.8 m^3.
2. Each metric cube of concrete contain 400 kg of cement, 140 kg of water, 507 kg of sand, and 600 kg of PCM-LWA (Memon, et al., 2015). This number also called the density of each component.
3. The amount of PCM (Paraffin) in the concrete mixture is 70 wt% of Paraffin-LWA as used in (Memon, et al., 2015)
4. The PCM only work in phase change period without any temperature change, and the latent heat capacity of Paraffin is 149 J/g (Memon, et al., 2015).
5. The energy store in lightweight aggregate, concrete, and steel reinforcement will not be count.

Total weight of PCM in the foundation can be calculated in equation below

$$m_{PCM} = x_{PCM} * \rho * V \qquad [1]$$

In which m_{PCM} is the mass of PCM, x_{PCM} is the amount of PCM in the mixture, ρ is the density of PCM-LWA, and V is the volume of the foundation.

The amount of energy stored in the paraffin only can be calculated with the equation below.

$$Q = m_{pcm} * L_{pcm} \qquad [2]$$

In which m_{PCM} is the mass of PCM and L_{PCM} is the latent heat capacity of paraffin.

With simple thermal conductivity equation, it is possible to calculate how long the energy in the PCM can manage to keep the room temperature (T_h) around 20°C. For the calculation, it is assumed that the average outside temperature (T_c) is 5°C. The wall thickness is 210 mm. The area of the wall is the same as mention in room size modeling. The thermal conductivity (k) of wall is assumed the same as thermal conductivity of concrete, which is 0.8 W/m.K. The heat will flow only through the wall. From the equation below, the amount of heat rate to the environment can be calculated.

$$H = k\,A\frac{T_h - T_c}{L} \quad [3]$$

In which H is the heat rate, k is the thermal conductivity of concrete, A is the total area of the wall, T_h is the temperature inside the wall, T_c is the outside of environment temperature, and L is the thickness of the wall.

3.2. Price Calculation

To evaluate a system whether is good or not, it is better to also include the price to install the system. The price estimation will not include the production price, working cost, and any additional cost that may enlarge the price. It only gives the price of the additional raw material beyond water, sand, and cement, which is available in the market.

For Paraffin-LWA, the additional raw materials are lightweight aggregate, paraffin, epoxy, graphite powder, and silica fume. According to the price from (Memon, et al., 2015), the price of lightweight aggregate is EUR 31 per 100 kg. This lightweight aggregate has a density of 600 kg/m^3. For the paraffin, the price is EUR 12.1 per kg. Epoxy is worth EUR 11.97 per kg. Graphite powder price is EUR 5.44 per kg. The last one is silica fume that is cost EUR 0.12 per kg. For 0.6 m^3 of Paraffin-LWA mix in the concrete, 105 kg of LWA, 74.4 kg of paraffin, 135 kg epoxy, 20 kg graphite powder, and 24 kg silica fume are needed (Memon, et al., 2015). Thus, for volume in the foundation of 4.8 m^3, it needs roughly 8 times higher than already calculate in the paper.

Scrap tire rubber that is used for an extra insulation layer can be bought almost for free. Price for scrap rubber is US$ 40-50 per ton of scrap tire rubber. Recycled nylon carpet fiber can also get it with a very cheap price, because it came from waste material. While the scrap tire rubber and recycled nylon carpet fiber is used to improve the insulation performance and thermal characteristic of the concrete, it also helps to save the environment. Rubber tires are harmful for the environment because it needs dozen years for the soil to decompose it.

3.3. Design Floor Heating System

To maximize the potential energy, the study evaluates all possibilities of materials that are available to put in the concrete. At the bottom layer before pour the hot mix, scrap rubber from tire is line up as an insulation layer. Then put the reinforcing steel before pour the concrete with fiber hot mix until the requirement thickness of foundation achieve. After the foundation layer dried, a heating layer that contain capillaries pipe for hot water that circulated from solar water heater can be lay down. Above the heating layer, Paraffin-LWA concrete can be pour out as the area where the excess heat store during the day and can be released during the night. Another heating layer that made of capillaries pipe laydown above the Paraffin-LWA layer. Also it is possible to install backup heating system to heat up the floor when there are not enough radiation to heat up the water until certain temperature to make the room warm.

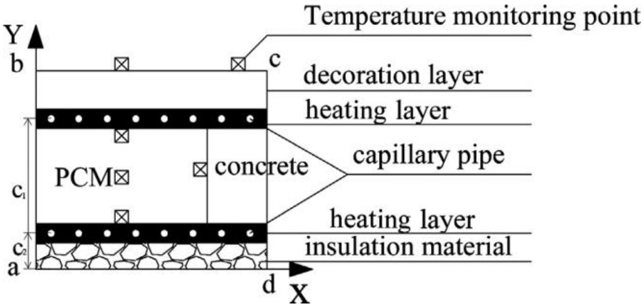

Figure 3.1 Configuration of PCM floor (Huang, et al., 2014)

Another way that is possible to use is combine fiber and Paraffin-LWA into the concrete and use it as the foundation concrete. This methods can made the storage capacity bigger because more volume in the floor section can be used as a heat storage medium. Half of the heat can be stored in the foundation and the other half can be store in extra PCM that located exactly under the floor decoration layer. Extra heating layer can be added in the foundation. The fiber in the concrete will improve the heat conductivity of the concrete so the heat transfer between the PCM, heat pipe, and floor can be improve and prevent a lot of losses while the heat transfer through concrete.

4. RESULTS

4.1. Energy Storage Capacity

Total weight of PCM in the foundation is 2016 kg. The amount of energy can be stored only in the paraffin is 300.38 MJ. Most of the foundation concrete thickness is 30 cm. If it is assumed this thickness is used, each square meter of room can store 18.774 MJ. In other way, 18.774 MJ/m^2, with the thickness of concrete is 30 cm and the PCM material is paraffin with latent heat capacity of 149 J/g.

4.2. Energy Losses

The energy losses through the wall is

$$H = 0.8\frac{W}{m.K}\ x\ (4\ x\ 4\ m\ x\ 2.5\ m)\ x\frac{(20-5)K}{0.21\ m} = 2285\ W$$

In the ideal condition, heat that emitted through the wall is replaced from the PCM. Heat is released from the PCM while it changes its phase from liquid to solid. In the ideal condition, the heat that is stored in the PCM can be used for 36.5 hours.

4.3. Price Estimation

To build a heat storage system in the foundation, extra cost need to be spent. With the amount of extra materials and price mention in section 3.2, it is possible to calculate the additional price. In total, EUR 21,060 is needed to buy the material that use to combine the Paraffin-LWA in the concrete to make the building more sustainable.

5. DISCUSSION

Once the PCM in the concrete melt perfectly, it stores enough heat to keep the room temperature stable in 20°C for 36.5 or 1.5 day. There are several possibilities to increase the amount of energy that can be stored in the house. The first method is changed the type of PCM with one that has bigger latent heat, for example, using RT28HC. RT28HC is product of Rubitherm PCM that basically made of paraffin. It has the heat storage capacity of 245 kJ/kg. For the same amount of PCM contain in the LWA, 493.920 MJ of heat can be stored during the phase change period.

The second methods is applied paraffin-LWA concrete in the wall. The same hot mix can be applied as a plaster wall. The plaster wall thickness is assume as 0.02 m. For the same room size as it is mentioned in previous chapter, the total mass of PCM stored in the wall is 336 kg. Thus, by apply paraffin-LWA concrete on the wall, 50kJ extra energy can be store during the phase change period of the PCM.

There is a main problem that has been discovered is the additional price is very high. Even for a room that has size about 16 m^2, the price for additional material already reach more than € 21,000. It is hard to find current price of the product used in the paper due to limited access for retail price. The price that is used came out from the paper itself. It is possible that the price quite high because they bought it only for a small amount that enough for the research. With the current price calculation, people will refuse this additional feature to their foundation because the price is too expensive.

The calculation done above is depended on data provide in the literature. To prove that the calculation is correct, a show model need to build and being tested. There are a lot factors are not covered in the calculation, such as effect of wind, temperature fluctuation, extra heat source inside the room, etc.

6. CONCLUSION AND RECOMMENDATION

6.1. Conclusion

From the study has been done in chapters above, there are some conclusion can be taken.

1. It is possible to combine PCM with concrete. The macro-encapsulate PCM in terms of Paraffin-LWA was used to combine it with the concrete to improve the thermal and mechanical properties of the concrete.
2. Total energy can be stored in the concrete is depend on the volume of foundation and PCM that used as the filler in the lightweight aggregate. With the configuration use in this study, 300 MJ of heat can be stored in the PCM during phase change period.
3. Total investment cost with current information is €21,060.

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APPENDIX

About Ortageo Group

The Dutch soil policy aims to achieve a sustainable soil quality and maintain. The policy is aimed at prevention and rehabilitation. For this purpose, manages the government have rules stipulating the minimum quality of the soil must be at different image land forms. The protection feature of the soil is mainly regulated by the Environmental Protection Act and the Soil Protection Act. In addition, various other laws a tangent plane to land, includes provisions for the same purpose (including Housing, Spatial Planning Act and the Groundwater Earth Removal).

For new construction projects and (re) development projects of rural, urban and industrial areas play an important role in soil aspects. Besides the bearing capacity of the soil and water management aspects, the environmental quality of the soil is very important. Capacity, (ground) water and soil quality issues are, the greater the efforts to be undertaken and the higher the costs to be incurred, to accommodate an area for the intended use. To gain insight into the (financial) risks that purchasing / commissioning of a site may entail, it is essential on the purchase of buildings and in making plans for the (re) development and direction of land, well have an understanding of the carrying capacity, water management and soil quality of the area.

The Ortageo Group consist of Envita Almelo, Envita Nijmengen, and Laknelma Geotechniek. Ortageo also have shares in Invsior Omgecingsmanagement, Hamabest and Explovision. They have expertise in various disciplines that are discussed in (inner-city) construction projects and planning issues within the rural, urban and industrial area. Often the aspect of soil just part of full implementation of such projects. Depending on the wishes consultants Envita and Lankelma can speed hill disciplines elaborate walked the integrated approach. Envita and Lankelma engage in the following activities.

Envita is working in this sector: environmental soil survey, asbestos survey (in soil), water bottom (substrate) survey, lot inspection (AP04), road and foundation survey, archaeological support, groundwater monitoring and modeling, geohydrological survey, drainage and infiltration advice, heat/cold storage in soil consultancy, preparation and coordination of (soil) remediation, calamity service, management and supervision, project and process management, and budgeting. Lankelma is working in this sector: cone penetration testing, hand penetration testing mechanical drilling, soil-displacing monitoring wells, undisturbed soil sampling (MOSTAP), clearance measurement and depth detection, unexploded ordnance (UXO), civil engineering (soil) survey, pipe-soil calculations, geotechnical consultancy and advice on foundations. Invisor is working in this sector: qualitative analysis of spatial planning and living environment, quantitative analysis of spatial issues, spatial solutions (e.g. demographic changes and housing-market problems), environmental management, and supervision of / support in spatial processes. Explovision is working in this sector: advice on unexploded ordnance, preparation of plan of approach, preparation of project risk analysis, creation of risk map, and subsidy applications. Hamabest is working in this sector: asbestos inspection in building and properties, asbestos laboratory for material analysis, clearance inspection after asbestos removal (demolition), supervision of asbestos demolition, risk assessment, and preparation of management reports and cost estimates.