CHAPTER I

INTRODUCTION

Overview

In Thailand, the ambient weather conditions are tropical; warm to hot weather all year round, with a limited wet season with limited cloud cover. A high level of solar radiation is experienced throughout most of the country throughout the year. The highest levels of solar radiation are experienced in the months of April and May, measured between 20 and 24 MJ/m^2-day and the daily average value of the solar radiation in a full year is around 18.2 MJ/m^2-day. These conditions lead to the significant accumulation of heat and moisture in building walls [1, 2, 3].

As a result of heat gain in the building, ventilating fans and air-conditioners are essential to provide a cool, controlled environment, removing the hot air from the building, or cooling the interior air. This is necessary for providing a comfortable environment for the inhabitants. This requires significant power consumption. City buildings and offices and residential housing are the largest electricity consumers in modern cities, and building owners and occupiers pay a high price for their power consumption. A decrease in energy dependence of buildings is one of the keys to reducing the amount and cost of energy consumption, and is now required and being demanded in the development of new and sophisticated building designs. New materials and construction systems must therefore contribute to meet power reduction requirements and thereby promote both energy conservation in construction and economic sustainability in energy generation.

One of the approaches to reducing energy consumption in buildings and enhancing the indoor thermal environment is the integration of phase change material (PCM) into a building or building services system to increase thermal storage effectiveness. Thermal storage effectiveness has three main aspects. First, the day-time insulating effect, second, the use of solar energy storage through a melting process during daytime and third, releasing the stored thermal energy into the surrounding environment at night, thereby reducing peak loads [4, 5, 6]. This is a significant and effective approach to achieving the necessary reduction in power consumption requirements.

Phase change materials (PCMs) were first used for thermal storage in buildings in 1980 [7]. Since then, experiments have been reported that used PCMs in trombe walls [8, 9], wall boards [10, 11, 12], shutters or windows [13], ceiling boards [14, 15] and on roofs [16, 17, 18].

In Thailand, around 28,000,000 m^2 autoclaved aerated concrete (AAC) was used in 2012. Its popularity was due to it being the only type of wall material which exhibited the ability to meet building energy saving requests of about 50% without adding other affiliated thermal insulation materials [19]. Of further importance, it is lightweight and has a highly porous structure (Approximately 80% of the volume of the hardened material is made up of pores, 50% being air pores and 30% being micropores). It therefore has a lower thermal conductivity, higher heat resistance, lower shrinkage, and an easier and faster construction process than traditional concrete [20, 21, 22, 23, 24, 25].

Several previous works have investigated the possibility of traditional raw materials replacement in AAC by using industrial waste such as coal bottom ash [24], copper tailings and blast furnace slag [26], air-cooled slag [27], efflorescence sand and phosphorus slag [28], lead–zinc tailings [29], iron ore tailings [30], calcium fly ash and natural zeolite [31] and siliceous crushed stone [32]. These studies have been undertaken to increase the range of raw materials possible, and to lower production costs.

However, investigations into traditional raw materials substitution have not investigated the use of sugar sediment waste as a raw material replacement in any depth or detail. Sugar sediment waste, is available in abundance as a waste product from the refining of sugar cane. Every year in Thailand approximately 750,000,000 kgs of sugar sediment waste are produced, and disposed of in landfills. Sugar sediment was also found that the chemical compound was general component of raw material in the mix of AAC. Using this abundant and free raw material for the AAC production has only once been reported in the literature. Few previous works are by Y. Ungkoon, et al. [33, 34]. The influence of sugar sediment mixture on the mechanical properties of autoclaved aerated concrete was investigated, and it was demonstrated to improve the physical and mechanical properties of the concrete. However, it also demonstrated that the thermal properties of the new concrete material (AAC-lightweight concrete) were not obviously enhanced. Furthermore, the correlation between the crystallinity of tobermorite phase and the strength of AAC has been insufficiently tested to demonstrate any increase of the tobermorite crystalline proportion thereby increasing the strength of AAC.

This current investigation is focused on two aspects of the use of waste sugar sediment. First, whereas the previous work investigated the replacement of sand by sugar sediment waste, the current work is intended to expand upon that previous work by analysing the effect of both sand and lime replacement by sugar sediment waste on the mechanical and physical properties of the AAC. This will expand the potential usefulness of this alternative raw material. Given that the thermal effectiveness of AAC-lightweight concrete is already considered to be highly efficient and superior to other building materials, this was selected for testing the further enhancement of the thermal effectiveness of this material, by the application of PCM as a coating is a second focus of the research. Consequential outcomes, such as the environmental and economic benefits of the use of sugar sediment waste, usually discarded in landfill sites, are also investigated.

In this work, the replacement of both sand and lime by sugar sediment waste, as various percentages, was investigated, to test the optimal replacement percentage of both sand, and lime, by the waste sugar sediment. Further, the effect of applying phase change material (PCM) as a coating on the exterior surface of three different building materials, including AAC-lightweight concrete was investigated. Coated AAC-lightweight concrete was compared with the other commonly used building materials; brick and concrete block. The dynamics of heat transfer was investigated using four simulated houses with the different wall materials (Brick, cement block, uncoated AAC and AAC with PCM coating). The crystallinity of tobermorite phase, microstructure, heat transfer time lag and cooling load of air conditioning plants in the four simulated houses were investigated and compared. Additionally, the economic and environmental analysis and the life cycle assessment of the autoclaved aerated concrete were also investigated.

Objectives of the study

1. To investigate the effect of using the sugar sediment and salt hydrated phase change materials for reducing both the sand and lime component of AAC-lightweight concrete.

2. To improve the physical and mechanical properties of autoclaved aerated concrete such as density, compressive strength, flexural strength and water absorption.

3. To study the techno-economic and environmental comparison (especially thermal effectiveness) between commercial concrete, other common building materials and improved AAC-lightweight concrete.

4. To evaluate the environmental impact of the autoclaved aerated concrete using the life cycle assessment principles.

Hypothesis of the study

1. Sugar sediment as a component of autoclaved aerated concrete can improve the physical and mechanical properties of this building material and consequently reduce the volume of both sand and lime as mixture component.

2. The autoclaved aerated concrete consisting of sugar sediment and phase change material can decrease the heat transfer from the outside of buildings to the interior, and thereby reduce the cooling load of air conditioning equipment.

Scope of the study

1. Study the phase transition behavior of the salt hydrated phase change materials by Differential Scanning Calorimeter (DSC) and the optimum composition of applied salt hydrated phase change materials in autoclaved aerated concrete.

2. Develop the physical and mechanical properties of autoclaved aerated concrete using the sugar sediment and phase change material.

3. Examine the basic properties for example:

3.1 Compressive strength: ASTM C1555-03a

3.2 Density: ASTM C642-97

3.3 Flexural strength: ASTM C1555-03a

3.4 Water absorption: ASTM C642-97

4. Test the actual use various building materials in the tropical climate of Thailand, on four test houses, constructed from concrete block, brick, commercial autoclaved aerated concrete and the improved autoclaved aerated concrete.

5. Study and examine the electrical energy efficiency of the air conditioning systems in the four test houses.

6. Investigate and analyze the economic value of PCM coatings by comparing the thermal effectiveness of coating the building materials of the four test houses.

7. Study and analyze the life cycle assessment of the improved autoclaved aerated concrete throughout the life cycle.

8. Assess and compare the environmental impact of the commercial autoclaved aerated concrete wall and the improved autoclaved aerated concrete containing waste sugar sediment replacing both sand and lime.