CHAPTER V

CONCLUSION

The purpose of this study was to explore the use of alternative materials in the manufacture of Autoclaved Aerated Concrete and its use as a building and construction material. Testing of a particular raw material, waste sugar sediment was done to discover and prove the extent of the enhancement of the physical and mechanical properties achievable for Autoclaved Aerated Concrete, particularly compressive strength and the thermal insulative effects of the concrete.

Subsequently, the use of PCM as a coating material on the Improved Autoclaved Aerated Concrete for the purpose of further enhancing the insulative properties of the building material, was extensively tested.

The study also considered the economic and environmental benefits that could accompany the use of these materials; waste sugar sediment, a waste product of the sugar processing industry and available in huge quantities, and PCM, a readily available material that nonetheless has an economic cost.

The replacement of sand and lime with waste sugar sediment, in the concrete mix, resulted in an Autoclaved Aerated Concrete material that displayed significant improvements in physical and mechanical properties, and some improvement in the thermal transfer properties of the new material.

Three test approaches were used to arrive at an optimum mix of raw materials, including the waste sugar sediment. First, the waste sugar sediment replaced sand in the mixture, in varying quantities. This product is referred to as 'AAC-S'. The control was using a 0% replacement, then 5%, 10%, 15%, 20%, 25%, 30%, 35%, 40%, 45% and 50% replacement of sand by weight. The results observed from testing indicated that the optimal composition to achieve the highest compressive strength was 30% replacement of the sand by the sugar sediment.

The second test approach was to replace the lime content by sugar sediment. This product is referred to as 'AAC-L'. This was done similarly to the sand replacement tests, with a control mix of 0%, then replacement of 5%, 7.5%, 10%, 12.5%, 15%, 17.5, 20%, 25% and 30% replacement by weight of the lime, by sugar sediment. The results observed indicated that the optimal composition to achieve the highest compressive strength was 7.5% replacement of the lime by the sugar sediment.

The third and final test approach was to combine the results of the first two test approaches, products AAC-S and AAC-L, thereby creating a combined mix where the sand was replaced by 30% by weight of sugar sediment, and the lime was reduced by 7.5% replacement. This product is referred to as 'AAC-SSR'. The mix in the AAC-SSR was further modified by the addition of recycling powder. The lime volume was held constant and sand/sugar sediment volume was replaced with the recycling powder (Recycling powder was made of finely ground AAC scrap) at 0%, 5%, 10%, 15%, 20%, 25%, 30%, 35%, 40% and 45% substitution by weight. The results observed indicated that the optimal composition to achieve the highest compressive strength was 0% replacement of the sand/sugar sediment by the recycling powder. This product is referred to as 'AAC-SSR0'.

The AAC-SSR0 exhibited the greatest compressive strength and the highest proportion of tobermorite phase. The maximum compressive strength was measured at 6.1 N/mm^2, showing an increase of approximately 22% over original AAC, and 35-169% increase over the works of Wang, et al., Jitchaiyaphum, et al., Wang, et al. and Yang, et al. The tobermorite phase calculations for each of the five product mixtures were, for AAC-S0 (0%), AAC-S30 (30%), AAC-L7.5 (7.5%), AAC-SSR0 (0%) and AAC-SSR (20%), increased by 28.9%. The higher crystallinity of tobermorite phase in the Autoclaved Aerated Concrete samples resulted in superior strength.

The surface crystalline morphology of the various test products was examined. It was found that the surface of the Autoclaved Aerated Concrete and the Autoclaved Aerated Concrete consist of sugar sediment was the finer needle-like crystalline morphology which overlapped each other forming a firm skeleton and emptied the cavities between the layers and all had a porous combined form.

The thermal properties of the test products were also tested. It was found that AAC-SSR0 can decrease more heat flux from outer wall to the inner wall than original. This indicates that the improved AAC has better thermal properties than original AAC but the increase in the insultative affects was not great. Further experimentation was undertaken in this aspect, wherein the application of PCM as a coating was studied. The heat transfer time lag of optimal composition comprising the content of phase change material of 50 g at the exterior surface was extended slightly in the heat wave propagation from outer wall to the inner wall and obviously decrease the ratio of its amplitude during this process. The time lag was positively proportionate to the thickness of the wall while the decrement factor increased inversely to its thickness.

The utilization of phase change material for thermal storage on exterior wall surfaces of buildings can reduce the heat wave propagation from the outer wall to the inner wall and therefore the interior room spaces. Electrical power consumption savings are achieved by the reduction in the cooling load on air conditioners in buildings. Our tests showed that power consumption of PCM-coated AAC was decreased by approximately 29.6% when compared with uncoated AAC, 38.9% when compared with uncoated brick and 47.6% when compared with uncoated cement block. The energy payback period for the uncoated AAC as compared to the uncoated brick was and the PCM coated AAC as compared to the uncoated brick was reduced from approximately 9.91 years to 4.11 years, respectively. The internal rate of return as compared to the uncoated brick increased from 9.290% to 13.568% when AAC was coated by PCM. The energy saved can recover the embodied energy of the PCM coating.

The effectiveness of PCM coatings on the exterior surface of buildings has been clearly demonstrated both in regard to thermal effectiveness, power consumption reduction and the resultant economic benefits.

The overall environmental and economic benefits were then identified as achievable by the recycling of waste sugar sediment in the way also described. Each year, about 750,000,000 kgs of sugar sediment are produced by the sugar processing industry in Thailand. If our scope is extended to other sugar producing countries, it is clear that well in excess of a hundred thousand tons of sugar sediment is produced annually, and at the moment all of it is disposed of in landfills and other waste dumps. This has an immediate economic cost of disposal, and more importantly, has an environmental cost. The economic cost is increased by the cost of managing landfill sites, together with any health costs that may be incurred by proximity to waste disposal sites.

Thailand can reduce the volume of sand and lime used by about 267 million kgs of sand, and 18.3 million kgs of lime per year if the new composition of AAC-SSR0 is used in the calculation. Thereby approximately 267 million kgs of otherwise waste sugar sediment would be used, approximately 36% of total annual volume produced. The raw material cost saving must also have other costs factored in, such as the savings on obtaining sand; quarrying, purchasing and transporting primarily, and producing and obtaining lime. Especially in the case of lime production there are manufacturing costs, including electricity costs, and environmental costs.

The justification for the research undertaken therefore based in considerable part on the economic, environmental and social costs that are inherent in the production of Autoclaved Aerated Concrete The mitigation of these significant environmental and human use impacts occasioned by the disposal of waste sugar sediment in landfills, and the quarrying and mining for sand and lime material, must be seen as substantial.

Therefore, Autoclaved Aerated Concrete with the optimum composition of sugar sediment can be suitably considered to be an alternative application. Furthermore, PCM coating on the exterior surface of buildings is highly recommended as an adjunct material to be applied concrete and masonry constructions in the future.