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A Proposal for Novel Reuses Application of Bottom Ash in Thermal Insulation of Buildings in Hot and Humid Climates

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ABSTRACT

During the past decade, Malaysia has undergone a significant social and technological evolution along with the rapidly- changing aspects of modernization, an unavoidable by-product of which is the increase in the rate of waste generation. A variety of techniques are recognized as methods of recycling from among which incineration has received serious consideration. Incineration of Municipal Solid Wastes has the advantage of reducing the volume, the toxicity and reactivity of the waste. Yet, the ashes produced pose a serious waste treatment problem. The Government of Malaysia (GOM) along with the determination for establishing a number of incinerators around Malaysia follows the policy of reusing the incinerator ashes. The issue of exploring new techniques and strategies to cope with the existing energy crisis in the world is highly urgent due to the scarcity of remaining resources. In Malaysia, high dependence on fossil fuels is alarming and necessitates the urgent substitution of other sources of energy. Meanwhile, buildings constitute a large group of contributors to energy dissipation, residential and commercial buildings consuming more than a third of the energy used around world. This fact points out the importance of proper thermal insulation, especially in certain climates, such as Malaysia's, where air conditioning systems consume a relatively large amount of electrical energy. The present study proposes a novel reuse application for MSWIBA in building insulation as a coating in order to enhance energy efficiency in this group of major energy consumers. It is expected that utilizing incineration ash would play a significant role in reducing the amount of BA to be landfilled. This would also lead to a considerable difference in preserving internal temperature of buildings and energy efficiency by coated buildings by new material as well as alleviating the need for more energy consumption by air-conditioning systems.

KEY WORDS: Waste Management, Green Architecture materials, Energy Crisis, Energy Consumption in Malaysia, Municipal Solid Waste Incineration Bottom Ash, Thermal insulation, Feasibility

1. INTRODUCTION

Fossil fuels are major energy providers all over the world which would end in a not-to-distant future based on the estimations and approximations. Malaysia is on its way towards a high-developed country, thus, there need to be attempts to optimize its energy consumption in sustainable development pattern towards improving quality of life. However, statistics from around the world reveal high tendency towards consuming fossil fuels in most parts of the world.

According to 2012 BP Statistical Review of World Energy Report (1), in 2010, almost 92% of the world energy came from oil, natural gas, coal and nuclear energy while only less than 8% of the energy was supplied from renewable energy resources mostly from the hydroelectric dams. Other renewable energy sources, such as wind power, geothermal, solar energy and waste to energy, have a very low energy supply (less than 1.4%.). The statistics also reveal that in 2011, the renewable energy consumption rate escalated up to 1.6% which indicates a relatively successful but less than sufficient effort in this field. Similar statistics indicate that renewable energy consumption in Malaysia is about 2.5% which has been completely allocated to hydro-electricity power, whereas the other types of renewable energies do not play a significant role in Malaysian power sector.

From another point of view residential and commercial buildings consume more than a third of the energy used today. This is while total building energy consumption in 2009 was about 48% higher than consumption in 1980(2).

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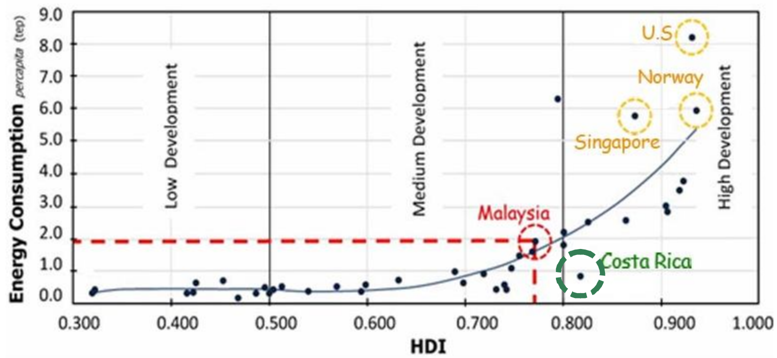

Figure1 Graphic of Human Development Index (HDI) vs. energy consumption in 1999(3)

Statistics such as the ones presented in Figure-1 will be very insightful for more accurate planning concerning Malaysian sustainable development. Therefore, Government of Malaysia (GOM) in "Ninth Malaysia Plan" has taken steps towards utilizing renewable sources of energy and has stressed out the importance of energy efficiency in buildings. In order to achieve these pre-established regulations on energy efficiency, the academic view needs to become allied with government prospective of future sources of energy. The present study, seeks to specify the path towards utilizing renewable sources of energy and applying methods in buildings which lead to substantial decrease in the rate of energy dissipation. The concept of Green architecture Material was selected as the research discipline supporting the idea of energy preservance behind this study.

Green architecture, a new scientific implication, has been developing during recent decades succeeding latter eco-trend and technologies. Since buildings are among the chief contributors to pollution, many institutions and organizations have been constituted to reclaim the concept of green building to become more comprehensive in the future. The main intentions in "Green Architecture" include:

1. Sustainable Sites
2. Energy Consumption
3. Water Efficiency
4. Materials & Resources
5. Environmental Quality

However, there are some gaps between most of these concepts. This study seeks to combine above concepts to fill a part of these gaps and to move towards the mentioned Malaysian target. As a major effective factor in energy consumption, insulating building envelope which includes walls, roofs and floors is essential for reducing the rate of heat transfer into the interior spaces of buildings. About sixty percent of the thermal transfer occurs from the walls and roof, so it seems extremely important to choose the right thermal insulation technique in order to reduce the waste of energy by buildings. To effectively decrease the amount of such transfer, proper selection of insulation must be made by accounting for the purpose, environment, ease of handling and installation, as well as the cost. Thus, the applied materials and resources play a significant role in this regard while feasibility can effectively improve this purpose.

2. FEASIBILITY

According to Skidmore, 1994(4), and Javahar Nisan, 2004(5), three major feasible dimensions are recognized as: technical aspect, operational aspect, and economical aspect. The technical aspect is pertained to appraising manners and facilities that will assist the essential variations. The operational aspect is concerned with the staff's approach to the proposed operations in view of their duties. The economic aspect alludes to the required costs estimation. In this case, we have to add the environmental aspect to the mentioned aspects to complete feasible dimensions for all types of construction and changes to get close to the aim of this study.

Existing buildings incorporate another major factor concerning thermal insulation. In this group of buildings, the biggest group among energy consumers, a valuable insulator can refer to a coating due to its significant role in reducing the cost of renovation.

3. PROBLEM STATEMENT

Based on the above issues, considering another major point in "Ninth Malaysia Plan, Section 87" refers to energy production and the government's determination to reduce dependence on non-renewable sources of energy.

Traditionally, energy production in Malaysia has been based around oil and natural gas production (6). Malaysia currently has 13GW of electrical generation capacity (7). Power generation capacity connected to the Malaysian National Grid is 19,023 MW, with a maximum demand of 13,340 MW as of July 2007 according to Suruhanjaya Tenaga (2008) total electricity generation for 2007 is 108,539 GW·h with a total consumption of 97,113 GW h or 3,570 kW·h per capital (8).The generation fuel mix is 62.6% gas, 20.9% coal, 9.5% hydro and 7% from other forms of fuel (9). In 2007, the country as a whole consumes 514 thousand barrels (23.6 million tons) of oil daily against a production of 755 thousand barrels (34.2 million tons) per day (10).

However, Malaysia only has 33 years of natural gas reserves, and 19 years of oil reserves, whilst the demand for energy is increasing. Due to statistics such as these, the Malaysian government is expanding into renewable energy sources (6). Currently 16% of Malaysian electricity generation is hydroelectric, the remaining 84% being thermal (7). These statistics and facts have given incentive to a large body of research in the field of renewable sources of energy, among which the present study is an attempt to stand in line with Malaysian Energy Policy to minimize the usage of fossil fuels.

Table 1. The rate of energy consumption around the world in 2011 (1)

Consumer	Oil	Natural gas	Coal	Nuclear energy	Hydro-electricity	Renewables	Total
The North America	1026.4	782.4	533.7	211.9	167.6	51.4	2773.3
S. & Cent. America	289.1	139.1	29.8	4.9	168.2	11.3	642.5
Europe & Eurasia	898.2	991.0	499.2	271.5	179.1	84.3	2923.4
Middle East	371.0	362.8	8.7	◙	5.0	0.1	747.5
Africa	158.3	98.8	99.8	2.9	23.5	1.3	384.2
Asia Pacific	1316.1	531.5	2553.2	108.0	248.1	46.4	4803.3
Total world	4059.1	2905.6	3274.3	599.3	791.5	194.8	12274.6
Malaysia	26.9	25.7	15.0	--	1.7	◙	69.2

◙ :Less than 0.05.

Note: Oil consumption is measured in million tons; other fuels in million tons of oil equivalents.

3.1. Incinerator Bottom Ash Applications

IBA is a source of competitively-priced aggregate that can substitute the primary aggregate extracted from quarries. Recycling IBA is an ideal technique to lower the rate of landfill disposal and although it is essentially inert, containing no more than 3% carbon, its utilization as a secondary aggregate makes space available for other needs, as well as avoiding the landfill tax liability. The use of secondary aggregate requires less transport than primary aggregate by utilizing IBA processing plants close to the building developments.Today, the incineration ashes are being used in four main applications including: (a) road-base material and landfills cover; (b) as construction material; (c) in underground disposal sites like mine remediation; and (d) in agriculture (11)(12). Some of these applications are from Fly Ash (FA), some from BA and the others from mixed ashes. Considerable tonnage of both ferrous and non-ferrous metals can be recovered from BA and the cement-like properties of processed BA give enhanced performance over virgin aggregate. BA is rigorously tested in line with European and UK guidance to ensure that their concentrations do not constitute a hazard. Hence, its utilization as a construction material is possible when its safety and non-hazardousness are determined and guaranteed.

3.2 Why Thermal Insulation?

Generally, there are a number of reasons why thermal insulation is essential in buildings. The primary reasons for insulation include: conserving energy, decreasing heat dissipation, preserving a certain temperature, keeping a product at a constant temperature, preventing condensation, and creating a comfortable condition (13).

An ideal and feasible thermal insulator is the one which enjoys appropriate size, type and thickness. Economic thickness is the thickness of insulation, which will result in minimum total cost of energy losses plus the cost of the erected insulation. It is not always easy to calculate economic thickness notwithstanding the fact that it is affected by a number of reasons. The exception is when retrofitting of insulation is expected. Retrofitting is the application of additional layers of insulation to existing insulation in order to further reduce heat loss or gain to reduce the cost of energy losses. It is preferred to allow the user prepare the economic thickness calculation rather than presuming it as the function of the insulation contractor. It includes significant factors such as:

- Cost of the energy losses, which include capital cost of installed equipment to generate/extract heat
- Expected price difference in the cost of fuel
- Capital cost of installed insulation
- Payback period that the user requires for capital investment

This research is an attempt to propose a cost friendly coating as a thermal insulation layer applicable to both the existing buildings and the new buildings by utilizing Municipal Solid Waste Incinerator Bottom Ash (MSWI-BA) which is the remaining material of waste- to- energy as a renewable source of energy. This can be regarded as an example of retrofitting. Figure 2 displays the problem statement of the present study.

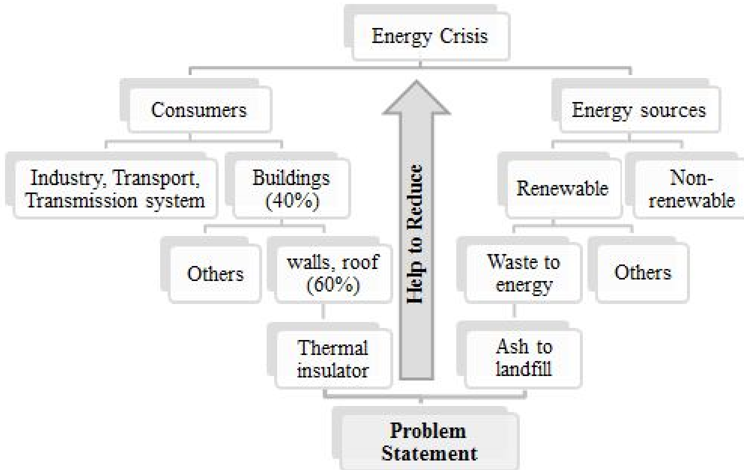

Figure 2 Problem statement diagram

4. AIM OF STUDY AND OBJECTIVES

The aim of this research is: "To explore a thermal insulator mixture coating by using MSWI-BA and an adhesive material." To this goal, this study puts forth a number of specific objectives as follows:

- 1stObjective: To investigate the possibility of MSWI-BA as a building material.
- 2nd Objective: To conduct laboratory experiment to find the properties of the existing MSWI-BA in Malaysia.
- 3rd Objective: To survey on adhesive construction materials and their reaction with MSWI-BA.
- 4th Objective: To investigate optimum thermal conductivity property in the proposed MSWI-BA compound materials.
- 5th Objective: To evaluate the performance of the new material onsite.
- 6th Objective: To calculate energy efficiency when the new material is used as energy efficiency majors.

5. RESEARCH METHODOLOGY OVERVIEW

To specify MSWI-BA characterization, especially its thermal conductivity property, and the issues related to waste composition in Malaysian setting, a survey and an experimental study need to be conducted. Overall 9 phases and 14 steps are planned to be carried out in this study based on the aforementioned objectives. Table-2 illustrates a brief overview of the methodological approach adopted here:

Table 2. Flow chart of research activities (Mapping of phases and tasks to achieve objectives)

Objectives	Phase	Tasks
Objective 1: To investigate the possibility of MSWI-BA as a feasible building material	**Phase I** (Preliminary investigation) **Phase II** (Data collection)	i. Review analysis on MSWI-BA properties. ii. Review analysis on MSWI-BA's applications around the world. iii. Review analysis on the relative amount of Municipal waste and its major compounds in Malaysia. iv. Waste collection and classification prior to entering incinerator to analyze waste composition. v. BA collection from fed incinerators through analyzing the waste.
Objective 2: To conduct laboratory experiment to find the properties of the existing MSWI-BA in Malaysia.	**Phase I** (Preliminary investigation) **Phase II** (Data collection) **Phase III**	i. Review analysis on required tests for recognizing BA's properties. ii. Survey and test to recognize collected BAs' structural properties. iii. Survey to recognize the similarity and differences between collected BAs and the other investigated BAs around the world. iv. Analyzing the results using GGDM method.

	(Laboratory testing)	
Objective 3: To survey on adhesive construction materials and their reaction in combination with MSWI-BA.	**Phase I** (Preliminary investigation) **Phase II** (Data collection) **Phase III** (Laboratory testing)	i. Study on construction mortars compounds and adhesive materials in construction mortars as well as their properties ii. Adhesive collection based on available and regular construction adhesives in Malaysia iii.Analyzing adhesive materials properties and their reactions in combination with BA. iv. Comparing the results to select the most appropriate adhesive material to be mixed with BA.
Objective 4: To investigate optimum thermal conductivity property in the proposed MSWI-BA compound materials.	**Phase I** (Preliminary investigation) **Phase II** (Laboratory testing) **Phase III** (Mathematical Analysis)	i. Systematic review analysis on thermal conductivity of sample materials especially thermal insulators ii. Making appropriate specimens to experiment on the thermal conductivity property of mixture materials iii.experiment on specimens and record results iv. calculating thermal conductivity of mixture materials by relevant computational methods v. Comparing the results to select the most suitable component as thermal insulator coating
Objective 5: To evaluate the performance of the new material onsite.	**Phase I** (Preliminary investigation) **Phase II** (Chamber design) **Phase III** (Field Testing)	i. Conducting systematic review analysis on field thermal chamber. ii. Survey and construct testing chambers by considering the most important orientation in waste of energy in Malaysia. iii.To conduct comparative study between two chambers, final component thermal insulator coating and regular coating in the direction that gives the greatest amount of energy waste on buildings in Malaysia
Objective 6: To calculate energy efficiency when the new material is used as energy efficiency majors.	**Phase I** (Preliminary investigation) **Phase II** (Mathematical Analysis)	i. Review analysis on energy efficiency by changing construction materials ii. Review analysis on energy consumption computational methods. iii. Survey and utilize the most appropriate energy consumption computational method. iv. To analyze and compare the results with a regular existing building to calculate yield energy efficiency by using new material.

5. EXPECTED RESULTS

The probable findings of this proposal will be advantageous to the researchers, scientists, scholars, architects, executive construction managers, and industries in construction sector via utilizing the two major results of this study. Firstly, specification of BA features will enhance the possibility of making more logical decisions concerning its application and utilization, and it can help develop the knowledge on BA in order to be able to think of its novel reuse applications especially in the field of construction. Secondly, it is expected that utilizing the final tested coating would lead to a significant difference in the rate of energy losses inside buildings not only through recycling a residue material of renewable energy plant but also by stabilizing and preserving internal desirable temperature in warm and humid climate to decrease the range of electrical energy consumption for air-conditioning systems that can be considerable for existing buildings as well as new constructions.

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7. REFERENCES

1. BP p.I.c. *BP Statistical Review of World Energy.* London : BP's publications, June 2012.

2. U.S. department of energy. Buildings Sector Energy Consumption. *Buildings energy data book.* Washington DC: s.n., 2012, p. 1.1.8 (Shares of U.S. Buildings Generic Quad).

3. *The limits of human development and the use of energy and natural resources.* Rubens A. Dias, Cristiano R. Mattos, Jose´ A. P. Balestieri. 2006, Energy Policy 34, pp. 1026–1031.

4. Skidmore, S. *Introducing Systems Analysis.* Oxford : Blachwell, 1994.

5. *Efficacy-information for implementing learning in construction.* L., Javahar Nesan. 1, s.l.: Emerald, 2004, The Learning Organization, Vol. 11, pp. 45-66.

6. Salsuwanda Selamat, Che Zulzikrami Azner Abidin. Renewable Energy and Kyoto Protocol: Adoption in Malaysia. *Universiti Malaysia Perlis - School of environmental engineering.* [Online] 9 24, 2010. Publicweb.unimap.edu.my.

7. Bhd, Tenaga Nasional. *National Energy Grid of Malaysia* . San Diego : Global Energy Network Institute (GENI), 2007.

8. Tenaga, Suruhanjaya. *Statistics of interim on the performance of the electricity supply in Malaysia for the first half year of 2007.* Kuala Lumpur : s.n., 2008.

9. Suruhanjaya Tenaga, Energy commission. *Electricity Supply Industry in Malaysia - Performance And Statistical Information 2006.* Kuala Lumpur : Department of Electricity Supply Regulation, 2007.

10. BP. *BP Statistical Review of World Energy.* s.l. : BP plc., 2008.

11. *Waste-to-energy – the search fo rbeneficial uses.* Millrath, K., Roethel, F.K., Kargbo, D.M. Savannah, Georgia : s.n., 2004, May 17–19. 12th Annual North American Waste to Energy Conference (NAWTEC 12).

12. *Aggregate material formulated with MSWI bottom ash and APC fly ash for use as secondary building material.* del Valle-Zermeño, R., et al. 2012, Waste Management, p. http://dx.doi.org/10.1016/j.wasman.2012.09.015.

13. TIASA, AAAMSA. *THERMAL INSULATION HANDBOOK.* s.l. : The thermal insulation association of southern Africa (TIASA), 2001.

14. U.S. department of energy. *Buildings energy data book.* Washington DC: s.n., 2012.

15. *Municipal solid waste management in Malaysia- Possibility of improvement.* Fauziah S.H., Agamuthu, Simon. 2004, Malaysian Journal of Science, pp. 23(2): 61-70.