SIBE2013

The Second International Conference on Sustainable Infrastructure and Built Environment

Faculty of Civil and Environmental Engineering
Institut Teknologi Bandung

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VOLUME I

"Accelerating Sustainable Infrastructure Developement - Challenges, Opportunities, and Policy Direction"

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Volume I

Topic 1 Structure and Material
Topic 7. Geotechnical Engineering

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The Second International Conference on Sustainable Infrastructure and Built Environment

Accelerating Sustainable Infrastructure Development – Challenges, Opportunities, and Policy Direction

BANDUNG – INDONESIA
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PREFACE

Infrastructure provides the basic needs of human beings, and sustainable infrastructure systems are essential for the survival, health, and well-being of a society. The civil, environmental, and ocean engineers are at the epicenter in seeking the means to enhance human life through modernization of infrastructure as evidenced by provision of shelter, water, and transport, amongst others.

The current fast rate of urbanization and industrialization has caused a rise in environmental issues, involving environmental mismanagement, which has been associated with unforeseen global catastrophes. The problems are further aggravated by the impacts of environmental degradation such as soil erosion, hurricanes, sea-level rise, depletion of water resources, etc. These issues have become the current focus of attention and studies of the world's academicians and professionals in infrastructure development. Relevant researches include not only hard infrastructure but also soft infrastructure aspects such as regulation, institution, and policy development framework.

To support economic activities and to offer a better quality of life, developing countries need to accelerate sustainable infrastructure provision. In many developing countries, including Indonesia, lack of infrastructure has been the main obstacle of investment and development activities. Besides limited available fund, the acceleration of sustainable infrastructure development still has to face the challenges of, among others, knowledge, human resources management, best practices, and capacity development. On the other hand, developing countries generally possesses abundant local natural resources, sufficient carrying capacity, and local wisdom.

In order to meet these multifaceted challenges, not only proper planning, design, implementation and verification exercises, but also clear policy and strategy direction of sustainable infrastructure development are required, via an integrated, multidisciplinary and holistic approach.

The global momentum for sustainable development must now lead to practical applications of the engineering and science of sustainability – an optimization – which allows an accelerated infrastructure provision with maximum attention on sustainability aspects.

The conference will provide an opportunity for professionals and researchers to learn, share and exchange the latest development and research in civil engineering and environmental engineering. The scope of the conference will be broad, covering all aspects of civil and environmental engineering practices.

Participants of the conference include researches, academic staffs, students, industries, public and local governments. The keynote presentations during the conference are as follows:

Keynote speakers:

- **Ir. Djoko Kirmanto**
  Minister of Public Works, Indonesia
- **Prof. Tamon Ueda**
  Head of International Committee of Faculty of Engineering, Hokkaido University, Japan
- **Dr. Ir. Bambang Susantono, MSCE., MCP**
  Vice Minister of Communication, Indonesia
- **Prof. Shyh-Jian Hwang**
  National Taiwan University, Taiwan
- **Prof. Ir. Suprihanto Notodarmojo, Ph.D.**
  Dean of the Faculty of Civil and Environment Engineering, InstitutTeknologi Bandung, Indonesia
- **Dr. Ir. Achmad Hermanto Dardak, MSc.**
  Vice Minister of Public Works, Indonesia
- **Dr. Ir. Dedy Supriadi Priatna, M.Sc.**
  Deputy Infrastructure of BAPPENAS
- **Dr. Ir. Lucky Eko Wuryanto, M.Sc.**
  Deputy Infrastructure of Coordinator Ministry for Economic Affair

The objectives of the conference are:

1. To provide a platform for exchange of ideas and information among academics, researchers, consultants, engineers, manufacturers and post graduate scholars in civil and environmental engineering
2. To discuss and evaluate the latest approaches, innovative technologies, policies and new directions in infrastructure development, pollution prevention and eco-friendly technologies adapted to developing countries
3. To promote cooperation and networking amongst practitioners and researchers involved in addressing infrastructure and built environment issues

The oral presentations are subdivided into 8 major sctions as following:

1. Structure and materials
2. Transportation system and engineering
3. Water resources engineering and management
4. Water & waste engineering and management
5. Ocean engineering
6. Construction management
7. Geotechnical engineering
8. Environmental protection and management

There are 131 contributors in oral presentation.

Finally, the organizing committee wishes that the conference is able to provide beneficial scientific information to the participants and other concerned readers

Bandung, November 2013

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TOPIC 7. GEOTECHNICAL ENGINEERING

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Study on the Development of Foamed Concrete for Wall Thermal Insulation

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Abstract. The largest energy consumption in building's life cycle occurs during operational period. During that time energy is consumed, among other, for creating living comfort. Thermal comfort is one of many important aspects of living comfort in building features. Such a fact is important to consider. While the needs for providing better thermal comfort in building remains on the raise, the ability of delivering affordable energy to fulfill those needs are threatened. To cope with that problem, the concept of passive design building can be applied to create optimum thermal comfort by maximizing the use of readily available thermal energy. Wall insulation will prevent heat transfer to occur in building sections, such that the thermal energy in a building section can be stored for longer period without additional energy. This paper presents a research on the development of foamed concrete for alternative building material. Foamed concrete is a type of concrete that has high porosity and low thermal conductivity. In particular, the research aimed at studying the thermal conductivity properties of foamed concrete to determine its suitability for wall insulation. The study conclude that, in addition to helps the application of green construction concept, the use of foamed concrete in building wall will result in reducing up to 40% in operation cost for running air conditioner system than those with regular brick wall.

Keywords: *Foamed Concrete, Thermal Insulation Wall, Green Construction Material.*

Introduction

With the rapid depletion of energy resources and steep increase in cost of energy, the world is in greater demands for better ways to cope with energy problem. Energy consumption is an important issue that took place in every building's life cycle, from extraction and manufacturing of raw material to construction, operation and maintenance, to demolition. More than two decade ago Cole and Kernan [1] determined that the largest consumption of energy occurred during the building's operational periods. Further, Kilbert [2] determined that most of these consumptions are attributed to electrical energy to power building light and thermal conditions. A study by Deblin *etal* [3] quantifiably determined that in order to provide living comfort, an average household would spend 23%, 26% and 32% of energy for lightings, water heather, and air conditioning, respectively. To get a clearer perspective of how important this issue, PT Energy Management Indonesia [4] suggested method to calculate energy consumption of a 550 watts Air Conditioning, and determined it as the highest energy consuming item in a typical office.

Aside from using air conditioning system, passive building design can provide similar building thermal comfort by manipulating the thermal effect of sunlight, air flow, vegetation and other surrounding objects. Now, the development and application of passive design building is encouraged due to our continued trapped in limited fossil energy. One application of passive design building is to utilize thermal insulation wall. By using thermal insulation wall, heat transfer from a room to the surrounding environment can be reduced and the amount to energy needed to operate air conditioning system will eventually be lowered, too.

Thermal conductivity is a measure of how effective a material is able to convey heat, which is dependent to many factors, including type of aggregate, porosity (type of, volume, size, distance and direction of pores), and humidity. Insulation material has low thermal conductivity that makes it capable of withholding flow of calorie. Microscopic cells in an insulation material are able to reduce heat radiation by means of shortening the wave length, which in turn this short wave radiation can be contained in insulation material. Foamed concrete (FC) is a type of concrete with no more than 20% porosity [5]. Such physical property enables this material to have low thermal conductivity, which is ideal to be used for thermal insulation wall [6]. Besides, FC can also be made of locally available material such as sand, cement and fly ash that makes it potential to justify one of many aspects in green construction [2].

Design of Study

The objective of this study is to determine the suitability of foamed concrete as alternative material for building's insulation wall. In particular, this study aimed at understanding the relationship between density and porosity to both the thermal and mechanical properties of foamed concrete, as opposed to regular brick wall. Mechanical property was be tested to determine its compressive strength, whereas thermal feasibility will measured against the amount of caloric energy lost or absorbed by the wall's thermal conductivity. All tests were conducted in accordance to ASTM and SNI standards as follows:

specified by SNI 03-0349-1989, therefore in order to increase the compressive strength, fly ash was added into the mixture.

Table 2 Summary of mix-design of Foamed Concrete.

Mix-design					Density (Kg/m^3)	Compressive strenght (MPa)
No	Water	Cement	Sand	Foamed (% mortar)		
1	0.50	1.00	0.67	60%	920.70	1.30
2	0.50	1.00	1.00	60%	811.25	0.64
3	0.50	1.00	1.50	60%	774.06	0.53
4	0.50	1.00	2.00	60%	716.40	0.44
5*)	0.50	1.00	1.60	60%	1,298.96	3.92

**) with fly ash*

Result

As shown in table 2, none of the early FC mix design met the minimum compressive strength of 2.5 MPa. Therefore, according to SNI 03-0349-1989 these mixes cannot be used as design of load bearing wall, but can still be useful for partition wall. With the same portion of mortar to foamed ratio, the introduction of fly ash into the mortar has significantly increased the compressive strength. However, it should be noted that this increment was also accompanied by a relatively increase in density.

Due to its limited compressive strength, regular concrete cement mortar mix can be used for partition wall insulation. As shown in table 3 below, this mortar mix can withstand its own weight up to 48 meter of wall height; much more than adequate for a typical building room.

Physical Properties of Foamed Concrete Mix

Further examination on the effect of fly ash, suggested that the increase of compressive strength was the result of better chemical reaction. Results from X-ray Diffraction (XRD) analysis showed that CHS reaction of fly ash-cement mortar mix was higher than those of regular cement mortar mix.

Table 1 Summary of testing standards.

No	Item	Standards	Remarks
1	Density	ASTM C 167-93, Standard Test Methods for Thickness and Density of Blanket or Batt Thermal Insulation	5 specimens of FC (20 cm x 10 cm x 5 cm)
2	Heat Capacity	ASTM C 351-92b, Standard Test Method for Mean Specific Heat of Thermal Insulation	3 specimens of FC, weights 10 + grams
3	Thermal Conductivity	ASTM C 1113-99, Standard Test Method for Thermal Conductivity of Refractories by Hot Wire.	2 specimens of FC (20 cm x 10 cm x 5 cm)
4	Compressive Strength	ASTM C165-95, Standard Test Method for Measuring Compressive Properties of Thermal Insulation	5 specimens of FC cylinder (20 cm and 10 cm diameter)
5	Porosity	ASTM C 642-90. Standard Test Method for Specific Gravity, Absorption and Voids in Hardened Concrete	5 specimens of FC (20 cm x 10 cm x 5 cm)

Thermal Feasibility of Foamed Concrete for Insulation Wall

The feasibility of foamed concrete for insulation wall material is determined by measuring two parameters; a) the quantity of calorie absorption, and b) the optimum time in withholding calorie transfer. The quantity of calorie absorbed by insulation wall is measured by the amount of calorie transfer, whereby calorie transfer is the amount of calories flow per unit of time.

$$Q = U.A.\Delta_t = 1/R.A.\Delta_t \qquad (1)$$

where: $U = 1/R$ and $R = \frac{x}{\lambda}$

Q = transfers of calorie (watts)
U = thermal transmittance = coefficient of calorie transfers ($W/m^2.K$)
R = thermal resistance
A = surface area of material (m^2)
Δ_t = temperature differences (^oKelvin) = $t_2 - t_1$
λ = thermal conductivity (W/m.K)
x = wall thickness (m)

Foamed Concrete Mix Design

The study was to examine the changing characteristic of mechanical and thermal conductivity properties of foamed concrete due to variation of fine aggregate portion or the mortar. The amount of foamed added into the mortar was set fix at mortar to foamed ratio of 40% : 60%. Because these early mixes did not meet the minimum compressive strength for load bearing wall, as

Table 4 Summary of mix-design of Foamed Concrete.

Mortar Mix	Density (Kg/m^3)	λ, Thermal Conductivity (W/m.K)		Porosity (%)	
		Average	Std. Deviation	Average	Std. Deviation
1	920.70	0.18	0.01	54.98	3.41
2	811.25	0.18	0.01	55.22	9.28
3	774.06	0.21	0.01	49.03	2.76
4	716.40	0.19	0.01	50.55	4.57
5$^{*)}$	1,298.96	0.30	0.01	23.38	3.73

The above table showed that the increase of density will lead to the increment of thermal conductivity. As the mortar gets denser, the porosity decrease and the heat transfer becomes easier. The relationship between density and thermal conductivity is given in the figure 2.

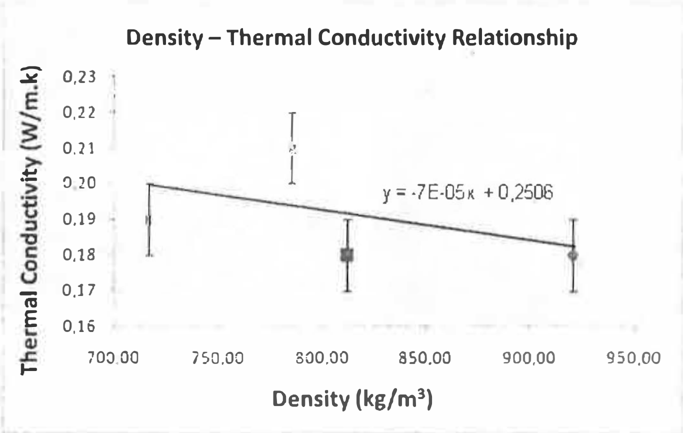


Figure 2 Density and Thermal Conductivity Relationship

Again, it is evidenced that while increasing the compressive strength, the introduction of fly ash into the mix will also increase its thermal conductivity by almost 50%. Yet, within the context of thermal insulation wall, such an increase in compressive strength should be carefully examined as to provide the optimal value of thermal conductivity. This issue is addressed in the discussion below.

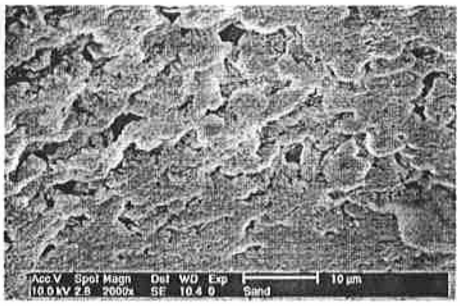
The Economy of Foamed Concrete Mix

The economic calculation of insulation wall made of foamed concrete was based on simulation of a hypothetical case for a 3m x 4m room with a 3,5m ceiling. It was assumed that the ambient temperature was 33°C and the inside temperature was set at 25°C. It was further assumed that no heat release was allowed except through the perimeter insulation wall. The objective of this

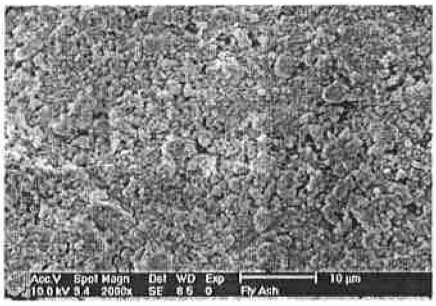
Table 3 Summary of mix-design of Foamed Concrete.

Mortar Mix	Chemical Composition (%)					
	Calcium Silicate Hydrate	Calcite	Quartz	Ettringite	Gypsum	Portandite
Cement-Fly Ash	43.4	38.6	31.8	4.5	5.2	3.3
Cement-Sand	27.4	29.8	14.0	3.6	4.9	2.5

Further examination on images of 2000x magnification on Scanning Electron Microscope (SEM) showed an obvious difference in the size and texture of pores between regular cement mortar and fly ash-cement mortar. As shown in figure1, fly ash-cement mix has lower and smaller size of pores as compared to the regular cement mortar mix. The texture of fly ash-cement mortar also looks smoother than the regular ones. Such evidence is consistent with the increase in density of the mix.



(a) Cement-Sand Mortar Mix



(b) Fly Ash-Cement Mortar Mix

Figure 1 SEM of Cement Mortar and Fly Ash-Cement Mix Mortar

Those results suggested that the addition of fly as into cement mix mortar will increase the bearing capacity of concrete wall (increase the compressive strength), but at the same time reduce the amount of pores in the mix; which in turn, will potentially reduce the thermal conductivity of the material.

Thermal Properties of Foamed Concrete Mix

The thermal property of foamed concrete was determined through series of test according to standards depicted in table 1. The results are summarized as follows:

simulation is to find the least cost of thermal energy for each cement mix foamed concrete, compared to ordinary clay brick wall. The duration of this simulation was set at 10 hours electrical energy utilization per day for 30 days, and the cost saving was calculated based on the energy saving for running air conditioning system for each type of foamed concrete wall as compared to ordinary clay brick wall. Applying equation (1) for heat transfers:

Table 5 Calculation of Heat Transfer in Foamed Concrete Insulation Wall

Mortar Mix	λ, Thermal Conductivity (W/m.K)	w, Wall thickness (m)	R, Thermal Resistance = w/λ	U, Thermal Transmittance = $1/R$	Q, Transfer Calorie		Energy Saving (%)
					daily (kWh/day	monthly (kWh/mo)	
CB *)	0.5	0.075	0.15	6.67	26.13	748.00	0
1	0.18	0.075	0.41	2.24	9.56	286.91	-62
2	0.18	0.075	0.42	2.37	9.30	279.01	-63
3	0.21	0.075	0.37	2.74	10.74	322.17	-57
4	0.19	0.075	0.39	2.56	10.05	301.50	-60
5**)	0.30	0.075	0.25	4.01	15.71	471.40	-37

**) ordinary clay brick ; **) with fly ash*

Conclusion

A study on foamed concrete has shown that it possesses the potential for alternative material for thermal insulation wall. Overall, the thermal properties of foamed concrete depends on the proportion of sand in mortar mixture, where the higher the sand content the lower the density. The amount of sand in cement mortar will affect the porosity of the material (both the texture and sizes), which then lead to improve heat insulation capacity of the material.

The introduction of fly ash will benefit not only increasingthe compressive strength but would also help reducing waste material. Such an application will be an answer for the application of green construction concept. However, it was also understood that adding fly ash into concrete mortar will increase density and thermal conductivity. But as indicated above, the addition of fly ash still has economic advantage over conventional clay brick wall insulation.

References

[1] Cole, R. J. and Kernan, P. C., *Life-Cycle Energy Use in Office Buildings*, Building and Environment, **31**(4), pp. 307-317, 1996.

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