Asian Journal of Applied Sciences (ISSN: 2321 – 0893)
Volume 03 – Issue 05, October 2015

Density and Strength Properties of Lightweight Composite Panel using Polysilicon Sludge

Sangsoo Lee*, Jeonggeun Lim

[a]Department of Architectural Engineering, Hanbat National University
Daejeon, 305-719, Korea

**Corresponding author's email: sslee111 [AT] hanbat.ac.kr*

ABSTRACT---- ***Environmental pollution problem related to global warming is rising all over the world, and the solar-light power generation in eco-friendly energy production industry uses polysilicon sludge as main material. Waste of 2 ton polysilicon sludge is generated in order to produce polysilicon 1 ton, which creates another environmental pollution to produce eco-friendly energy. Recently, the previous wet construction method has continuously changed to dried lightweight wall panels in construction works but the existing lightweight wall panel needs separate curing process with poor water resistance as well as fire resistance and so, it is required to have a research to replace it. In this connection, this study aims to analyze density and strength properties of lightweight composite panel utilizing polysilicon sludge. Lightweight composite panel was manufactured using only inorganic materials without using cement for both surface and core material of panel, and density of core material was 0.79g/cm^3, compressive strength showed 6.23MPa, and flexural strength of panel was 10.8MPa.***

Keywords--- Polysilicon Sludge, Lightweight Composite Panel, Solar-light Power Generation

---

1. INTRODUCTION

1.1 Background of research

Environmental contamination associated with global warming has come to the fore worldwide. Efforts have been made vigorously to produce eco-friendly energy amid depletion of natural resources and crude oil. There have been ongoing multifaceted endeavors to develop eco-friendly energy such as wind power, tidal power, hydroelectric power, geothermal power, solar power, solar-light power generation, etc.

Particularly, solar-light power generation has continued steep annual growth of 42%, the fastest growing segment. However, solar-light power generation requires the device called 'solar panel' which is made primarily from polysilicon. 2 tons of poly-silicon sludge, the waste, are generated from every ton of poly-silicon produced. This implies that production of eco-friendly energy gives rise to another environmental contamination. Polysilicon sludge generated in this way is processed entirely as waste, resulting in lack of landfill sites. As solar-light power generation is expected to outstrip fossil fuel consumption by 2040, a growing number of new polysilicon manufacturing plants have been operational around the globe. Although development of polysilicon manufacturing technology has been pushed forward actively, little study has been conducted on the measures for recycling polysilicon sludge. In addition, dried lightweight wall panels, which represent an improvement from conventional wet method, have recently found increasing application to non-bearing walls for indoor partition in construction works carried out in construction industry. Conventional lightweight wall panels require separate special curing process(such as autoclave curing, etc). However, conventional lightweight wall panels have inadequate water-resistance and fire-resistance and have disadvantage that they generate toxic gases during a fire because they are made from organic materials. Thus, it has become imperative to conduct research into lightweight wall panel made up of inorganic materials. Lightweight wall panel consists of surface material on outer surface and core material filled inside. Surface material is required to have flexural strength of at least 8MPa for application as wall panel while core material needs to achieve compressive strength of 6MPa or higher and low density below 0.8g/cm^3. Therefore, research needs to be conducted to investigate lightweight composite panels using polysilicon sludge.

1.2 Purpose of research

The purpose of this study was to develop surface material and core material of lightweight composite panel by using polysilicon sludge, an industrial by-product that has not been covered by any separate processing procedures and has yet to be researched for recycling. Specifically, this study was intended to analyze the density and strength properties of lightweight composite panel that provides excellent water resistance and fire resistance and does not require any separate special curing process.

2. EXPERIMENT PLANS AND METHODS

2.1 Used materials

Surface materials used in this study are blast furnace slag, polysilicon sludge, PVA fiber, fiber sheet, NaOH, an alkali activator. For core materials, we used blast furnace slag, polysilicon sludge, paper ash, pearlite, and NaOH, an alkali activator. Three types of blast furnace slag used in this study had a density of 2.91g/cm^3 and fineness of 4,460cm^2/g. Polysilicon sludge, a high-purity polycrystalline molecule, had a density of 1.75 g/cm^3 and fineness of 7,120cm^2/g. PVA fiber used in this study had excellent chemical resistance and weather resistance, and particularly, did not generate toxic gases during combustion. Moreover, PVA fiber had a diameter of 40μm, length of 12mm, tensile breaking strength of 1,600MPa, and elastic modulus of 38,900MPa. Fiber sheet was coated with acrylic binder on woven plain fabric based on mesh for dryvit. NaOH, an alkali activator, was in powder form and had a purity of 98% and density of 2.13 g/cm^3. Paper ash was obtained from sludge which had been incinerated after being discarded from selection process at paper mill. The paper ash used in this study had a density of 2.70g/cm^3 and fineness of 3,600cm^2/g. Pearlite used in this study was very lightweight(density ranging between 0.04 ~ 0.20g/cm^3), expanding 10~20 times the original volume due to the generation of void inside as a result of expansion of particles after pearllite was processed. Table 1 presents the chemical composition of binder(blast furnace slag, polysilicon sludge, and paper ash).

Table 1. Chemical component of using materials

Materials	Chemical components (%)							
	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Na_2O	TiO_2
BFS	35.08	13.87	0.52	41.10	3.60	2.36	-	1.20
PS	46.60	0.57	-	45.16	0.69	0.16	2.16	-
PA	13.00	10.10	0.90	65.70	4.40	1.70	-	0.40

2.2 Polysilicon Sludge

Silane raw material is produced through high purity purification process from metal silicon solid called MG-Si with a purity of 99%, as shown in Fig. 1. The silane raw material, produced in this way, undergoes Si precipitation process to produce polysilicon. Using the polysilicon produced in this way, ingot is made. The ingot is sliced to create wafers with a wire saw, which are then stacked like building blocks to form solar photovoltaic module. At this time, silane raw material goes through the process of being separated and recycled. Polysilicon sludge is the waste which remains after this process.

Figure.1 Polysilicon Production process

2.3 Experimental plans

Experimental factors and levels are the same as shown in Table 2 and Table 3. Table 2 shows experimental factors and levels of surface materials, and Table 3 presents experimental factors and levels of core materials. Then water/binder (w/b) ratio for surface materials was set to 0.43. Blast furnace slag and polysilicon sludge, etc., were used as binder. Polysilicon sludge replaced 8% of binder's total weight. The addition ratio of NaOH, an alkali accelerator, was fixed to 7%. PVA fiber was added by much as 2% of binder volume. Meanwhile, 2 fiber sheets were introduced and cured at constant temperature and humidity conditions.

Table 2. Experimental factor and level (Surface Material)

Factor	Level	
W/B	● 0.43	1
Binder	● Blast Furnace Slag, Polysilicon Sludge	2
Replacement ratio of Polysilicon Sludge	● 8 (wt.%)	1
Addition ratio of Alkali Activator	● NaOH 7 (wt.%)	1
Addition ratio of PVA Fiber	● 2 (vol.%)	1
Fiber Sheets	● 2 Sheet	1
Curing Condition	● Relative humidity (80±5) %, Temperature (20±2) ˚C	1

For core materials, water/binder (w/b) ratio was set to 0.46. Blast furnace slag, polysilicon sludge, paper ash, etc., were used as binder. Polysilicon sludge replaced 8% of binder's total weight. Paper ash was added by as much as 9% of binder weight. Pearlite was added by much as 10% of binder weight. Meanwhile, NaOH, an alkali activator, was added by much as 10.5% of binder weight and cured at constant temperature and humidity conditions. Aforesaid experimental factors and levels were set based on optimal mixing according to the preceding studies. The test items which were measured include density of core material, compressive strength of core material, flexural strength of panel, etc.

Table 3. Experimental factor and level (Core Material)

Factor	Level	
W/B	● 0.46	1
Binder	● Blast Furnace Slag, Polysilicon Sludge, Paper Ash	3
Replacement ratio of Polysilicon Sludge	● 8 (wt.%)	1
Addition ratio of Paper Ash	● 9 (wt.%)	1
Addition ratio of Pearlite	● 10 (wt.%)	1
Addition ratio Alkali Activator	● NaOH 10.5(wt.%)	1
Curing Condition	● Relative humidity (80±5) %, Temperature (20±2) ˚C	1
Test Item	● Density of Core Material, Compressive Strength of Core Material, Flexural Strength of Panel,	3

2.4 Experimental methods

As polysilicon sludge is generated in a cake-like state containing some moisture, polysilicon sludge was used as binder after being dried and pulverized separately. NaOH, which was in a pulverized state, was dissolved in the mixing water and stabilized for 24 hours before being used. Lightweight composite panel was produced by making the surface material first as shown in Fig. 2, followed by the introduction of hardened surface material into both ends of separate cast and placement of core material at the center. Polysilicon sludge and paper ash will form hydrogen gas, as shown in formula $Si+2NaOH+H_2O \rightarrow Na_2SiO_3+2H_2+423.8$(kJ/mol) through reaction with unreacted Si component and NaOH, an alkali activator, which are contained in binder, and generate voids in matrix, thus affecting density reduction of core material significantly. Therefore, the panel was produced by removing the foamed material from upper surface of test piece and hardening it from initial setting to final setting after placement of core material.

Figure.2 Lightweight Composite Panel

3. RESULTS AND ANALYSIS

3.1 Density of Core Material

Based on the measurement of density of lightweight composite panel core material, the density was found to satisfy 0.796g/cm^3 which was equal to or less than the target density value of 0.8g/cm^3. The addition of polysilicon sludge and paper ash led to hydrogen gas generation, resulting in formation of void in matrix. The addition of pearlite, a lightweight material, led to low density and lightweight.

3.2 Compressive Strength of Core Material

The compressive strength of lightweight composite panel core material was measured. The compressive strength was found to be 5.2MPa at the age of 3 days and 6.23MPa at the age of 28 days which exceeded the target strength of 6MPa. The very lightweight test piece with a density of 0.796g/cm^3 developed strength exceeding 6MPa, which is considered attributable to the use of polysilicon sludge (made up primarily of SiO_2 and CaO) resulting in compressive strength rising above 6MPa even with low density.

3.3 Flexural Strength of Panel,

The results of test showed that flexural strength of lightweight composite panel reached 8.6MPa at the age of 7 days which exceeded the target flexural strength of 8MPa. The flexural strength rose to 10.8MPa at the age of 28 days, hovering above the target flexural strength. That is attributed to the use of polysilicon sludge in optimal quantity which led to higher strength in the same way as compressive strength. Moreover, the reinforcement with PVA fiber and fiber sheet is considered to have facilitated development of high flexural strength.

4. CONCLUSION

The analytical results of density and strength properties of light composite panel using polysilicon sludge are as follows:

1) The results of core material density test showed that the density stood at 0.796g/cm^3 which was below the target density value of 0.8 g/cm^3, demonstrating excellent lightweight property with performance equal to or greater than conventional lightweight composite panel.

2) The results of compressive strength test of core material showed that compressive strength reached 6.23MPa at the age of 28 days, which exceeded the target compressive strength of 6MPa, demonstrating excellent compressive strength with performance equal to or greater than conventional lightweight composite panel.

3) The results of flexural strength test of lightweight composite panel showed that flexural strength reached 8.6MPa at the age of 7 days which exceeded the target flexural strength of 8MPa, demonstrating excellent flexural strength with performance equal to or greater than conventional lightweight composite panel.

Based on aforesaid results, lightweight composite panel using polysilicon sludge is expected to find extensive applications in construction sites if various aspects are examined such as water absorption, fire resistance, thermal insulation, sound insulation, etc., of lightweight composite panel in the period ahead.

ACKNOWLEDGEMENT

This work was supported by the Technological Innovation R&D Program (S2083341) funded by the Small and Medium Business Administration(SMBA, Korea)

REFERENCES

[1] Jihwan Moon, Jongpil Park, Gyuyong Kim, Sangsoo Lee, Hayoung Song, "The Dynamic Performance Evaluation for Type Replacement Ratio of the Polysilicon Sludge and Fly ash", *Jounal of the Korea Institute of Building Construction*, Vol.12, No1, 2012, pp85~86.
[2] Jihwan Moon, Hayoung Song, Sangsoo Lee, "Dynamic Property of Binary Carbon Inorganic Composite Based on Polysilicon Sludge", *Jounal of Architectural Institute of Korea*, Vol.32, No2, 2012, pp.551~552.
[3] Jeonggeun Lim, Yunmi Kim, Sungyu Park, Sangsoo Lee, "Strength Properties of Non-cement Matrix Using Polysilicon Sludge", *Journal of Architectural Institute of Korea,* Vol.32, No2,2014 pp655-656.
[4] Jeonggeun Lim, Jihwan Lee, Heegon Park, Sangsoo Lee, "Dynamic Properties of the Inorganic Binder Based on Blast Furnace Slag and Polysilicon Sludge ratio", *Korea Institute of Building Construction* Vol.14, No2, 2014, pp146-147