MATEC Web of Conferences 38, 02006 (2016)
DOI: 10.1051/matecconf/20163802006

Design and Development of Green Eco-House

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Abstract. As humanity craves progression, there is an increase in the number of buildings being constructed on a global scale; this in turn leads to an increase in energy consumption to satisfy the development process which leads to more tons of greenhouse emissions can be released to accommodate the energy demand. Due to this there is increase in energy demand; the world has to face the fact that our resources will soon be depleted. This project aim is to construct a prototype of an eco-friendly house which is constructed and powered with minimal CO_2 emissions which replacing cement in construction. The main focus on reducing the production of CO_2 is by utilizing an innovative material known as geo-polymer cement and the usage of a solar panel to power the prototype fully using a clean and renewable energy source. This will in turn reduce our dependency on fossil fuels. Fly ash is created as a byproduct of the combustion of coal in power plants and it is usually disposed however it can be fully utilized by recycling it.

1 Introduction

1.1 Background

Constructions of building are rapidly increasing along with the latest technologies and advancement. Physical development of a country does not only cover construction of buildings in the cities but also the residential area. As the demand continuously increasing, the usage of cement in the production of concrete, which is widely used in the process of construction, has indirectly acted as one of the significant sources of carbon dioxide (CO_2) emission on a global scale, making up approximately 7 percent of global CO_2 emissions from industrial and energy sources [1]. CO_2 is a potent greenhouse gas that plays a vital role in the increase of the Earth's surface temperature through radiative forcing and the greenhouse effect. The geo-polymer concrete which consists of fly ash, sodium hydroxide (NaOH) and sand, will act as the replacement of cement. Fly ash is created as a byproduct of the combustion of coal in power plants and it is usually disposed of and not utilized. So this byproduct can be fully utilized by recycling it and using it for a worthy cause. To overcome the solar panels with low efficiency, a microcontroller, servo motor and other electronic components are utilized to align the solar panel with the sun's position in the sky, this allows for optimum power production by the solar panel during daytime. This research is very important as it boosts the "going green" initiative by building carbon neutral houses in the future which are powered completely by solar energy and produce negligible amounts of greenhouse gases in the construction process, this in turn leads in the direction of balancing the ecosystem and reducing the pollution of our environment.

1.2 Problem Statements

The production of cement will also produce carbon dioxide as a byproduct which will cause the greenhouse effect. In order to reduce the greenhouse

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effect, we need to search for alternatives that will help us to reduce greenhouse emissions. In this project, the normal cement concrete will be replaced by geo-polymer concrete which will produce an eco-friendly house equipped with solar power system.

1.3 Objective

The aim of this research is to build a prototype of an eco-friendly house using byproduct and powered with solar energy which can produce minimal CO_2 emissions. The main focus is utilizing an innovative material known as geo-polymer cement as a replacement for regular cement and usage of a solar panel to power the prototype fully using a clean and renewable energy source; this will in turn reduce our dependency on fossil fuels.

The objectives of this project are:

1. To build a prototype of house by using geo-polymer concrete.
2. To build a solar panel that can rotate to align itself with the position of the sun.
3. To integrate the prototype of the geo-polymer house with the solar panel.

2 Literature Review

Ordinary cement, often called by its formal name of Ordinary Portland Cement (OPC), is a serious atmospheric pollutant. According to [2], he claimed that one ton of Portland cement produces 0.55 tons of chemical Carbon Dioxide (CO_2) in a reaction is released into the atmosphere where made into buildings, bridges and other structures. The term "cement" and "concrete" is often taken as confusion. A cement is a binder whereas concrete is the composite material resulting from the addition of cement to stone aggregates. Cement is sold to companies that make concrete.

The cement is globally used in order to make a concrete in mostly construction but the production of cement will cause a carbon footprint which known as carbon dioxide gas. The cement consumption is globally increasing by 5% per year with the growing of the industries [2]. The cement contains the chemical properties of lime or calcium oxide, CaO: from limestone, chalk, shells, shale or calcareous rock, Silica, SiO_2: from sand, old bottles, clay or argillaceous rock, Alumina, Al_2O_3: from bauxite, recycled aluminum, clay, Iron, Fe_2O_3: from clay, iron ore, scrap iron, Gypsum, $CaSO_4.2H_20$: found together with limestone. Cement, (Ordinary Portland cement), results from the calcinations of limestone (calcium carbonate) at very high temperatures of approximately 1450-1500°C, and silico-aluminous material according to the reaction:

$$5CaCO_3 + 2SiO_2 \longrightarrow (3CaO,SiO_2) + (2CaO,SiO_2) + 5CO_2$$

This means that the manufacture of 1 metric tonne of cement generates 1 metric tonne of CO_2 greenhouse gas. As time passes by, Portland cement manufacture increases CO_2 emissions, and, therefore, the predicted BaU (Business as Usual) values for future atmospheric CO_2 concentration should be corrected accordingly [3].

The only exceptions are so-called 'blended cements', using such ingredients as coal fly ash, where the CO_2 emissions are slightly suppressed, by a maximum of 10%-15%. Fly ash-based geo-polymer cements reduce CO_2 emissions by 90% when compared to Portland cement. The GEOASH (2004–2007) project was carried out with a financial grant from the Research for Coal and Steel of the European Community [4]. The GEOASH project is known under the contract number RFC-CR-04005. Seventeen samples of (co-)combustion European fly ashes were tested on their suitability for geo-polymer cements. Normally, curing of fly ash-based matrices is done at temperatures between 60 and 90°C. In this project, since the idea is to use the geo-polymer as a cement, the curing is taking place at ambient temperature, with a modified (Ca,K)-based geo-polymeric system. The Final Technical and Scientific Report were presented in mid-2008.

The number of photovoltaic installations on buildings connected to the electricity grid has grown in recent years. Government subsidy programs (particularly in Germany and Japan) and green pricing policies of utilities or electricity service providers have stimulated demand. Demand is also driven by the desire of individuals or companies to obtain their electricity from a clean, non-polluting, renewable source. These consumers are usually willing to pay only a small premium for renewable energy [5].

3 Methodology

3.1 Progress of the project

The flowchart below is the progress of the project.

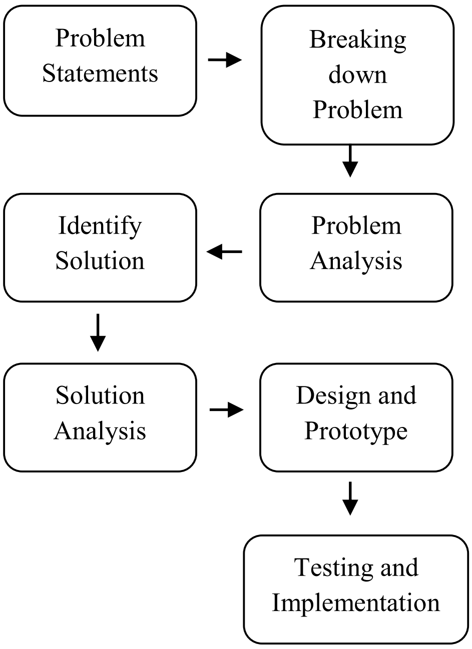

Figure 1: Progress of project.

3.2 Design of the house

The conceptual design for the prototype of the house can be shown in Figure 2.

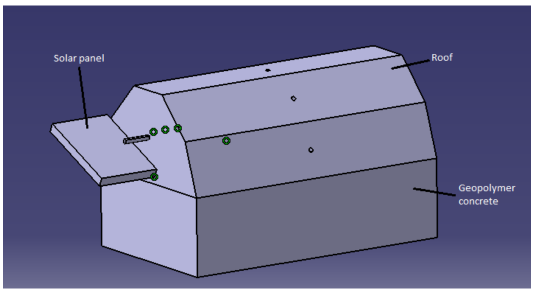

Figure 2: Conceptual design of the house.

There are three main components for the prototype as given below:

3.2.1 Solar Panel

Solar cell also called as photovoltaic (PV) cell convert sunlight directly into electricity. Solar panel is one of the component uses to recycle natural energy which convert from heat energy to electrical energy through radiation and natural convection process. The traditional solar cells are made from silicon are usually flat plate and the most efficient. Solar panels used to power homes and businesses are typically made from solar cells combined into modules that hold about 40 cells.

A typical home will use about 10 to 20 solar panels to power the home. The solar charge controller has been attached to the roof. The purpose of this component is to make a connection between the solar panel, the rechargeable battery and the LED circuit that is in the house in such a way that the solar panel charges the battery and powers the circuit at the same time, in case of inadequate sunlight, the LED circuit is powered by means of the rechargeable battery. This allows the house to be powered throughout the day. The angle of the solar panel also plays important role in gathering maximum radiation from the sunlight. The solar panel should be perpendicular towards the sunlight to obtain the maximum radiation so that the power obtained from this process is more and efficient.

A solar panel need to be placed at the side of the house so that it can rotate different angles depends on the amount of sunlight received by the photoresistor. The solar panel is rotated by using servo motor.

The circuit has been connected and the wiring of the Arduino has been made. The soldering process described in the proposal has allowed the five sensors to be attached to the roof at different angles. The sensors have been strategically placed to ensure the sun shines directly on only one sensor. Each sensor gives a signal of different strength to the Arduino microcontroller and through coding and it can signal to the servo motor which angle to turn the solar panel. The solar panel has been attached to the servo motor by Vero boards.

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The servo motor can rotate from 0 degrees to 180 degrees as there are five sensors with five specific angles such as 70º, 45º, 180º, 135ºand 160º. Each sensor gives a certain value depending on the amount of sunlight shining on it. The Arduino compares the values of all the sensors and choose the angle that coincides with the sensor with the highest value.

3.2.2 Geo-polymer concrete

Geo-polymer concrete is the mix of fly ash and sodium hydroxide. Basically, fly ash material can be getting from byproduct and it does not produce carbon dioxide while sodium hydroxide can be bought in order to make geo-polymer concrete which does not cost expensive.

Currently, in Malaysia industry, the concrete use is a mix of course aggregate, fine aggregate, water, and cement which is the material that will be replaced with fly ash. The cement use nowadays is called as Ordinary Portland Cement (OPC). The procedure to make cement is complicated and use a high temperature. One of the procedures in making cement will release a lot of carbon dioxide gas. This is the problem that occurs in cement process that will cause environmental pollution.

Normally, the concrete use for industry is called as reinforced concrete because the characteristic of concrete itself is to resist the load applied on it which known as tension and compression. The reinforce concrete consist of steel bar and concrete. The function of steel bar is to resist tension while the concrete is to resist compression. When this two materials combined, the load applied on the reinforce concrete can be resist, so that none of the part of the building will collapse because of loads.

A geo-polymer concrete was constructed using two main ingredients which are fly ash and an alkaline. The optimum curing temperature for geo-polymer concrete is 60℃ using 10M sodium hydroxide solution. Sodium silicate is also used as an alkaline activator to enhance its strength, but for this project we only used sodium hydroxide solution as the binder [5]. The mixing process started with weighing the fly ash and sodium hydroxide by following the ratio of 3:1. Both materials are poured inside a mortar mixer to be mixed at a certain stipulated time. Once the mixtures are well-mixed, it will be transferred to our specified mould and inserted into the curing oven at 60˚C for 24 hours. The molarity of sodium hydroxide and curing temperature directly affects the strength of geo-polymer concrete [6].

3.2.3 Roof

The roof is divided into five different angles with five photoresistors to be attached on the roof. The function of photoresister is to detect the sunlight, in every part of the roof in order to make sure that the solar panel will rotate in total of 5 different angles. The reason for the first angle is 70º, which meant to detect the sunlight in the early of the morning (7am – 9am). As for 45º which meant to detect the sunlight in the time before the noon (9am – 11am), therefore we decided to make the second angle less steep compare to the first angle. Then for the top part of the roof which got 180º and meant to detect the sunlight in the afternoon as shown in Figure 2.

3.3 Procedure

There are some procedures for building the prototype of the house. Firstly, all the dimension that required to make the roof parts on the plywood are marked using steel ruler and marker pen. Secondly, the plywood was clamped and cut by using the jigsaw power tool.

Then, as for the angle part of the roof, set the jigsaw base to 20º for the roof angle 70º. Set the jigsaw base to 45º for the roof angle 45º. Next, all the roof parts are assembled and joined them by using the hot-glue gun. After that the parts are joined together as planned in the conceptual design.

Finally, the circuit need to be placed inside the roof and the solar panel is mounted to the side of the roof.

4 Results and Discussion

Geo-polymer concrete is tested for it compression strength. Most of the concrete should be achieved a design compression test to take a larger load to prevent a building for collapse. Three different batch of geo-polymer concrete (A, B, and C) with different concentration of 4M, 6M, 8M, 10M, and 12M. From the result of compression test, 15 blocks of geo-polymer concrete achieved compression design strength which equivalent which normal concrete strength that mixed which Ordinary Portland Cement (OPC). All the three batches were tested by applying equal compressive stress of 90 N and the results were recorded as shown in Table 1.

Table 1: Results for concrete at varied temperatures

Concentration (M)	Average Stress 40 C	Average Stress 50 C	Average Stress 60 C	Average Stress 70 C	Average Stress 80 C	Average Stress 40/60 C
4	0.72	1.57	2.10	1.46	1.71	1.76
6	1.31	2.44	3.25	2.33	2.67	2.75
8	5.70	4.57	6.09	5.45	5.37	5.64
10	5.09	5.03	6.71	5.61	5.78	6.03
12	4.46	5.49	7.32	5.76	6.19	6.42

Based on Figure 3, we observe that the compressive strength of the concrete increases with the increase in concentration of Sodium Hydroxide and also the temperature. However, the most conducive concentration and temperature is 10 M at 60˚C as it gives the most consistent outcomes.

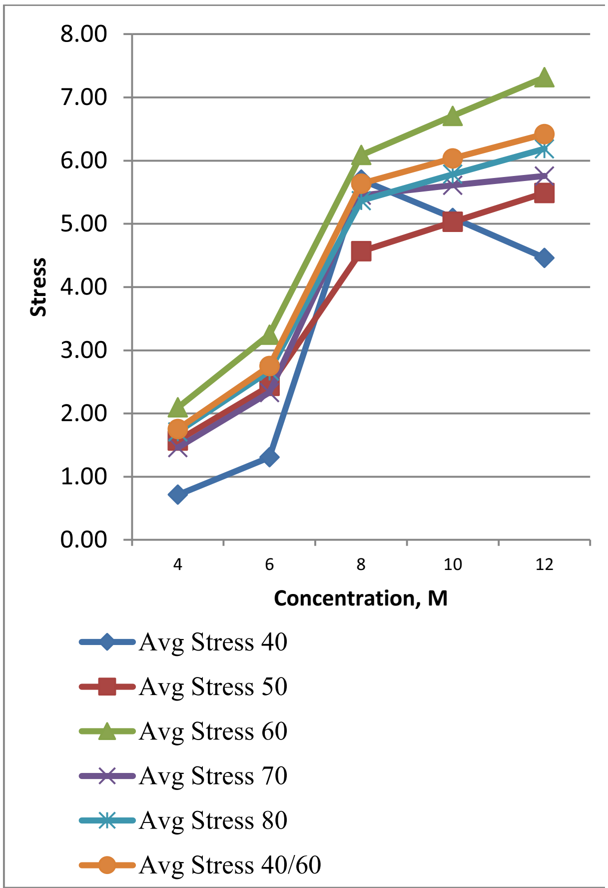

Figure 3: Graph for average stress versus concentration at various temperatures

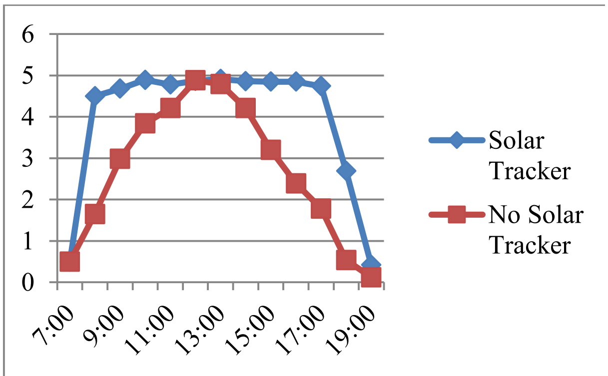

Figure 4: Graph for Power (W) versus Time (hrs) for Solar Tracker and Non Solar Tracker

The Figure 4 shows that the power (Watt) collected in a day from morning until the sunset. The installation of the solar tracker produces constant maximum power throughout the day. Compare to the no solar tracker, the maximum power collected is at noon.

5 Conclusion

As conclusion, Green Eco-House is one of the alternatives to reduce carbon emission. The main part consist in this house geo-polymer concrete with an additional features the solar panel. The development of the prototype is the sample of a house that uses the geo-polymer concrete by replacing cement as the main component in construction which is also equipped with the solar panel. The solar panels has been tested and able to rotate correspond to the sunlight with the help of the shape of the roof. This house can really assist in reducing pollution of the environment by using recycled the waste product of coal from power plant and at the same time producing clean energy without depending on the fossil fuels.

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