INNOVATIVE CURING CHAMBER FOR SUSTAINABLE GREEN GEOPOLYMER BRICK

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ABSTRACT

The aim of this study is to create a new technology to dry the brick that made from fly ash. This technology is simple, efficient, inexpensive and also using a green technology. The technology that I propose in this research is innovative chamber. This technology is based on direct solar heat type. This concept makes the solar heat distributed from above to below the chamber through the roof. The chamber is made using steel structure and has two sections. The wall of this chamber has three layers to make the chamber seal the heat inside the chamber much longer. The chamber temperature was observed under daytime and the temperature range in the chamber is between 30°C to 55°C. The fly ash brick specimen is designed and constructed to test the efficiency of the chamber. There are two mixtures of fly ash brick which is 90kg/m^3 and 100kg/m^3 of sodium silicate. For curing process, there are three different conditions namely, in the chamber, in the oven and at the ambient. The compressive test was conducted in 3,7,28 days. The result from compressive test shows that curing condition significantly affects the mechanical properties of fly ash brick.

Keyword: Fly ash, chamber, fly ash brick, sodium silicate, curing process

ABSTRAK

Tujuan kajian ini adalah untuk mewujudkan satu teknologi baru untuk mengeringkan bata yang diperbuat daripada abu terbang. Teknologi ini adalah mudah, berkesan, murah dan juga menggunakan teknologi hijau. Teknologi yang saya cadangkan dalam kajian ini adalah kebuk yang inovatif. Teknologi ini adalah berdasarkan kepada jenis haba solar langsung. Konsep ini menjadikan haba solar disebarkan dari atas ke bawah ruang melalui bumbung. Kebuk ini dibuat menggunakan struktur keluli dan mempunyai dua bahagian. Dinding kebuk ini mempunyai tiga lapisan untuk menjadikan kebuk tersebut kedap haba di dalam tempoh yang lebih lama. Suhu kebuk telah diperhatikan pada waktu siang dan julat suhu didalam kebuk ialah antara 30 ° C hingga 55 ° C. Spesimen bata direka dan dibina untuk menguji kecekapan kebuk tersebut. Terdapat dua jenis campuran bata iaitu 90kg/m3 dan 100kg/m3 natrium silikat. Untuk proses pengawetan pula, terdapat tiga keadaan berbeza, iaitu di dalam kebuk, di dalam oven dan pada suhu bilik. Ujian mampatan dijalankan pada 3,7,28 hari. Hasil daripada ujian mampatan menunjukkan bahawa keadaan pengawetan memberi kesan dengan ketara kepada sifat-sifat mekanik bata tersebut.

Kata kunci: Abu terbang, kebuk, bata abu terbang, natrium silikat, proses pengawetan

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LIST OF ABBREVIATIONS

OPC	Ordinary Portland cement
CO_2	Carbon dioxide
CaO	Calcium oxide
Na_2SiO_3	Sodium silicate
CHS	Circular hollow section
RHS	Rectangular hollow section
ASTM	American Society for Testing and Materials

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Most people in the earth do not like extreme sunlight heat. But most people also do not know that sunshine can replace other energy like electricity. In other word, this sunshine is called solar energy. Actually, our ancestor was used this solar energy long time ago. They used this solar energy for drying the food, clothes, and others. Nowadays, solar energy in drying application becomes more important and viable alternative since it decrease the consumption of conventional energy by 27-80% (Arata et al., 1993). (Mahapatra and Imre., 1990) said that solar energy easily provides low temperature heating.

Since solar energy can decrease the usage of conventional energy, many researchers' interest in this alternative energy and has been noticed in the design, development and testing of various types of solar dryer like direct (Singh et al., 2006; Saleh and Badran, 2009), greenhouse (Farhat et al., 2004; Sethi and Arora, 2009), indirect (El-Sebaii et al., 2002; Sreekumar et al., 2008) and mixed mode (Tripathy and Kumar, 2009). But according to (Leon et al., 2002) these three systems can be broadly grouped into three major types as direct, indirect, and mixed mode. These major types also depend on the arrangement of system component and mode of solar heat. According to the fact, these dryers operations are primarily based on the principle of natural or forced air circulation mode.

In this study, the chamber is designed to dry the fly ash brick. The chamber is designed to keep the heat from solar as long as possible inside it. This chamber using a direct type which is the chamber was placed at open space to get as much solar heat. To make sure the heat can get through into the chamber, the roof of the chamber is made by transparent plastic board. To make sure the heat reaches at the bottom of the chamber and to make the circulation of the heat uniformly, the aluminium plate has been used as well at inside the chamber. The wall which is behind the aluminium plate has two inch polystyrene to keep the heat from solar energy in the chamber. To make the chamber look nice, zinc plate was used to cover the polystyrene layer.

The specimen that used in this study is fly ash brick. This fly ash brick is used geopolymer as a major material to replaced ordinary Portland cement (OPC). Nowadays, there is increasingly interested in environmental issue that has pressured industries to develop new product more environmentally friendly. This interest drives new material production and process development more to sustainable practices (Gabel et al., 2004). The major material in this specimen has a good potential to reduce CO_2 (Habert et al., 2011). This material was used in the masonry brick production could support construction sustainability. It also gives the contribution to the development to the civil engineering in terms of reducing the consumption of natural resources.

The brick industry can easily use the material because bricks are not a complicated product to produce it (Hodge et al., 2010). Hodge et al,. also said that in the brick productions, not the only concern at environmentally but also a major economic concern. This economic concern includes combustion of fossil fuels for the heat. Besides that, this material could give high strength to the brick itself. The brick also a high temperature resistance and good chemical resistance (Barbosa et al., 2002). The material is fly ash class F. This fly ash was taken from Manjung Power Plant.

Fly ash, also known as pulverized fuel ash and it is produced from burning pulverized coal in electric power generating plants (Barnes and Sear, 2004). Barnes and Sear also explain the cycle ash from electric power plants until becoming fly ash. Firstly at combustion phase, impurities mineral in the coal float out of the combustion chamber along with exhaust gases. Then the fused material rises, it cools and solidifies into spherical glassy particles called fly ash. After that, it is a finegrained where the powdery particulate material that is collected from the exhaust gases.

There are three types of fly ash according to the Standard Specification for Coal Fly Ash (ASTM C618). The first type of fly ash is Class F which is low in Calcium oxide (CaO). These types are normally produced from burning anthracite or bituminous coal. The second type is Class C. Fly ash in this type is generally produced from lignite or sub-bituminous coal. This type also has both pozzolanic and varying degrees of self-cementitious properties. The third type is Class N and it is a raw or calcined natural pozzolans. Example for this type such as some ditomaceous earths, opaline chert and shale, stuffs, volcanic ashes and pumice.

The dimension for this specimen brick are 165mm x 73mm x 222mm. The material for this mixture is fly ash which is main material, sand, sodium silicate and water. These materials are mix according mix design. There are two types of mixture for this study. The differences between these two mixtures are density for sodium silicate which is mixture 'A', the density for sodium silicate are 90 kg/m^3 and for mixture 'B' are 100kg/m^3.

1.2 PROBLEM STATEMENT

Nowadays, pozzolans from industrial and agricultural by-products such as fly ash catch more attraction since their purpose usually to increase the properties in blended cement concrete, the cost and the reduction of negative environmental effects. Using fly ash to replace OPC is a good choice in the brick manufacture. The fly ash has more advantage than OPC for example it makes the brick achieve high strength for the compression test.

However, to make the brick achieve higher strength is the problem. Generally, fly ash brick should cure in the hot place to make it achieve the highest strength. Yet, if the brick exposed to the heat too long or the heat too hot, it will make the brick failed to achieve it strength.

To solve this problem, some manufactures usually use an oven to cure the brick or just dry the brick under the solar heat. When use oven to cure the brick, it would increased the cost to produce it such as the manufactures must pay the high cost for electricity and need more work space for oven. Same for dry the brick under solar heat, the problem manufactures will see that the heat transfer to the brick does not uniform. Besides that, it is difficult to dry the brick under solar heat because of the weather not uncertain. This is the challenges to the fly ash brick manufactures.

1.3 OBJECTIVES OF THE STUDY

The objectives of the study are:

i. To determine the compressive strength of fly ash based geopolymer brick.
ii. To determine the suitability of sunlight based curing chamber for geopolymer brick production based on the compressive strength performance.
iii. To determine the porosity and water absorption of fly ash based geopolymer brick.

1.4 SCOPE OF STUDY

In this study, fly ash from Manjung Power Plant was used to replace the used of OPC. The fly ash were used is class F. There are two types of sample. The difference for this sample is just at the density of sodium silicate. For mixture 'A', density for sodium silicate are 90kg/m^3 and for mixture 'B' are 100kg/m^3. Each mixture has same dimension which is 165mm x 73mm x 222mm.

For curing process, there are three different conditions where the first condition is each sample will be placed in the chamber until the testing day which is

3, 7 and 28 days. The chamber will be placed at open place to make sure the chamber get enough heat from solar. For the second condition is the sample will be placed in the oven for 24 hours after the sample mix at 60˚C. After 24 hours, the sample would be placed at room temperature. For the third condition is the sample will be placed at room temperature.

This study has same test for concrete which is compressive test and density test. For the porosity test, the fly ash brick will be cut into four parts. For the high temperature test, the fly ash brick will be cut into two parts and then these two parts will be placed in the furnace at 600˚C for half hour.

Table 1.1: Mixture of fly ash brick

Sample	Fly ash (kg/m^3)	Sand (kg/m^3)	Na_2SiO_3 (ml)	Extra Water (%)	Curing Condition
A	300	650	90	30	Chamber
B	300	650	100	30	Chamber
C	300	650	90	30	Ambient
D	300	650	100	30	Ambient
E	300	650	90	30	Oven
F	300	650	100	30	Oven

1.5 SIGNIFICANT OF STUDY

The study will serve as the best application of material engineering theories into practice by giving the opportunity to the industry. The application of the chamber to cure the fly ash brick could make manufacturers save their cost by not paying the electricity to use an oven. For the fly ash brick, the utilization of fly ash in brick production brings economic benefits because it is usually a low-cost material and it can be used to replace higher cost materials. Besides that, the advantages of the fly ash are more valuable to replace the OPC.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

In these modern days, manufacturing of brick still uses traditional methods to produce it. Yet, it is an important industry in developing the developed countries. To fulfil the industry demand and in line with technology development in this era, there are advanced technologies in brick making. Many researchers have been conducted to gaining the technologies in brick production. Thanks to that, brick manufacturing is now easy and inexpensive in capital investment.

The technologies in brick making are gaining from basic manual production to semi automated operation (Zhihong Zhang., 1997). Zhihong Zhang also said that, brick technologies grow fast at past four decades in industrialized countries. There are two types of brick that is clay brick and cement brick. The brick making process can divided into four stages which is clay preparation, molding, drying and burning. According to Zhihong Zhang, energy that use in the brick production process happen in the second last stages that is drying and burning green bricks. Thus, energy use has become a critical apprehension due to industrial development. Besides that, environmental issue for energy resource such as global warming and changes in climate has pressured mankind to find an alternative source of energy. The statistics that had done by the World Health Organization (WHO) shows effects of climate change caused the death of 160,000 people per year and the rate will be doubled by 2020 according to their estimation. This climate change can cause natural catastrophe and also some ailment become outbreak among societies. This situation brings new development to industries and also in material production towards a sustainable practices process (Gabel et al., 2004).

Table 2.1: Changes in scale and productivity of brick making in China.

Industry component	1986	1993
Production (billion bricks)	345	641
Number of enterprises (thousand)	100	90
Number of employees (million)	5.0	4.6
Production per enterprise (million bricks)	3.5	7.2
Production per employee (thousand bricks)	69	140
Employees per enterprise	50	51

Source: China Township and Village Enterprises Yearbook (in Chinese), China Agriculture Press, Beijing (volumes published from 1989 to 1995)

Industries have found a renewable energy source such as wind, biomass, solar, hydropower and wave energy that free from CO_2 as an alternative (Schnitzer H et al., 2007; Ernest F Bazen et al., 2009). Although the public awareness of advantages of uses renewable energy, only 15% of these sources were demand in 2006. The estimation at 2030, the trend is increase to 1.8%. Table 2.2 shows a world industrial energy usage for various sources for the year 2006 and 2030 (Abdelaziz Ea., Saidur R., Mekhilef S., 2011). For table 2.3 shows the industrial sector energy usage for some selected countries (Abdelaziz Ea., Saidur R., Mekhilef S., 2011).

Table 2.2: World industrial energy usage for various sources

Sources of energy	2006	2030
Liquids	34.6	28.6
Natural gas	24.1	25.6
Coal	24.8	24.3
Electricity	14.9	19.7
Renewable	1.5	1.8

Source: (Abdelaziz Ea., Saidur R., Mekhilef S., 2011)

Table 2.3: Industrial sector energy usage for some selected countries.

Country	Industrial sector energy use (%)
China	70
Malaysia	48
Turkey	35
USA	33

Source: (Abdelaziz Ea., Saidur R., Mekhilef S., 2011).

Because of higher prices in conventional fuel and resistance of environmental, business are not interested anymore in using fossil fuels in the industrial sector. The greenhouse could be reduced by using renewable energy based on industries. Figure 2.1 shows an industrial energy consumption trend 2006 until 2030 (Abdelaziz Ea., Saidur R., Mekhilef S:, 2011). For that, conventional energy supplies could be changed to renewable energy and then new technology should to be invented and used for the industries. According to S. Mekhilef, R. Saidur, Asafari, solar energy attracted more attention in between all the renewable energy sources as a biggest promising option to be used in the industries. They also claim that solar energy is abundant, free and clean where it is not makes sound or other kind of pollution to harm the environment. Until now, there are many experiments have been conducted to extract solar energy like sun trackers, giant mirrors and solar collectors in an effort to applied it in industrial purpose.

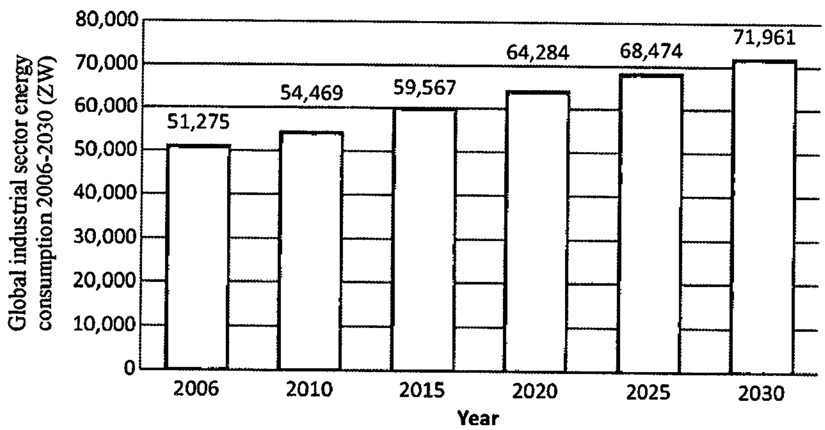

Figure 2.1: World industrial sector energy consumption

Source: (Abdelaziz Ea., Saidur R., Mekhilef S., 2011)

The most common application in the solar energy is steam, drying and dehydration processes, hot water, preheating, concentrations, pasteurization, sterilization, chemical reactions, washing, cleaning, industrial space heating, food, plastic, textile industry, building and even business concerns (Muneer T., Maubleu S., Asif M., 2006). Table 2.4 shows the share of different sources of renewable energy for industrial applications (Cesare S., 2001). Based on world energy shortage and controlling environmental impacts, solar energy applications have received much attention in the engineering sciences. Thus, strong research based on effective and economic methods to captured, stored, and converted the solar energy to useful energy should not be aside (www.life.illinois.edu). In this literature, there is no complete review of solar energy applications in brick making industries. However, brick process and classification of drying systems were discussed in this literature and expected it can help other researchers improve the brick making industries.

Table 2.4: Share of Different Sources of Renewable Energy for Industrial Applications

Renewable source	Annual production (TJ)	% Global demand
Solar thermal	228720	0.523
Solar thermal (electric)	1200	0.003
Photovoltaic	630	0.001
Geothermal	128060	0.292
Geothermal (electric)	151390	0.345
Wind	35760	0.082
Tidal	2160	0.005
Total	547920	0.806

Source: (Cesare S., 2001)

2.2 BRICK MANUFACTURING

2.2.1 Clay Preparation

The raw material for clay brick is clay, where it is usually released from the local land (Zhihong Zhang., 1997). The clay was prepared based on the properties of clay and the finishing product requirement. To make sure the raw material consistency, the clay must be screened and treated as well. The preparation process that involves is crushing the raw material, mixing it with water, blending and screening. There are two major equipments that are extruders and high speed breaking rolls that important in the advance brick plants.

Zhihong Zhang cites that waste fuel or any carbonaceous material could be added in the clay to allow the green brick to burn completely during the burning process. 20% of brickwork with an annular kiln in China mixes other kind of carbonaceous waste in the clay act as a body fuel to reduce coal use (Ministry of Agriculture, 1993). Some practice are not only saves fuel for brick burning, but also reduces industrial solid waste and also saving land resources by adding waste material for clay.

2.2.2 Brick Molding

There are several processes for brick molding in industries. It includes extrusion, soft mud molding, semi dry or dry pressing and vibration compaction. The most widely used methods in China, to produce common brick is extruded. For these processes, the clay is blended in the pug mill and then fed into the extruding machine which consists of a helix rotating within a cylindrical barrel. After that, the clay is forced through an die to form a column of clay. Then, the extruded column is cut into bricks with a wire cutter. There also brick manufactured by manually in China. The process for manual brick making are firstly throws a lump of clay into a collapsible wooden box, slicing away the surplus clay from the top and then removing the wooden box (Young. J., Mcphail. R., 1988).

2.2.3 Brick Drying

Normally, green bricks can be dried in open air or by using some kind of dryer. The large amount of energy requires during brick drying since the process must evaporate the water content in the brick, raise the temperature of the brick and heat the airs which affect the process. Drying 1000 freshly extruded bricks requires

2900-8200 MJ of energy that is equivalent to burning 70-196 liters of No. 5 heavy oil (Knizek, I., 1978).

Racks are used in the drying brick at open air process using solar energy. Since the open air process exposed to rain, brick making with open air becomes a seasonal operation resulting in fully utilized of production capacity (Zhihong Zhang., 1997). Zhihong Zhang also said that drying brick using some kind of dryer can be done on the hot floor with a roof on top which gives protection from the weather and allows the evaporated water to escape. For example for dryer is chamber. Batch process occurs in chamber drying. Finger car is used to load or unloaded the brick into the chamber, where bricks dry by waste heat recovered from the kiln that may be supplied by steam from external sources (Zhihong Zhang., 1997). He also cites that modern chamber dryers have advanced control systems to ensure product quality and heat efficiency. Chamber drying and tunnel dryers are same and more efficient than floor drying. The proof is 14-25% for hot floor drying but 20-54% for chamber and tunnel drying (West, H. W. H., 1969).

2.3 CLASSIFICATION OF DRYING SYSTEM

Drying system can be classified primarily according to their temperature range. It can be divided into two groups that is high temperature dryer and low temperature dryer. But commonly it generally classified according to their heating sources which is fossil fuel dryer (more commonly known as conventional dryers) and solar energy dryer (O.V. Ekechukwu., B. Norton., 1999).

2.3.1 High Temperature Dryer

This group of dryer is required for very fast drying. It's usually used when the product requires a short exposure to air drying like if air drying still in contact with the product until equilibrium moisture is reached, serious over drying will occur. Hence, the product only dried to the required moisture content and later cooled (McLean KA., 1980). This group is normally classified into batch dryer and continuous flow dryer (Hall CW., 1980). According to Hall CW, the product in the batch dryer are dried in a bin and subsequently moved to storage. Meanwhile, continuous flow dryer is heated columns through the product flows under gravity and is exposed to heated air while descending (Hall CW., 1980). Based on the temperature ranges commonly in the high temperature dryer, majority designs are electricity or fossil fuel powered. However, there are very few practically realised designs of high temperature drying systems are solar energy heated (Ekechukwu OV., 1987).

2.3.2 Low Temperature Dryer

For low temperature dryer system, the product moisture content usually brought into equilibrium with the air drying by constant ventilation. Therefore, they do compromise shortly or variable heat input. This enables the product to be dried in bulk and is most suited also for long term storage systems. Hence, they are normally known as bulk or storage dryer (McLean KA., 1980). Mclean KA also said, the variable heat input makes low temperature drying most appropriate for solar energy applications. Therefore, some traditional dryer is most practically released designs of solar energy dryer for low temperature type.

2.4 CLASSIFICATION OF SOLAR ENERGY DRYING SYSTEM

Figure 2.2 shows a systematic classification of drying systems, the sub-classes and the group linage of solar drying systems. Solar energy can be divided into two major groups which are active solar energy drying system and passive solar energy drying system (Ekechukwu OV., 1987). In this major group system, there are three distinct sub-classes that can be classified which are integral type solar dryers, distributed type solar dryers, and mixed mode solar dryers.

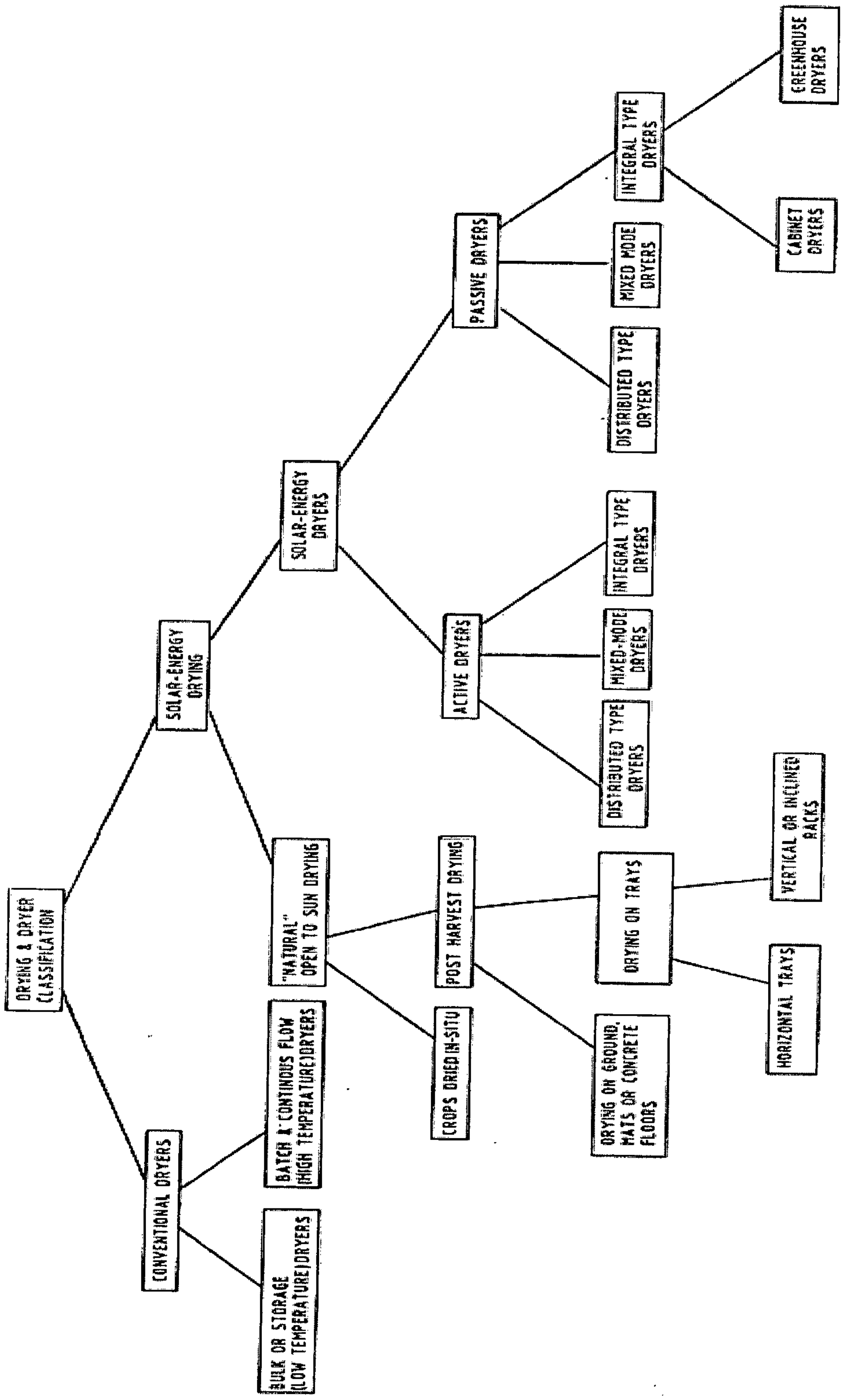

Figure 2.2: Classification of Dryer and Drying Modes.

Source: (Ekechukwu OV., 1987)

Figures 2.3 show the main feature of typical design of the various classes of solar energy.

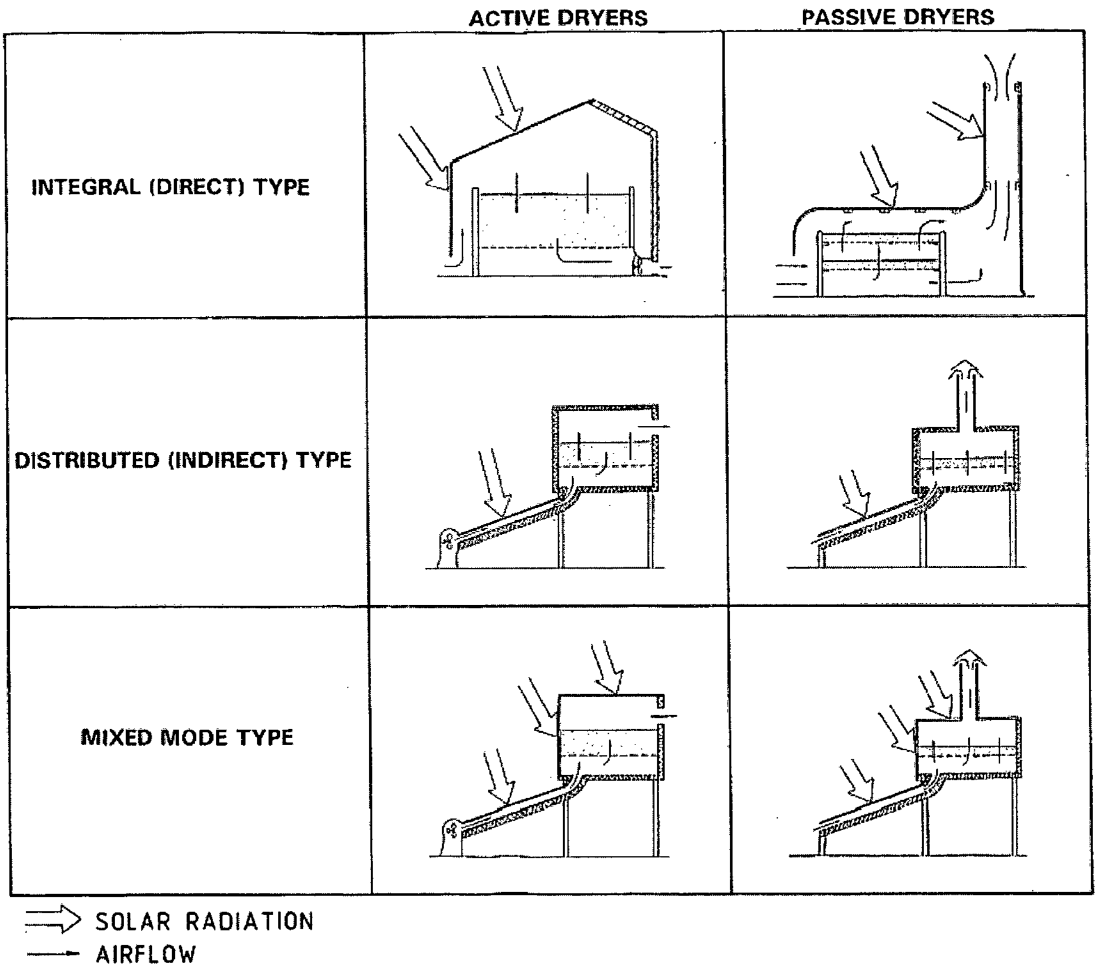

Figure 2.3: Typical solar energy dryer design.

Source: (Ekechukwu OV., 1987)

2.4.1 Active Solar Drying System

Active solar drying systems lean on solar energy. All active solar dryers are forced convection dryers. Active solar dryer depend on solar energy as the heat source but lean on motorized fan to force air circulation (O.V. Ekechukwu., B. Norton., 1999). Conventional fossil fuel dehydrators supply an active solar dryer system in other major application for large scale commercial (Bowrey RG., et., al., 1980). Thus, it's reducing the overall conventional energy use while maintain the control for drying condition. Solar energy could be used if the temperature is warm enough. However, the fossil fuel fired dehydrator could be used to raise the drying temperature.

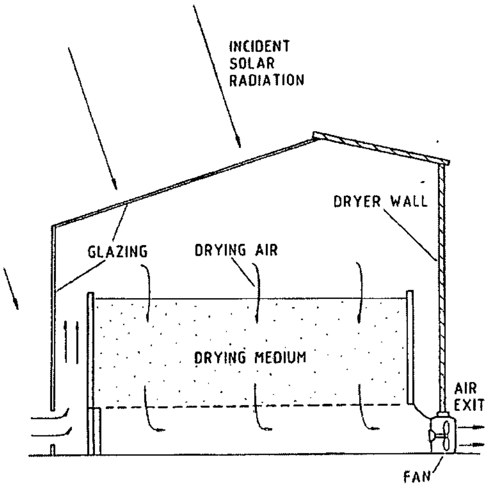

Figure 2.4: A forced convention transparent roof solar barn.

Source: (Ekechukwu OV., 1987)

2.4.2 Passive Solar Drying System

In passive solar drying systems, there are two traditional methods which are undertaken in tropical countries. This method is drying "in-situ" and drying on the ground, mat, cemented floor or placed on either horizontal or vertical shelves exposed to solar radiation and to natural air currents. Although the nature of the process involved, some technique still remain in common use. Because the power of solar radiation is readily available in the ambient environment, a little or no cost is required and low running cost needed.