World Journal of Applied Chemistry
2016; 1(1): 16-21
http://www.sciencepublishinggroup.com/j/wjac
doi: 10.11648/j.wjac.20160101.13

Fly Ash Building Concrete

Mahmoud Mohsen Ali Ahmed Alsayes

Science Department, STEM High School for Boys, Giza, Egypt

Email address:
14135@stemegypt.edu.eg

To cite this article:
Mahmoud Mohsen Ali Ahmed Alsayes. Fly Ash Building Concrete. *World Journal of Applied Chemistry*. Vol. 1, No. 1, 2016, pp. 16-21. doi: 10.11648/j.wjac.20160101.13

Received: September 3, 2016; **Accepted**: September 22, 2016; **Published**: October 15, 2016

Abstract: Despite its significant importance in the economy growth, concrete industry faces several environmental and economic challenges like the emissions of toxic gases during production and high prices of the products, respectively. Consequently, the project aims to produce an alternative solution to the conventional concrete by following the design requirements of low cost, high efficiency and through recycling the fly ash, another industrial pollutant. The idea depends on mixing the fly ash with a liquid alkaline activator, under certain conditions to produce solidified concrete that has proven efficiency after testing. Finally, the mixture, put for 24 hours in 75°C in dry oven to solidify, has shown the best results. In conclusion it can be easily deduced that such cement is an eco-friendly cheap alternative to conventional concrete; in addition to getting rid of another pollutant.

Keywords: Fly Ash, Alkaline Activator, Aggregates, Mixer

1. Introduction

The industrial retardation is one of the grand challenges that faces Egypt, for example the cement industry which is relevant to other domestic grand challenges as the pollution and housing crises. The production of a ton of cement produces a ton of CO2; furthermore, the high price of cement directly increases the building costs. As a result there have been several promising prior substitutes to the cement in the concrete as mixing it with fly ash to reduce its quantity or using gypsum, but these solutions are not practical enough to a provide suitable quality, and they have not stopped the cement usage but only reduced it. Due to the increasing problems, the chosen solution has satisfied three essential design requirements: cost to make the product easily available for customers, quality to assure that the proposed solution is a suitable substitute to cement and can totally compensate it and finally eco-friendly to fight one of the biggest sources of industrial pollution.

In order to achieve these design requirements an ambitious solution was designed that aims to totally substitute the cement used in concrete by using fly ash which contains the main components of Portland cement mixed with alkaline liquid activator made from sodium hydroxide and sodium silicate to increase the polymerization rate. Where the type of ash was determined using the LO.10 of polymerization studied in chemistry. The quantity of materials used and their ratios have been determined after several experiments in several conditions.

2. Other Solutions Already Tried

The current solution:

Now in Egypt and most of the world the most common solution is the use of conventional concrete which is made by mixing: cement, water and aggregates in certain portions (This solution is working well but suffers from the high prices of cement and pollution produced from cement industry.)

The previous solution:

A tried solution was the mixing the cement with gypsum, fly ash or lie to reduce the amount of cement used. (This didn't totally work because it didn't remove the cement totally, and reduced the quality)

3. Design Requirements

Design requirements tell you what success looks like on a project. We chose some design requirements, to meet, that confirm our success and that our project achieve its purposes. These are: the cost – the eco-friendship – the quality.

The cost:

It's one of the most essential requirements in any project because of the bad economic conditions we're facing right now in Egypt. Thus, a project must be affordable for all strata of society, including the poor. That is, our project is a cheap one with affordable materials. That would help reducing the current economic problems.

By comparing the production cost of 1kg of our produced concrete with the cost of 1kg of the normal concrete, we could find whether we achieved this design requirement or not.

Being eco-friendship:

A solution can't be considered successful without being eco-friendly. It mustn't pollute the environment, knowing that it's being polluted by many other sources and our solution shouldn't be one of them.

That is in our project, through the recycling of the fly ash till the production of concrete, nothing harmful is being sent out to the environment.

By comparing the environmental impacts of our concrete production with the conventional one, we could know if we achieved this design requirement or not.

The quality:

It's the main requirement the product relies on. It tests whether the produced concrete is reliable and can replace the conventional one or not. It ensures that our concrete is consistent and valid for use usage as a resistant construction material.

By comparing the quality of our concrete, its compressive strength, with the normal concrete quality, its compressive strength, we could find whether we achieved this design requirement or not.

4. Selection of Solution

One of the most challenging problems in Egypt is caused by the concrete industry as it is responsible for the vast amount of toxic gas emissions. Also the products of this industry are at high prices. This promising problem needs to be solved; therefore we chose our design requirements, which are eco-friendship, high efficiency, low cost, and profitability. We searched about the previous solution to this problem, we found different methods and techniques and compared them according to the design requirement. We chose the techniques with high quality and low cost and we make a lot of modifications intending to cover all of its defects.

We decided to make an idea that makes an alternative solution to the conventional concrete according to the design requirement; thus we used an industrial pollutant to get rid from it, and we used simple chemicals that are cheap in price and work in a certain conditions to produce solidified concrete that has proven high quality. This product is an eco-friendly cheap alternative to conventional concrete.

The stages of the solution were the following:

1st Alternative cement

Fly ash is brought from the burning of coal in an electrical generating station. It is used instead of the Portland cement in producing concrete. It is an efficient, cheap, and Ecofriendly material so it meets the design requirements.

The fly ash is a very important material that Is used instead of cement. The primary components of the fly ash are Silicon oxide (SiO_2), Aluminum oxide (Al_2O_3), and calcium oxide (CaO). Instead of using vast amounts of water in the ordinary concrete, we will decrease the water percentage by 30% compared to Portland cement concrete of the same workability. The calcium content of the fly ash is likely to be the best indicator of the behavior of fly ash, and it depends mainly on the type of the burned coal.

2nd Geo-polymerization

In the Geo-polymerization process we use something called alkaline activator that is composed of sodium hydroxide, sodium silicate, and water. It is efficient, cheap and doesn't harm the people or the environment, thus it meets the design requirement.

Geo polymerization process is very important in the production of the new fly ash concrete. Geo-Polymerization is to form the geo polymer homogeneous paste .This paste is prepared by mixing sodium hydroxide, sodium silicate, and water with ratio 0.6:1:2.4 respectively. Polymerization occurs at a high rate when the alkaline activator contains soluble silicate as compared to the use of alkaline hydroxides only. The addition of sodium silicate enhances the process of geo polymerization. The researches shows that as the molar concentration of sodium hydroxide liquid increases, compressive strength of concrete also increases.

3rd Aggregates

Aggregates are made by mixing fine aggregates such as sand, and coarse aggregates such as the fragments of crushed stones with water. Aggregates are found naturally in Egypt, and have no impacts to the people or the environment. This aggregates proved to have low cost and increase the efficiency of the concrete, hence it meets the design requirements.

Aggregates are fine and coarse aggregates that mixed with water. They are an essential ingredient in concrete. Aggregates account for 60 to 75 percent of the total volume of concrete. Aggregates are important component of the concrete as they are the cheapest component. The ratio of the coarse aggregate to the fine aggregate is 65:35 respectively. This ratio makes a high compressive strength.

4th Cement Mixer

A mixer is made from a container and a DC motor. The mixer doesn't have any environmental impact, and has low cost as it depends only on the little amount of electricity that is responsible for rotating it. It also showed a high efficiency in mixing fly ash, alkaline activator, and aggregates together, consequently it meets our design requirement.

A DC motor is a device that converts (electrical energy) into mechanical energy. This mechanical energy rotates the container around its axis to mix all of the components together to be homogeneous.

5. Selection of Prototype

Low Cost: Ensuring that the new product is at low cost and maintain the quality

Eco-Friendship: Ensuring that the new product doesn't produce any harmful pollutants

Quality: Ensuring that the new product is reliable and at high quality that could replace the conventional product

Stages

1st Fly ash: Meeting the Eco friendship design requirement as it doesn't produce any harmful pollutant that affect the humans or the environment.

Meeting the low cost design requirement as it has a very low cost.

Meeting the high efficiency design requirement as the compressive strength between fly ash concrete and the conventional one is 23:21 respectively.

2nd Alkaline activator: Meeting the Eco friendship design requirement as it doesn't produce any harmful pollutant that affect the humans or the environment.

Meeting the low cost design requirement as it has a very low cost.

Meeting the high efficiency design requirement as the efficiency increases when the mass ratio of sodium silicate to sodium hydroxide is 2.5, and as the sodium hydroxide concentration increase, compressive strength increase.

3rd Aggregates: Meeting the Eco friendship design requirement as it doesn't produce any harmful pollutant that affect the humans or the environment.

Meeting the low cost design requirement as it has a very low cost.

Meeting the high efficiency design requirement as the efficiency increases when the mass of combined aggregates is taken as 60-75 percent, and the proportion between coarse aggregates and the fine aggregates is 65:35 respectively.

4th Cement Mixer: Meeting the Eco friendship design requirement as it doesn't produce any harmful pollutant that affect the humans or the environment.

Meeting the low cost design requirement as it has a very low cost.

Meeting the high efficiency design requirement as the mixer works it provides all the components to be mixed well to provide high quality.

6. Test Plan

Low Cost: Objective: ensuring that our product is cheaper than the conventional concrete and reducing the building process.

Tools: calculator – www.icis.com

Procedures:

1) Calculating the price of 1kg of our geopolymer concrete and 1Kg of conventional concrete.

2) Comparing results to find which is cheaper.

Eco-Friendship: Objective: ensuring that our concrete doesn't produce any harmful pollutants.

Procedures: Comparing the environmental impact of our geopolymer concrete production with the conventional one.

Compressive Strength: Objective: Ensuring that our produced concrete is valid for usage as a resistant construction material.

Tools: 1000*1000*1000 mm3 samples - testing machine – calculator - hand gloves - safety goggles

Steps:

1- Preparing different samples under different conditions: fly ash to alkaline activator ratios, NaOH to Na2SiO3 ratios, curing temperature and curing period.

2- Sample is placed and the machine is turned on to lower the piston against the sample until it breaks, then the piston's removed and compressive strength's calculated by dividing weight by area.

3- Repeating the procedures on all samples and recording the results.

Slump Test: Objective: measuring the concrete consistency.

Tools: Slump cone - measurement scale- Temping rod (steel)

Steps:

1- Slump cone is put on its base

2- Wet concrete is put in three layers each one is temped.

3- When the cone is filled, its top is struck off and the cone is lifted vertically and slowly.

4- The slump is measured using measuring tape.

7. Data Collection

Low Cost: The cost results showed that fly ash concrete was cheaper than the conventional one which increases its role in fighting the housing problem.

Fly ash concrete

Sand price = 7.5 x 7 x 10-4 = 5.25 x 10-3 $

Fly ash price = 15 x 2.143 x 10-4 = 3.2145 10-3$

Sodium Hydroxide price= 100 x 0. 2.45 x 10-5 = 2.45 x 10-3$

Sodium silicate price= 150x 0. 6.12 x 10-5 = 9.18 x 10-3$

Total price =20 x 10-3$ / kg

Conventional concrete

Sand price = 7.5 x 7x 10-4 = 5.25 x 10-3 $

Cement= 105.5 x 15 x 10-5 = 1.58 x 10-2 $

Total price =21.08 x 10-3$ / kg

Eco-Friendship: Conventional concrete raw materials: 1- Chemically inert mineral aggregate (Sand or gravel).

2- A binder (natural or synthetic cement).

3- Chemical additives, and water.

4- Calcareous material (limestone)

5- Silica, alumina, iron oxide and magnesia

Its Environmental impacts: Concrete industry contributes to 7% of the total greenhouse gas emissions.

It produces Sulphur Oxide, Nitrogen Oxide, and carbon dioxide with vast quantities.

It produce VOCs which are precursor to ozone formation and cause health hazard like irritations in respiratory tract and eyes, damage to body systems.

My concrete contains: Fly ash "Silicon oxide (SiO_2), Aluminum oxide (Al_2O_3), and calcium oxide (CaO)", Sodium hydroxide "NaOH" -It results from the reaction of a salt solution and water: $NaCl(aq)+H_2O=Cl_2(g)+H_2(g)+2NaOH(aq)$-, and Sodium Silicate "$Na_2SiO_3$", sodium oxide ($Na_2O$) and silicon dioxide "silica" (SiO_2). They Have no harmful impacts to humans and the environment.

Quality: The results of changing several procedures in the mixing process are shown here in the graphs below

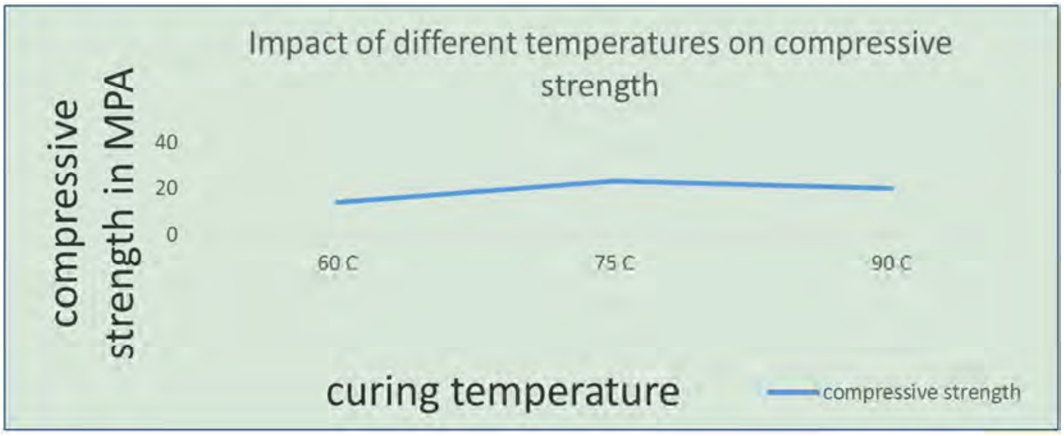

Fig. 1. *Impact of different temperatures on compressive strength.*

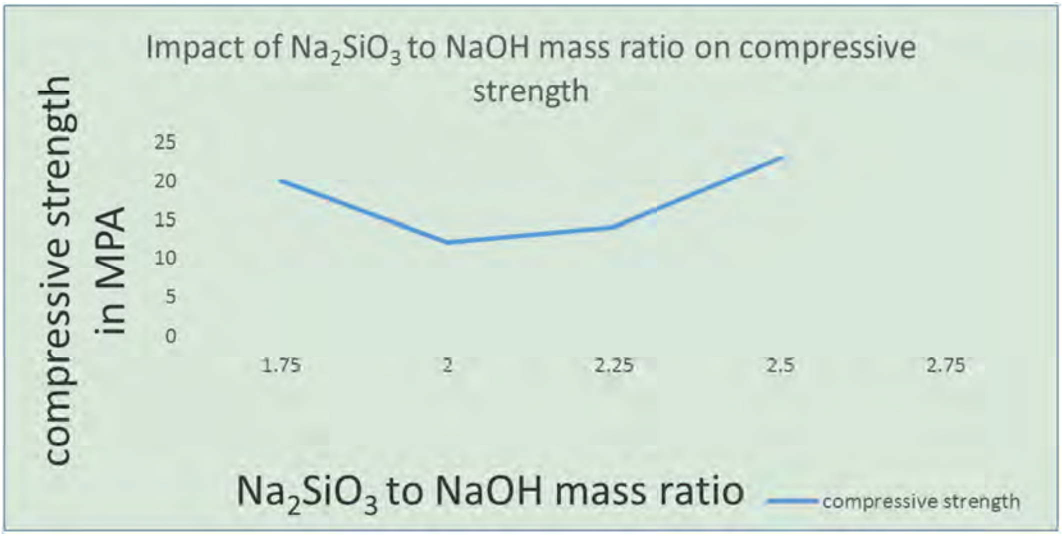

Fig. 2. *Impact of Na_2SiO_3 to NaOH mass ratio on compressive strength.*

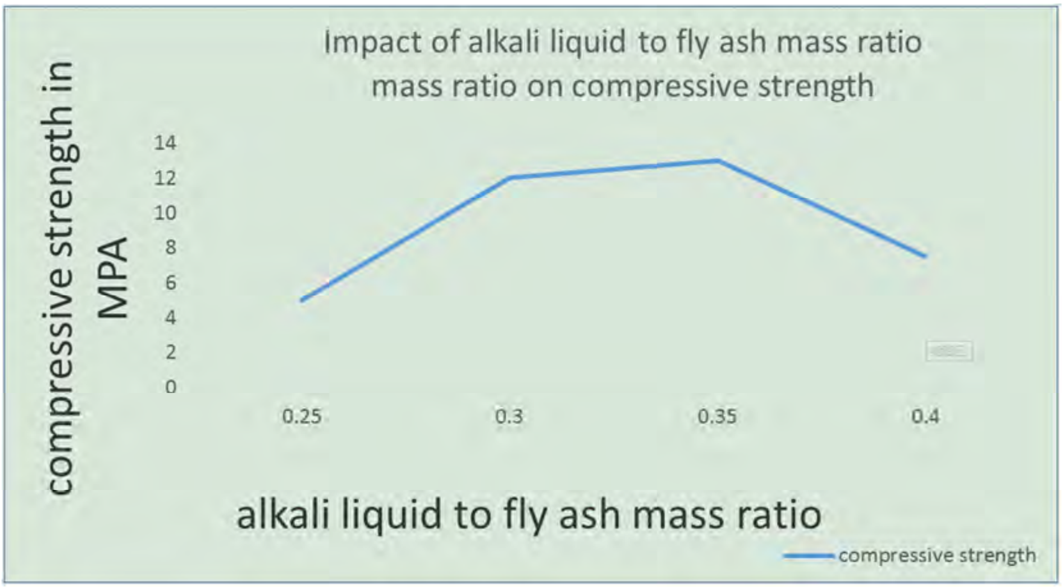

Fig. 3. *Impact of alkali liquid to fly ash mass ratio mass ratio on compressive strength.*

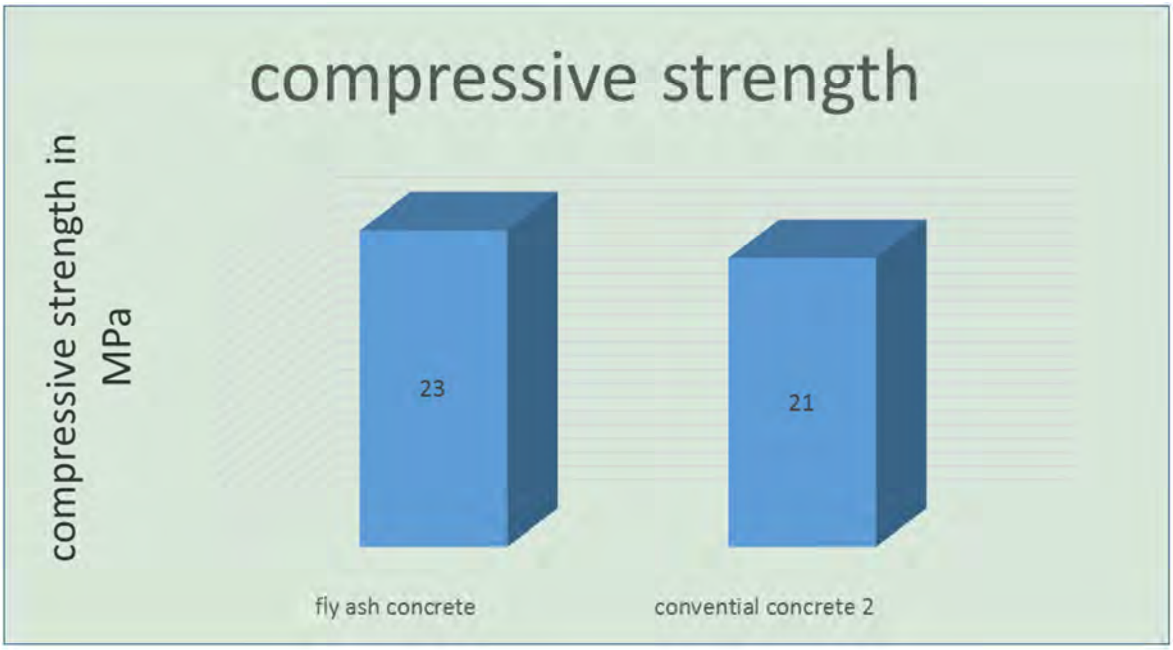

Fig. 4. *Compressive strength.*

8. Discussion

Fly ash is a by-product of burning pulverized coal in an electrical generating station. The fly ash represents an essential part to from the geo polymer concrete, as it is the same composition of the Portland cement. Instead of using the ordinary cement, we will use the fly ash that is more affordable, has less harmful impacts to the people and the environment, and has higher compressive strength. The performance of fly ash in concrete is strongly influenced by its physical, mineralogical and chemical properties. The mineralogical and chemical composition are markedly dependent on the composition of the coal and since it's highly used due to a wide range of domestic and imported coals.

The major difference between fly ash and Portland cement is the relative quantity of each of their several compounds. The microstructure of fly ash appears to be glassy, hollow, spherical particle due to rapid cooling. Furthermore, the surface texture appears to be smooth, dense and highly porous. Fly Ash particles provide a greater workability of the powder portion of the concrete mixture which results in greater workability of the concrete and a lowering of water. Consequently, the use of fly ash should permit the concrete to be produced at a lower water content when compared to Portland cement concrete of the same workability. A gross approximation is that each 10% of fly ash should allow a water reduction of at least 3% required for the same concrete consistency. The calcium content of the fly ash is likely to be the best indicator of how the fly ash will behave in concrete. The calcium content depends mainly on the type of the burned coal.

Low-calcium fly ashes (< 8% CaO)

Medium-calcium fly ashes (8-20% CaO)

High-calcium fly ashes (> 20% CaO)

Alkaline activation is a chemical process in which fly ash is mixed with an alkaline activator. The most common alkaline liquid used in geo-polymerization to form the geo polymer homogeneous paste is a combination of sodium hydroxide (NaOH) and sodium silicate; however, potassium hydroxide and potassium silicate can also be used. The alkaline liquid components are Na2O = 14.61%, Na2SiO3 = 25.18% and water = 59.99%. Alkaline liquid plays an important role in the polymerization process. Polymerization occurs at a high rate when the alkaline liquid contains soluble silicate as compared to the use of alkaline hydroxides only. The addition of sodium silicate enhances the process of geo polymerization. The alkaline solution is prepared with NaOH of molar concentration 12M. As the molar concentration of sodium hydroxide liquid increases, compressive strength of concrete also increases. The mass ratio of sodium silicate to sodium hydroxide is 2.5; the mass ratio of alkaline liquid to fly-ash also is 0.03.

Aggregates are inert granular materials such as sand, gravel, or crushed stone that mixed with water. They are an essential ingredient in concrete. Aggregates need to be clean, hard, strong particles free of absorbed chemicals or coatings of clay and other fine materials that could cause the deterioration of concrete Aggregates, which account for 60 to 75 percent of the total volume of concrete, are divided into two distinct categories fine and coarse. Fine aggregates generally consist of natural sand or crushed stone with most particles passing through a 3/8-inch. Coarse aggregates are any particles greater than 0.19 inch, but generally range between 3/8 and 1.5 inches in diameter. Gravels constitute the majority of coarse aggregate used in concrete with crushed stone making up most of the remainder. We used sand as fine aggregate (FA) and mineral rock fragments that are derived from basalt as coarse aggregate (CA). Aggregates are important component of the concrete as they are the cheapest component. The mass of combined aggregates (CA + FA) is taken as 77% of mass of concrete in the proportion of 65:35 respectively. Furthermore, it provides volume stability by reducing the shrinkage volume; thus, it reduces the cracking potential.

A simple mixer was made using a container and a 12 v DC motor to rotate it. A DC motor in simple words is a device that converts direct current (electrical energy) into mechanical energy. It's of vital importance for the industry today. This system of mixing is made to mix the components together homogeneously as possible.

Recommendations

Making a regeneration for the carbon dioxide that is accompanied with fly ash emissions. The capture of carbon dioxide is made by using a carbon scrubber as sodium hydroxide. First, CO_2 is absorbed by an alkaline sodium hydroxide solution to produce dissolved sodium carbonate. Second, limewater is added to sodium carbonate forming limestone. Third hydrochloric acid is added to limestone to produces carbon dioxide which is stored.

$2NaOH (aq) + CO_2 (g) \rightarrow Na_2CO_3 (aq) + H_2O (l)$

$Na_2CO_3 (aq) + Ca(OH)_2 (s) \rightarrow 2NaOH (aq) + CaCO_3 (s)$

$CaCO_3 (s) + 2HCl (I) \rightarrow CaCl_2 (aq) + H_2O (I) + CO_2 (g)$

Covalent organic framework (COF) is a porous material that act as a catalyst which is a ring-shaped organic molecule with a cobalt atom at its core, called a porphyrin. When added to a solution with two electrodes and some dissolved CO_2, the porphyrin splits it into CO and oxygen.

Acetobacter bacteria is a type of aerobic bacteria that is used to make fermentation to the wastes to produce hydrogen and an industrial product of acetic acid or vinegar

Carbon monoxide that result from the sodium hydroxide scrubbing and hydrogen that result from the fermentation of Acetobacter bacteria are reacted to form methanol according to the following equation. $CO(g) + 2H_2(g) \rightarrow CH_3OH$.

We could use methane as a fuel by making combustion to it according to the following equation:

$2CH_3OH + 3O_2 = 2CO_2 + 4H_2O$

The use of electrostatic precipitators which uses force of induced electrostatic charge to precipitate particles

The use of 0.5 µm bag filters to collect fly ash particles by preventing the fly ash from escaping.

For the next teams: We recommend the next teams that will work on the project after us to work in the optimum conditions that we mentioned before in the conclusion because these conditions proved the best quality and also to find other materials that can increase the quality while decreasing the price

References

[1] Thomas, M. (n.d.). Fly ash for concrete. Is548-optimizing-the-use-of-fly-ash-concrete. doi:10.3403/03270538u.

[2] Lackner, K., & Grimes, P. (2014). Capturing Carbon Dioxide From Air. CO2 Management Technologies Carbon Capture and Storage, 363-376. doi:10.1201/b16845-19.

[3] T. M. (2013). Partial Replacement Of Cement And Fine Aggregate By Using Fly Ash And Glass Aggregate. International Journal of Research in Engineering and Technology IJRET, 02(13), 351-355. doi:10.15623/ijret.2013.0213066.

[4] Joshi, S. V., & Kadu, M. S. (2012). Role of Alkaline Activator in Development of Eco-friendly Fly Ash Based Geo Polymer Concrete. IJESD International Journal of Environmental Science and Development, 417-421.

[5] Abdullah, M. M., Kamarudin, H., Bnhussain, M., Nizar, I. K., Rafiza, A., & Zarina, Y. (2011). The Relationship of NaOH Molarity, Na2SiO3/NaOH Ratio, Fly Ash/Alkaline Activator Ratio, and Curing Temperature to the Strength of Fly Ash-Based Geopolymer. 44-49.

[6] L. Y. (2015). Soaking Up Carbon Dioxide and Turning it into Valuable Products | Berkeley Lab.

[7] Adam, D. (2007). The unheralded polluter: Cement industry comes clean on its impact.

[8] Zumdahl, S. S., & Zumdahl, S. A. (2014). Chemistry, ninth edition Steven S. Zumdahl, Susan Arena Zumdahl. Australia: Brooks/Cole Gengage Learning.

[9] Desideri, U., Arcioni, L., & Tozzi, M. (2008). Feasibility study for a carbon capture and storage project in northern Italy. International Journal of Energy Research Int. J. Energy Res., 32(12), 1175-1183. doi:10.1002/er.1454.

[10] Ren, J., Lau, J., Lefler, M., & Licht, S. (2015). The Minimum Electrolytic Energy Needed To Convert Carbon Dioxide to Carbon by Electrolysis in Carbonate Melts. J. Phys. Chem. C The Journal of Physical Chemistry C, 119(41), 23342-23349. doi:10.1021/acs.jpcc.5b07026.

[11] Schiller, B. (2015, June 18). MIT Students Create A Brick That Could End Pollution From Dirty Brick Kilns. Retrieved May 22, 2016, from http://www.fastcoexist.com/3047345/mit-students-create-a-brick-that-could-end-pollution-from-dirty-brick-kilns.

[12] Basham, K., & France, T. (2007). What is Fly Ash? Retrieved May 22, 2016, from http://www.concreteconstruction.net/concrete-construction/what-is-fly-ash.aspx.

[13] Oh, E. (2015, July 15). This New Brick by MIT-Researchers Uses Little Energy and Helps Deplete Landfills.

[14] R. (2013). Homemade cement mixer. Retrieved May 22, 2016, from https://www.youtube.com/watch?v=W4WA0Ua4fFs.