EVALUATION OF ENERGY AND CO_2 EMISSION FOR CONCRETE WASTE

***Pooria Rashvand[1], Muhd Zaimi abd Majid[2], Khairulzan Yahya[2],Mohammad Moslemi Haghighi[3], Vahid Bigdeli Rad[4]**

[1]Faculty of Civil Engineering, Universiti Teknologi Malaysia, UTM Skudai, Johor 81310,Malaysia; Email: *rpooria2@live.utm.my (Corresponding author)

[2] Faculty of Civil Engineering, Universiti Teknologi Malaysia, UTM Skudai, Johor 81310,Malaysia

[3] Department of Architecture, College of Engineering, Marvdasht Branch, Islamic Azad University, Marvdasht, Iran. Email: moslemi09@yahoo.com

[4] Department of Urban & Regional Planning, Faculty of Built Environment, Universiti Teknologi Malaysia, Johor, Malaysia Email: vahid.bigdeli@gmail.com

ABSTRACT : *A large number of wastes produced each year by the construction and demolition activities. This leads to the public concern by producing a large pollution to the environment. Concrete after water is the second most consumed product on the planet. The huge popularity of concrete also carries environmental costs, the most harmful of which is the high energy consumption and CO_2 release during the production. This paper investigates the amount of energy used and CO_2 emission generated during the production of concrete. Furthermore to estimate the total impact of both indicators based on concrete wasted generated on site. Data were obtained through questionnaire survey and interview within the building construction projects in U.T.M. These impact assessment were followed the life cycle assessment (LCA) methodology. The results show that the raw material production and concrete transportation is the main contributor to the total environmental load. The highest impact value was generated during the production of cement at upstream level. The amount of energy used and CO_2 emission by cement production was about 70 percent of the total embodied energy and 95% of the CO_2 emissions of concrete production. The transportation of concrete is the largest contributor equal to 25% to 28% the production of concrete and on the other hand 12% to 14% for CO_2 emission.*

Keywords: Environmental impact, Energy and CO_2 emission, Construction waste

INTRODUCTION

The impact of concrete material to environmental and human health impacts are a hidden cost of our built environment. The impacts that may occur along the life cycle such as manufacturing, installation, transportation, use and disposal of construction materials could be major, yet often invisible. The materials for construction and products can be manufactured hundreds, even thousands, of miles from a project site. However the extraction and manufacturing at the project site affect the ecosystems and it is unseen at the location. Similarly, the extract of raw materials for such products can happen far from the manufacture point which affects the environment. Transportations use fuel and make pollutions to the atmosphere. Disposal of manufacturing waste produce environmental impact as well. These impacts are “invisible” because they are not happening in the site.

Almost 3.7 million tons of concrete were consumed in buildings, roads and other construction projects in Malaysia in 2010. That’s why the concrete is the most common materials in building on the market. In concrete, aggregate is the main ingredients with 70% to 80 %, cement with 10-20 % and water with 7-9 % and also to improve better performance of concrete for specific behavior, chemical admixtures (less than 1 %) are added.

Portland cement is the key ingredient in concrete binding the aggregates together in a hard mass. However, it is also the ingredient in concrete that produces the greatest environmental burden. In 2006, more than 2 billion tons of Portland cement were consumed worldwide, with 131 million metric tons (MMT) consumed in the United States. This is a 16% increase over 2002. Ninety-nine MMT of cement were produced in the United States and 32 MMT were imported, primarily from Canada, Thailand, China, and Venezuela [1].

Production of cement is an energy-intensive process with primarily use of fossil fuel sources. Cement composes about 10% of a typical concrete mix but accounts for 92% of its energy demand. Cement production requires the preprocessing of large quantities of raw materials in large kilns at high and sustained temperatures to produce clinker. An average of almost 5 million Btus is used per ton of clinker. In 2004, the cement sector consumed 422 trillion Btus of energy, almost 2% of total energy consumption by U.S. manufacturing [2].

Portland cement manufacturing include different emission such as carbon dioxide (CO_2), particulate matter, carbon monoxide (CO), sulfur oxides (SOx), nitrogen oxides (NOx), total hydrocarbons, and hydrogen chloride (HCl). Emissions are different from different type of cement, compressive strength, blended constituents and CO_2 emissions. The cement sector as the main greenhouse gas is responsible for about 5% of all man-made emissions of CO_2 [3].

The impact of aggregate production in both terms of manufacturing and CO2 emission are not significant. The considerable impact by the aggregate production refers to dust in operations of mining and blasting, quarry roads, loading and unloading, crushing, screening, and storage piles which are not the concern of this paper [4].

With the fast development and growth in Asia, the construction and demolition(C&D) impact on environment are becoming a critical issue in urban waste management[5]. C&D waste management are not well known in developing countries such Asian region. The shortcoming such as type of waste, resource depletion, shortage of landfill and illegal dumping, among are existing in this region. Moreover, these countries in Asia does not have enough information on C&D waste and management aspects, especially on C&D waste generation and composition; practices and policy, key actors and participation of different stakeholders' [6].

According to Graham (2009), construction activity was regarded as one of the major contributors of CO_2 emissions and other greenhouse gases to the atmosphere [7]. According to Kulatunga et al. (2006), around 40% of the waste that generated obtains from construction and demolition of buildings [8]. The construction industry in Malaysia produces a lot of waste that makes huge influences on the environment and consequently will increase the public concern. Therefore, the reduction of waste in construction has become a critical matter. There exists different source of waste in construction at the project site that concrete and aggregate is the largest component of waste in site with 65.8% [9]. The production of $_{CO2}$ has been lead to climate change and global warming and Malaysian governments have plan specific targets to reduce national emissions. Half of the energy in the world was consumed by building [10]. Concrete has the highest portion in consuming energy in the building. Production of concrete on sites is of direct importance both in terms of the contribution to CO_2 and energy. The impact of Environmental and human health of materials are a hidden in our environment. The impacts from transport, manufacture, use, installation, and disposal of construction materials can be significant, yet often invisible. The aim of this research is to investigate the impact of concrete waste in construction sites in term of energy consumption and CO_2 emission: to achieve the aim, the following objectives were identified.

A. *To determine the amount of concrete waste in construction sites.*
B. *To estimate the amount of energy used and CO_2 emission for production of concrete.*
C. *To estimate the total energy and CO_2 emission based on the different weight of concrete waste on sites.*
D. *To evaluate the disposal option of concrete waste.*

Literature review

Concrete is the most commonly used material in the world, while water is regarded as the second one on the planet. Each year the concrete industry uses 1.6 billion tons of cement, 10 billion tons of rock and sand and 1 billion tons of water worldwide. Every ton of cement produced requires 1.5 tons of limestone and fossil fuel energy inputs [11]. And its use is expected to double in the next 30 years (Eco Smart Concrete).The huge popularity of concrete also carries environmental costs, the most harmful of which is the high energy consumption and CO_2 release during the production of Portland cement. While the resources for aggregate and cement are considered abundant, they are limited in some areas, and more importantly, mining and extraction of the raw materials results in habitat destruction, and air and water pollution [11].

Cement is a hydraulic binder, which hardens when it is mixed with water. The main constituents of cement are limestone and clay. However in 2006, more than 2 billion tons of Portland cement were consumed worldwide, with 131 million metric tons (MMT) consumed in the United States. This is a 16% increase over 2002. Ninety-nine MMT of cement were produced in the United States and 32 MMT were imported, primarily from Canada, Thailand, China, and Venezuela [1].The production of cement is an energy-intensive process using primarily fossil fuel sources. Cement composes about 10% of a typical concrete mix but accounts for 92% of its energy demand [4].CO_2 emissions. Worldwide, the ceme$_{nt}$ sector is responsible for about 5% of all man-made emissions of CO_2, the main greenhouse gas that make global climate change [3].Coarse and fine aggregates in concrete make up between 60% and 75% of the concrete volume. Aggregates are either mined or manufactured. Energy to produce coarse and fine aggregates from crushed rock is estimated by the PCA's Life Cycle Inventory to be 35,440 kJ/metric ton. The energy to produce coarse and fine aggregate from uncrushed aggregate is 23,190 kJ/metric ton [4].

C&D waste is a highest component of the solid waste stream. This is very critical since the large quantities of it could either be reused or recycled. C&D has been working on reducing the waste that sent to landfill, on contrary working on placed them as reuse and recycle. From this point, a problem arised in Asian countries for the disposal sites of which C&D waste largely account to it[4].on G8 Sea Island Summit in USA in 2004, the three Reduce, Reuse, and Recycle ("3Rs") Plan and its implementation on Science and Technology for Sustainable Development were adopted. Further, in 2005, these three actions were launched formally at a Ministerial Conference in Tokyo, Japan [7].

Asian countries have the largest C&D waste generation in million metric tons. China, Japan and South Korea have the largest amount of waste generation. Central Pollution Control Board India estimated the total generation of waste from construction industry to be 14.7 million tons per year [12]. Different countries have different roles and regulation for controlling of waste generation. Some countries only consider large and middle project size to comply with the construction regulations. However many countries does not have the recognized regulation for demolition. Countries like Malaysia, Indonesia, India and Thailand practiced demolition in only few states. No regulations are formed for the demolition activities at present in many countries in Asia.

The environmental impact from the construction industry has become a critical issue. The construction industry produced about 32,710 tons of construction wastes per year in 1998, nearly 15% above the figure in 1997. The data obtained from Environment Protection Department (EPD) [13]. To have the right management for the large quantity of construction wastes, a policy must be adopted for disposing waste to either land reclamation or landfills. For many years, landfill was the convenient and cost-effective way to the wastes that generated from the industry [14]. Construction wastes contain 29% of the solid-wastes in the USA. The landfills, originally expected to last 40 to 50 years [15]. From the investigations, the construction industry is producing a large amount of waste and therefore it is critical to consider some actions to protect the environment through managing construction wastes properly. After the structures were demolished, concrete from the waste will be crushed and will be used again as a virgin aggregate. The virgin aggregates will be used in different forms for wide variety of construction application. USA consumed more than 2 billion tons of aggregates each year; however 5 percent of these aggregate came from recycled sources such as asphalt pavement and concrete [16]. Concrete is recycled in an "open loop" i.e., concrete is recycling into a different product other than itself.

In Malaysia, few roles and regulating were conducted in some cities that involved with construction waste management. The regulations are as follows: Natural Resources and Environment Ordinance (NREO), Local Authorities Cleanliness by law (LAC) and Local Authorities Ordinance (LAO).

Case Study

Three different construction sites in Malaysia were visited and the data required for the analysis were gathered. Data for the study was collected by questionnaire survey and interview. The questionnaire was structured into four sections.

Section A: To obtain information about the respondent's background

Section B: To survey the level of wastage in construction sites

Section C: To survey the different mixing design

Section D: To survey disposal option

Subsequently, data being analyzed and their results and inference will be presented.

The environmental assessment follows the standard LCA methodology, (ISO 14040-14043). The results are presented both per kg material for each raw material and per functional unit which is equivalent to 1 m^3 of concrete. The data reported included, energy, and CO_2 emissions to air for each stage in the manufacturing. The ready mixed concrete for three super structure building represents in this study with the strength levels 20 MPa (3,000 psi).

The aim for the inventory phase is to determine the amount of energy, materials and CO_2 pollutants that produced with the product.

The data for production of cement and other ingredient of concrete collected from various ingredients utilized in cement production in Cement AB's report. The aggregate production Data is obtained from an existing LCA report [17]. Data for admixtures were obtained from an EPD by the European Federation of Concrete Admixture Associations (EFCA). Data on transportation modes, Cement, aggregates and other constituent materials transportation to ready-mix plant and distances for raw materials are obtained from NTM [17].

Comparison of disposal options i.e. Land filling and recycling was also conducted by using data sources of emission factors developed by the U.S. Environmental Protection Agency (EPA) such as greenhouse gas (GHG) emission factors for recycled concrete, and land filling. To estimate the advantages of using recycling concrete to the virgin aggregate, the following steps were conducted: Step 1: To calculate the emission from the virgin aggregate production, Step 2: To calculate the emissions related to the transportation process, Step 3: To calculate the differences between the emission occurred by recycled and production scenarios.

The analysis cement replacement material like Fly ash and Slag was also conducted. The data for Slag manufacture are obtained from LCI data and the Emission by EPA U.S.

System boundaries

Figure 3.1 shows the different phases of the concrete life cycle that included in this study. Since water is not considered as a limited resource so that it is excluded from this study. The concrete carbonization was not being taken into consideration since the duration of this process is too long for this study. Concrete plant distances are assumed 100 km (60 miles) for Portland.

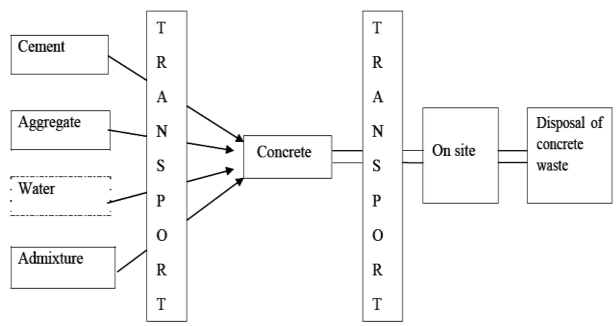

Figure 1. General flow chart of concrete life cycle (Jeannette Sjunnesson, 2005)

Data analysis

Upon the collection of questionnaire, every type of the data received under different question will be separated to answer different study objectives. The data will be analyzed manually by using the tables which mentioned in this chapter. For calculation the wastage of concrete level, there is formula [14].

(1) Cumulative order quantity

(2) Cumulative work done

(3) = (1) - (2) = wastage}

Stages of the study

Three stages of the action were formulated for the approach of the study. In stage 1, in depth literature reviews were conducted related to the interest of the study. This part of methodology is same as what has been done in the study by Rashvand and Abd Majid [18]. This stage involve of a search on the 'review of the current concrete wastage issues in construction industry sites. Stage 2 comprises of interview and questionnaire survey involving the key personnel of stakeholders. The target respondents were identified by their qualification. In the questionnaire there are three sections which start by finding the amount of concrete wasted in construction sites by asking for quantity of ordering and cumulative of work done for the concrete for super structures.

The second part consists of amount of ingredient for making of concrete in 1 m3 from aggregate, water, cement and admixtures. The third part would ask about the disposal of concrete in different situation such as Recycling or Land filling and Incineration. Stage 3 comprise of analysis and discussion.

FINDINGS

Result of the amount of concrete used at superstructure from three different construction sites were, 1728m3, 370m3, 500m3, and the amount of concrete wastes generated were 84 m^3, 20 m^3, and 20 m^3 respectively. The amount of concrete waste indicated that the wastage level is about 5%, 5.5 %, and 4% which are considered more than the norm for the concreting trade which is 4 % [12].The aim of the inventory phase is to investigate the amount of all materials, energy, and pollutants that lead to the product. This includes the manufacturing of Portland cement, aggregate, transportation of materials to site, concrete plant operations, and admixture production. This was done to find out the energy wasted in production term and environmental impact by CO_2 emission by this wastage.

Based on the following figures, it can be observed that 4.84%, 4.33% and 4% are extra percentage of the energy used to produce these amounts wastage. 7 %, 5.5 %, and 4 % are the extra percentage of CO_2 emission produced by the amount of concrete wasted in construction sites.

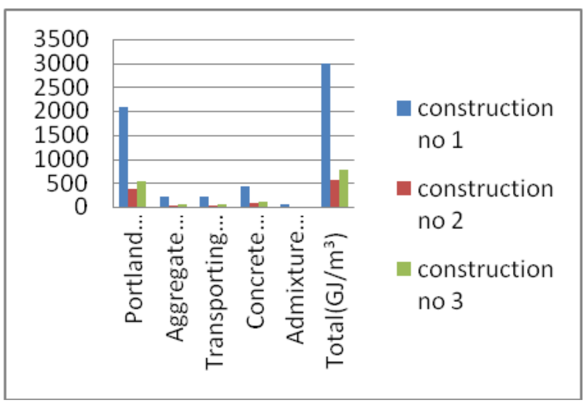

Figure 2. Energy input of total concrete production

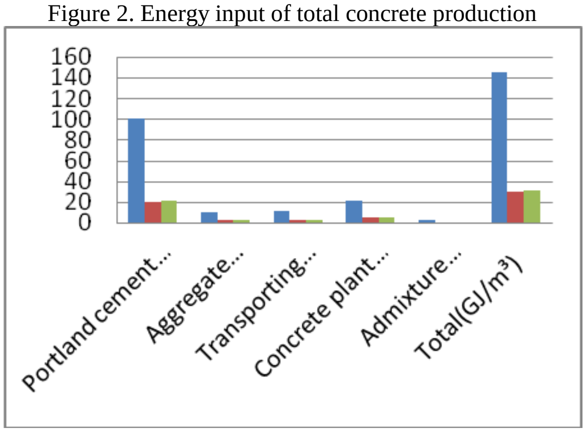

Figure 3. Energy input for total waste production

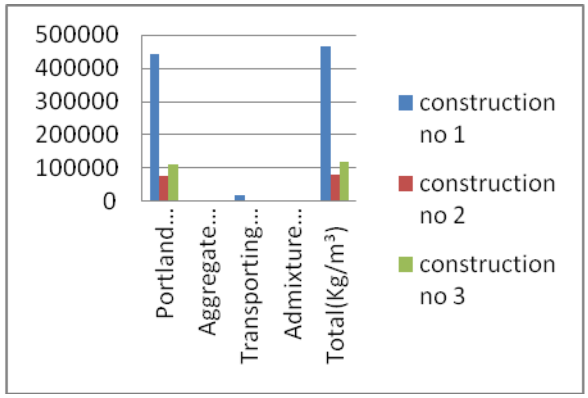

Figure 4. CO_2 emissions by total concrete production

Based on the following figures, it can be concluded that transportation of concrete to the site is one of the important and critical factor in both energy consumption and CO_2 emission in which in this study found out that transportation the concrete to the site is equal 25% to 28% the production of concrete and on the other hand 12% to 14% also equal for CO_2 emission. So that by reduction the distance between concrete production and delivering on site, it can useful in both terms of CO_2 emission and energy consumption.

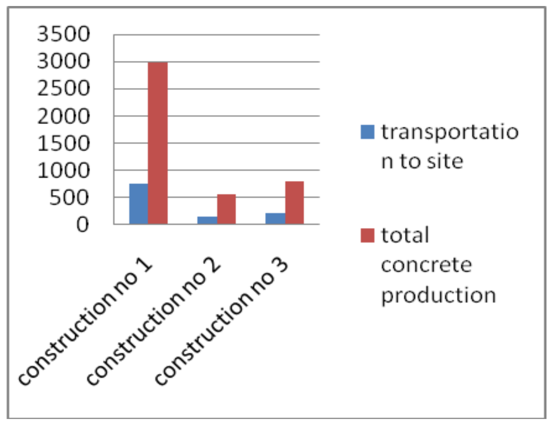

Figure 5. Energy comparison of total energy for concrete production and transportation to site

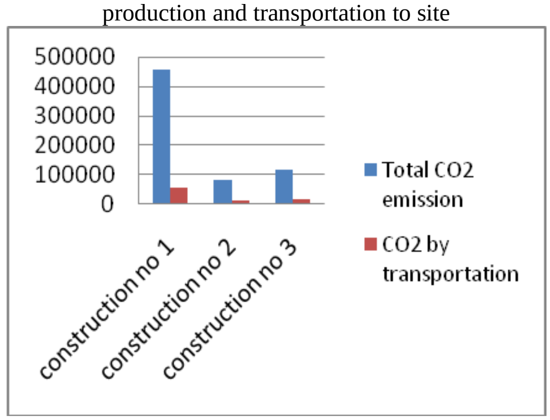

Figure 6. CO_2 comparison of total energy for concrete production and transportation to site

End of life

Based on the finding, and as it shows in Figure 7, Recycling of wasted concrete can be useful by 1.5 to 2 times more saving energy and CO_2 emission than producing virgin aggregate.

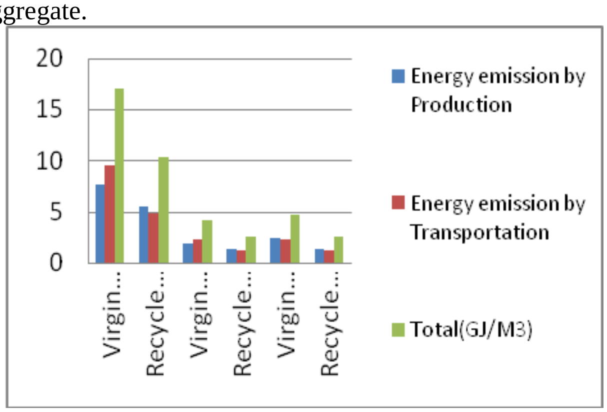

Figure7. Energy Comparison between Virgin and Recycled Aggregate

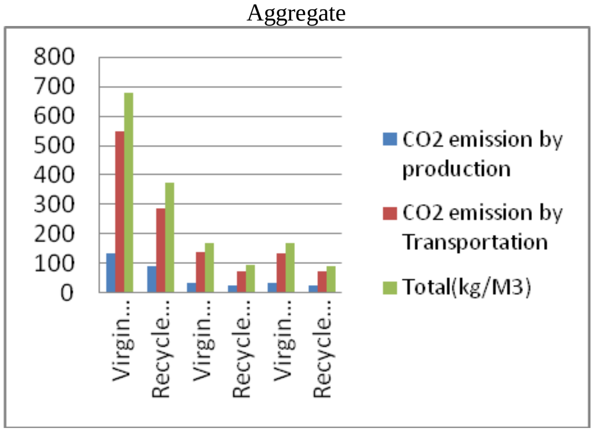

Figure 8. CO_2 emission between Virgin and Recycled Aggregate

Land filling

As a result, the emission of landfilling occurs from collection of the waste and operates of landfilling. 1932 kg, 460 kg, 460 kg are the CO_2 emission by land filling the wasted concrete.

DISCUSION

The data presented, documents the LCI for different concrete mixtures utilizing slag cement and fly ash. The mixtures include ready mixed concrete. Slag cement mixtures assumed 35 percent slag cement and 20% fly substitution for Portland cement. Energy and CO_2 emissions are reduced significantly once slag cement and fly ash were used as aggregate replacement for Portland cement in concrete. The energy that saves with using slag cement is ranging from 29 to 30 percent and on the other hand a carbon dioxide emission was saved for 31 to 33 percent; and on the other hand 20% fly ash can save energy for 19 to 20 percent and CO_2 emission for 16 to 17 percent.

CONCLUSION

The finding of the study shows that the production of raw material together with the transportation and concrete plant operations were the main causes for the concrete environmental impact. Cement was consumed energy more than other materials. Although it is only used for 10 to 20 percent of an entire concrete mixture, the energy that they produced is up to 70 percent of the total embodied energy and 95% of the carbon dioxide emissions of concrete.

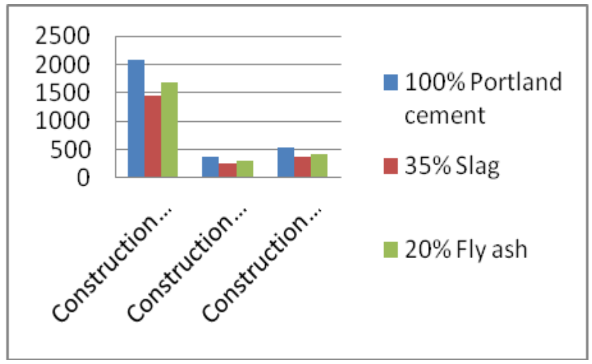

Figure 9. Effect of Slag and Fly ash in embodied energy

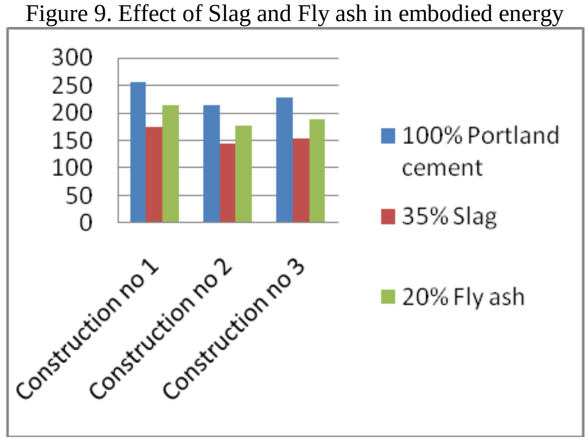

Figure 10. Effect of Slag and Fly ash in CO_2 emission

Cement consumes a large amount of energy and therefore having the highest environmental impact among the concrete materials.

Based on the finding in recycling and producing virgin aggregate, it shows that Recycling of wasted concrete can be useful by 1.5 to 2 times more saving energy and CO_2 emission than producing virgin aggregate

Using Fly ash and Slag cement as a replacement of cement can be useful in both energy saving in production and CO_2 emission by savings energies from 29 to 30 percent for production issue and a savings of CO_2 emissions for 31 to 33 percent. On the other hand 20% fly ash can save energy for 19 to 20 percent and CO_2 emission for 16 to 17 percent.

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