REDUCING CARBON FOOTPRINT AT A CEMENT CASTING PREMISE USING CLEANER PRODUCTION STRATEGY

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Reducing Carbon Footprint at a Cement Casting Premise using Cleaner Production Strategy.

Field of Study : Cleaner Production

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ABSTRACT

Construction sectors release a huge amount of carbon footprint (CFP) from various activities. Cleaner Production (CP) is one the strategies in reducing carbon footprint which focuses on the CFP prevention generation. As a case study, a cement casting premise was chosen to conduct CP generation options and feasibility study by considering the environmental issue, economics, safety and health aspect at the premise. From the CP generation, the concrete waste contributes about 262,145 kgCO_2/month, diesel contributes 22,058 kgCO_2/month and the electricity consumption being the least contributes 1,809 kgCO_2/month. The CFP per unit panel was 70 kgCO_2 and equaled to 3,433 tonnes CO_2 for one-year panel production (49,000 units). Three CP options were generated and the implementation of these CP options was expected to reduce to 5.1 kgCO_2per unit panel, an approximately 93%of reduction. That was equaled to 250 tonnes CO_2 per one year panel production process. The concrete waste which use at the premise as road pavement resulted inapproximately zero waste of concrete and gave a huge impact in CFP. With estimated investment was RM 7,190, the payback period expected to be gained with a maximum period of 3 years. This study proves that this cement casting premise is potential to be operated with greener operations and economically. This method can be applied to other cement casting premise which suggests the same impact.

ABSTRAK

Sektor pembinaan menghasilkan karbon jejak dalam kuantiti yang besar dari pelbagai aktiviti. Pengeluaran bersih adalah salah satu strategi dalam karbon jejak yang memfokuskan pencegahan penjanaan karbon jejak. Untuk kajian kes, premis kerja acuan simen dipilih untuk dijalankan pilihan penjanaan pengeluaran bersih kajian kemusabahan dengan mengambilkira isu alam sekitar, ekonomi, keselamatan dan kesihatan di premis. Dari Pengeluaran Bersih yang dijana, sisa konkrit menyumbang sebanyak 262,145 CO_2kg/month, diesel menyumbang 22,058 kgCO_2/sebulan dan elektrik menyumbang paling sedikit iaitu 1,809 kgCO_2/sebulan. Nilai karbon jejak untuk seunit panel adalah 70 kgCO_2 dan bersamaan dengan 3,433 metrik tan CO_2 untuk satu tahun penghasilan panel (49,000 unit). Sebanyak tiga pilihan Pengeluaran Bersih telah dijanakan dan pelaksaan pilihan Pengeluaran Bersih ini dijangka dapat mengurangkan nilai karbon jejak kepada 5.1 kgCO_2seunit panel, iaitu berkurang sebanyak 93%. Ini bersamaan dengan 250 metrik tan CO_2 untuk satu tahun proses penghasilan panel. Sisa konkrit yang digunakan untuk menurap jalan menghasilkan hampir sisa sifar untuk sisa konkrit dan memberikan kesan besar kepada nilai karbon jejak. Dengan anggaran pelaburan sebanyak RM 7,190, tempoh perolehan semula dijangka dapat dicapai dalam masa maksimum 3 tahun. Kajian ini membuktikan bahawa premis kerja acuan simen berpotensi untuk dijalankan secara operasi hijau dan ekonomik. Cara ini juga boleh digunakan untuk premis kerja acuan simen yang lain dengan mencadangkan kesan yang sama.

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LIST OF SYMBOLS AND ABBREVIATION

CP	:	Cleaner Production
CO_2	:	Carbon Dioxide
OPC	:	Ordinary Portland Cement
UNEP	:	United Nation Environment Program
LED	:	Light Emitting Diode
ROI	:	Return on Investment (unit = year)
NOx	:	Nitrogen Oxides
SOx	:	Sulfur Oxides
HC	:	Hydrocarbon
CO	:	Carbon Monoxide
PPE	:	Personal Protection Equipment

CHAPTER 1:

INTRODUCTION

1.1 Research Background

Global warming is one of the major issues in the world nowadays and some of the significant impacts are the increase in the sea levels, shifting weather patterns and the ecosystem.This is due to the increase of greenhouse gases being released into the atmosphere, mostly from burning fossil fuel. The Industrial Revolution in about 1750 had caused the carbon dioxide levels to increase to nearly 38 percent. And, as of 2009, and methane levels to 148 percent **(**The Earth Observatory)**.**

The Department Of Statistics Malaysia reported the performance of construction sector in the second quarter of 2017 is increasing at a fast rate of 11.2 percent year-on-year to record RM33.8 billion compared to the first quarter record at rate 9.7%. This scenario shows the increasing demand of cement. The cement industry is expected to see reasonable growth in the next two to three years with the support from the major government infrastructure development projects. For example, affordable housing projects, the Refinery and Petrochemical Integrated Development and Mass Rapid Transit projects which need a high demand for cement. All these however, will contribute to moreCO_2being released if no action is taken.

Cement is a vital substance of concrete and forms a fundamental element of any housing or infrastructure development. The use of cement and concrete are essential for the rapid urbanization all around the world. It is considered as a key component in social, economic and infrastructural development because cement and concrete are vital construction materials in building many mega infrastructures such as buildings, roads, culverts, bridges, flyovers, tunnels, river protection structures and railways. The concrete industry is producing up to 5% of worldwide man-made emissions of CO_2, of which 50% is from the chemical process and 40% from burning fuel. The industry also generatesother industrial by-product such as NOx, SOx and micropollutants(World Business Council for Sustainable Development, 2002). Production of cement and concrete have a significant amount of environmental footprint, mostly due to the huge amount of energy. It takes to heat limestone, cement's key ingredient, and the subsequent chemical process it undergoes. Therefore, it is important to develop green concrete that can be used for building and structures.

To greening the concrete, the continuous application of environmental prevention strategy must be applied along the life cycle of the product to optimize the process and minimize the risk to human and environment. "The preventive strategy includes the raw materials and energy, and reduce toxicity amount of emissions and wastes before discharge to the environment". This process is known as cleaner production(Zainon Noor, 2012). Thus, an excellent way to reduce carbon footprint by reducing carbon dioxide(CO_2) emission is by using Cleaner Production (CP) strategy(Rahim & Abdul Raman, 2017).

1.2 Problem Statement

Cement casting method is part of industrial construction and has a series of processes in producing cast concretes. Along the processes, there are possibilities of waste and pollutants generate. The possible wastes generate are material waste, energy waste, waste water and fuel waste. The CO_2 emission is occurring within the processes and should be reduced by analyses the possible entities.

From the selected casting yard surveyed, it can be seen that the critical issue is to manage the concrete waste produced in the processes and continue to increase. The increasing demand of the product will severe the situation. The fuel consumption of vehicles used at premise to transport the fresh concrete and cast concrete is high. These vehicles release high greenhouse gases when fossil fuel is burned and thus, emits huge amount of CO_2. The electricity is also among the resources used to run the machinery and services during process operations. The CP strategy is applied in minimizing the waste and suggesting the opportunity for improvement in the process. The CP audit should be conductedto quantify the total resources consumption and wastes generate from the production processes and activities in the premise. Also, suggest the improvement in terms of resources consumption and productivity.

This problem statement arises research questions as follows:

1. Are the cement casting premises in Malaysia currently practicing the strategies to reduce carbon footprint?
2. Can cleaner production be a strategy to reduce carbon footprint at selected cement casting premise?
3. What are the benefits of reducing carbon footprint at cement casting premise financially and in term of carbon footprint reduction?

1.3 Aim of the Research

This study aims to determine the most feasible CP options to reduce carbon footprint at a selected cement casting premise.

1.4 Research Objectives

To achieve the aim of the research, the following objectives are defined:

1. To conduct cleaner production audit at a selected cement-casting premise.
2. To estimate carbon footprint generated per unit of product.

3. To propose and evaluate the cleaner production options to reduce the carbon footprint generated per unit of product.

1.5 Scope of Study

The research was conducted at selected cement casting premise at Jalan Kuari, Kampung Baru Kuang, Selangor. The research boundary was within the premise whereby the cement casting production and concrete manufacturing activities. The activities like the panel transport delivery outside the premise's gate were beyond the research boundary. The cement casting hereafter will be called the panel.

1.6 Report Outline

The main features of the report are outlined below:

Chapter 1 covers the introduction and background of the research and containing the research problems, aims, objectives and scopes of the research.

Chapter 2presents the literature review of the cement industry issues in contributing a global warming. The awareness of many countries including Malaysia on the carbon footprint that result from an action plan for reducing carbon footprint is discussed. The cement and concrete manufacturing method and arisen issue are overviewed. The CP as a tool in overcoming the environment issue is highlighted and the application of cement casting premise also discussed.

Chapter 3 briefly explains the methodologies in this research that reflect the cleaner production strategy to reduce CO_2 emission. The method includes collecting datas from company's inventory, interviewing and observation, conduct a detail audit, identify problem source, data analysis, generate CO_2 emission and present the most feasible option study by considering financial analysis.

Chapter 4 discuss the result and findings from the detailed audit before and after applying CP strategies. The potential good practices with no cost implications are elaborated. The environment issue also relates here.

Chapter 5 concludes the research findings and recommendations for future research.

CHAPTER 2:

LITERATURE REVIEW

2.0 Introduction

Climate change has become a serious global issue nowadays. Countries development and populationincrease have encouraged the scenario by emitting huge amount of CO_2 and greenhouse gases that affect the increase in the global temperature thus, leading to global warming. The current series of extreme weathers like a big flood, violent storm, severe drought and heat waves are affectedfrom the global warming where the world communitiesneed to address the issue. There are both natural and human sources of carbon dioxide emissions. Natural sources include decomposition, ocean release and respiration. Human sources come from activities like cement production, deforestation as well as the burning of fossil fuels like coal, oil and natural gas, have seriously altered the global carbon cycle. Thus, the Cleaner Production method has developed rapidly to resolve or reduce the human carbon emission (Huisingh, Zhang, Moore, Qiao, & Li, 2014).

In the middle of 2002, many global cement companies and members of the World Business Council for Sustainable Development (WBCSB) had joined a commitment to sustainable development in cement industry. One of the agendas is to reduce the emission including the CO_2(World Business Council for Sustainable Development, 2002). In Malaysia, The Prime Minister aims to reduce 40% of Malaysian CO_2 intensity compared to that in 2005 by 2020 during the United Nations Climate Change Conference in Copenhagen and one of the options is by CP. CP is applying to integrate environmental objectives with industrial production processes to reduce waste and emissions. Thus, it will reduce the cost of production, improve the efficiency of resource usage and promote environmentally friendly practice (Hens et al., 2017; Joshia, Naithani, Varshney, Bisht, & Rana, 2017). However, in Malaysia, CP strategy has not been used widely in cement casting premise. So, the feasibility study of using CP strategy to green the cement casting premise needs to be carried out.

2.1 Cement Production

Ordinary Portland Cement (OPC) is a general-purpose cement type and suitable for concrete construction. The Portland Cement that has been used in this premise study is Tasek Cement. OPC is a composite of lime (CaO), silica (SiO_2), alumina (AL_2O_3), iron (Fe_2O_3) and sulfur trioxide (SO_3). This cement manufacturing shown in Figure 2.1 consists basically of grinding the calcium carbonate ($CaCO_3$) from limestone, chalk or other calcium-rich materials, mixing them very well in certain fractions and burning in a large rotary kiln at a temperature of up to about 1450^oC to form lime (calcium oxide or CaO) and carbon dioxide. This is called calcination process and show at Equation 2.1. The lime combines with silica-containing material as clays provide to the kiln to form dicalcium or tricalcium silicates as a part of the compound in the clinker. The clinker is cooled and ground to a fine powder, with some gypsum(SO_3) added, and the resulting product is the commercial Portland cement.

Calcination or Calcining Process: $CaCO3 + Heat \rightarrow CaO + CO_2$ *……Equation 2.1*

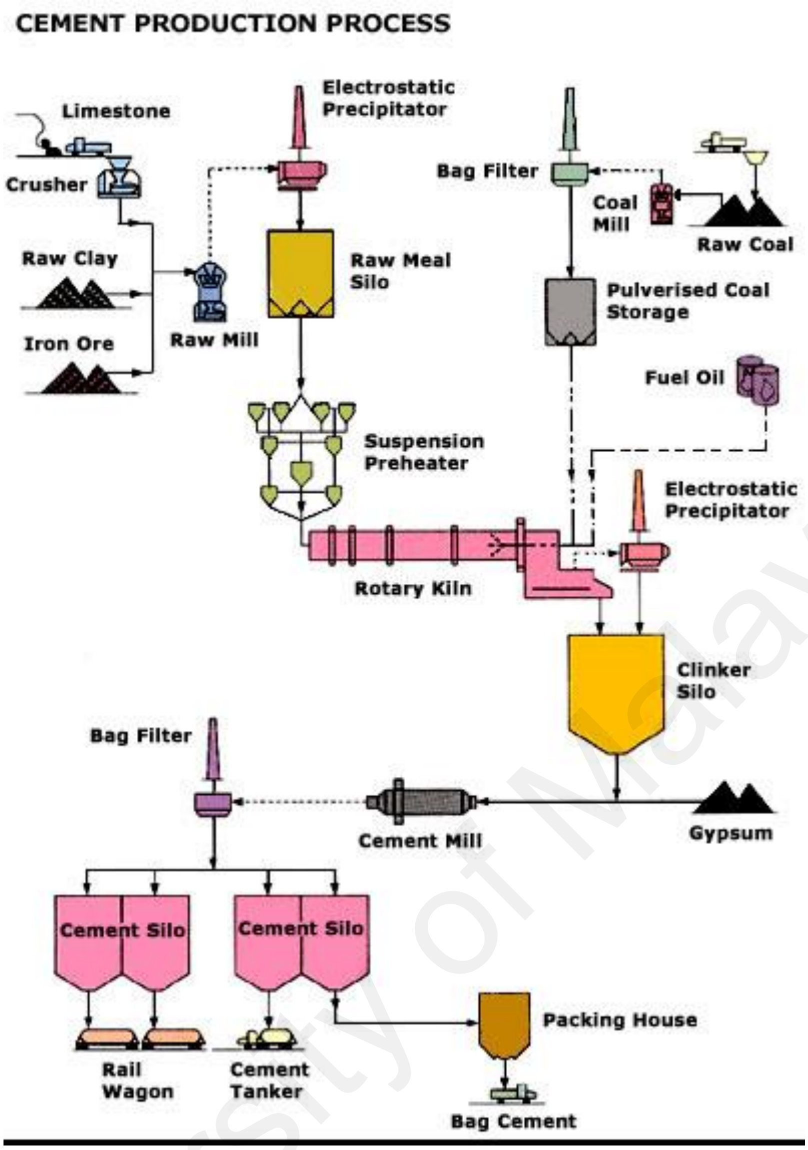

Figure 2.1 : Portland Cement manufacturing by Tasek Cement manufacturer

(Source:http://www.tasekcement.com/index/cement_facts/manufacture_of_ordinary_portland_cement.html)

The Portland Cement quality is defined by Malaysian Standards MS EN 197-1:2007 and applied to a series of test which is commonly presence(Tasek Corporation Berhad):

- Fineness - Blaine Method

  Also known as air permeability method. The principle is observing the time taken for a fixed quantity of air to flow through compacted cement bed of specified dimension and porosity.

- Chemical Composition

  Variations in chemical compositions affect the cement properties like hardening/hydration, setting time, corrosion and others. The chemical composition is verified by chemical test and the analyses of the oxide composition will be used in the calculation.

- Strength - Mortar / Concrete Cubes

  Conrete cube testing is to determine the strength of concrete and can be done in both destructive and non-destructive methods of testing.

- Setting Time - Vicat Method

  Vicat Method is to determine the quantity of water required to produce a cement paste of standard consistency by finding out the consistency of initial setting time and final setting time of the cement of the test.

- Soundness - Le'Chatelier Method

  Soundness means the ability to resist volume expansion. In the soundness test, a specimen of hardened cement paste is boiled for a fixed time. The volume expansion that caused by the presence of unburnt lime may develop crack in the cement.

Carbon dioxide emissions from cement production are essentially directly proportional to lime content, so productions of cement lower in lime yield emits less CO_2. Because CO_2 is emitted during clinker production (rather than cement production itself), emission estimates should be based on the lime content and production of clinker. Some countries are importing the clinker from another country, so, the emission estimates are depending on cement quantity only.

2.1.1 Environmental issue on cement production

Carbon dioxide emitted during the cement production process represents the most important source of the non-energy industrial process of global carbon dioxide emissions. Carbon dioxide is produced during the production of clinker and intermediate product from which cement is made. The Portland cement itself contains 95% cement clinker. The Cement production represents 20% to 40% of total production cost whereby the fuel is used in cement clinker production and electricity for grinding raw materials and finished cement(Taylor, Tam, & Gielen, 2006).

The cement demand forecast the peak of demand between 2015 and2050(Taylor et al., 2006). So, alternatives in reducing energy during clinker stage are conducted in various options by substituting of other material with a certain percentage of quantity and replace the fuel with biomass. The CO_2 emission by cement industry will continue with the rise on development. By 2050, the world CO_2 emission is targeted at 9% to 10% in cement. Thus, a cement production is the main emission source(Taylor et al., 2006).

Hemalatha, Mapa, George, and Sasmal (2016) and Kumar, Gupta, and Shrivastava (2017)had done the studies to green the cement casting with a few options. The studies were used the method to substitute a partial part of the coarse aggregate (sand) or a partial part of cement usage.Hemalatha et al. (2016) found that the fly ash(FA) with below than 40% can be substituted a part of cement usage but with a certain amount of micro size of calcium carbonate(CC). This is to ensure the strength of concrete is still good. The fly ash is used because it's abundant availability, compatibility, and low cost. Also, it will contribute to the reduction of green house gasses.

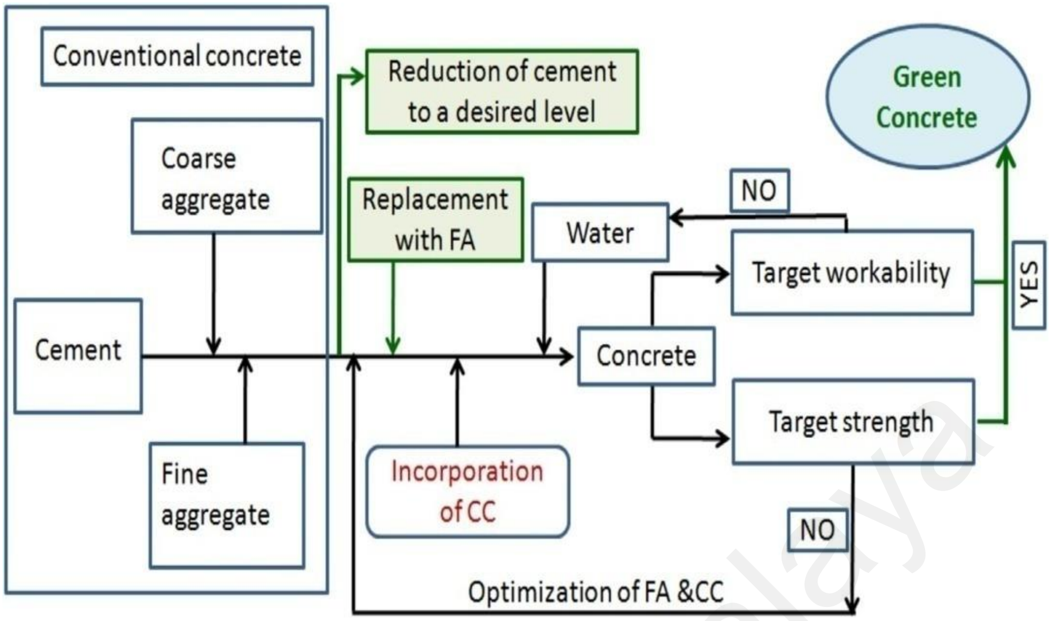

Figure 2.2: Schematic diagram showing the integrated system for technological scale-up.(Hemalatha et al., 2016)

Kumar et al. (2017) was using quartz sandstone waste as a partial replacement in coarse aggregate. It was found that the quartz sandstone can be used up to 40% for the concrete mixes having a water-cement ratio above 0.45. From the result, it can be concluded that the use of quartz sandstone wastes in cement concrete can be a future transformation. Also, will reduce depleting natural aggregates and the landfilling problems which donate to the overall environmental benefits and sustainability.

2.2 Concrete Manufacturing Process

Most of the construction sectors currently are using ready-mixed concrete as it is more versatile, economical to use and when hardened, strong and durable. Ready-mixed, as shown in Figure 2.3, refers to concrete that is batched for delivery from a central plant instead of being mixed at the site. It is produced by mixing precise proportions of cement, aggregates, sand, water and where required additives to derive certain properties.

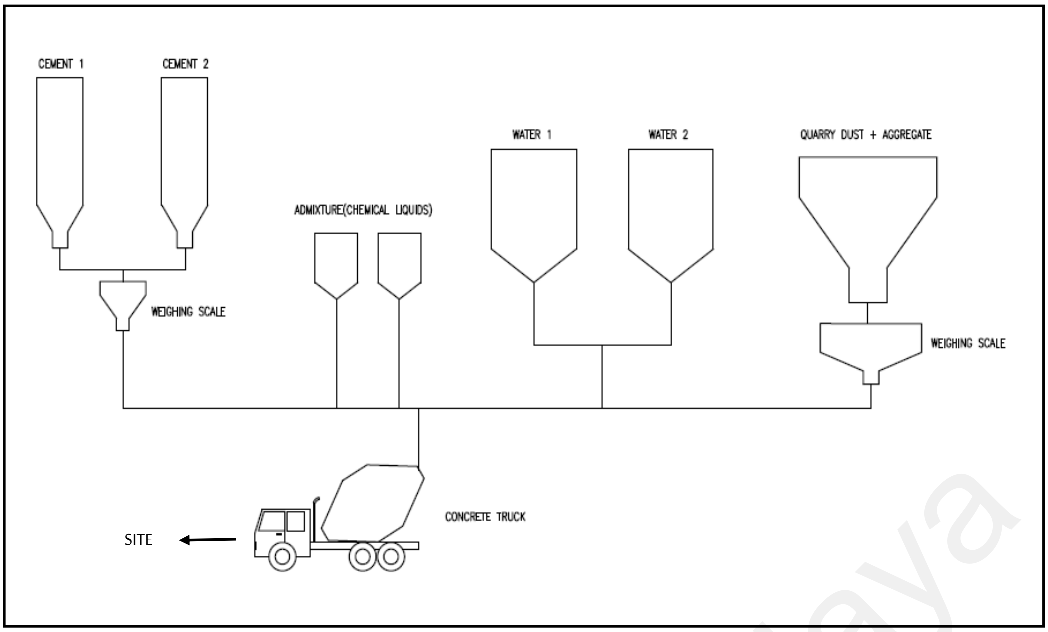

Figure 2.3 : A schematic diagram showing the concrete batch mixer operation

The plant consists of silos and bins for the storage of cement and aggregates respectively, weigh batchers for proportioning different ingredients of concrete, a high-efficiency mixer for thorough mixing of ingredients, and a computerized system controlling the entire production process.The selected cement casting premise uses the Portland cement and the quarry dust instead of sand as the quarry dust is cheaper than sand and give more consistent concrete strength result.

Concrete batching plant process flow will start from the feeding of quarry dust and cements into individual bins and weigh individually as per the design set in the control panel. After weighing, they will be transferred by conveyor directly into the concrete truck. Water and admixture is pumped into the concrete truck with setting volume. All the substances are mixed well within a time frame. Then, the concrete truck is ready to transport it to the moulding area.

During the operation, the fresh concrete is prepared by concrete batch mixer plant once the moulds are ready to be used. The fresh concrete volume is prepared to $5m^3$ per trip and is compatible with the volumes of the concrete truck use at the premise.

After pouring the fresh concrete into the moulds, the balance of the concrete which stayed in the concrete truck is considered as waste. Each trip produces concrete waste and it must be reused or recycled for more beneficial usage.

2.3 Cleaner Production

Industrialized countries have made an effort in committing to achieve sustainable production by methods, practices, and technique by making a declaration through Agenda 21 at United Nations Conference on Environment andDevelopment (UNCED) in Rio de Janeiro in 1992. As an action plan, UNIDO and UNEP are launched a Cleaner Production projects to determine preventive environmental strategies in selected countries.

UNEP (United Nations Environmental Program) which was developed in 1991 defined Cleaner production as "the continuous application of an integrated, preventive strategy applied to processes, products, and services in pursuit of economic, social, health, safety and environmental benefits" (UNEP, 1998). The definition and scope have been widening along the time and areas. Glavič and Lukman (2007) have elaborated Cleaner Production in industrial context as "These activities encompass resource use minimization, improved eco-efficiency, and source reduction, in order to improve the environmental protection and to reduce risks to living organisms. It can be applied to processes used in any industrial sectors and to products themselves (cleaner products)". Nowadays, Cleaner Production has been seen as a business strategy in contributing the sustainable development.

Cleaner production is a family of pollution prevention and the approach can be represented by the following method:

1. Good Housekeeping by taking appropriate management at working area and operational practices.
2. Equipment Modification by modifies current production equipment which gives better efficiency, lower waste and emission.
3. Technology Change by replacing the technology or processing sequence.
4. Input Substitution by substituting less toxic or renewable material or longer lifespan material
5. Using New Technology to improve equipment and process control.
6. On-site recovery and reuse the wasted material within the company in the process.
7. Effectiveness use of energy resources by adopting more efficient technology or production process or method to reduce energy losses.

2.3.1 Cleaner Production in Malaysia

Cleaner Production was initiated in Malaysia in January 1996 by cooperation between Government of Malaysia and Government of Denmark under the technical programmed known as Danish Cooperation for Environment and Development (DANCED)(DOE, 2018). The initiatives are implemented by the Standards and Industrial Research Institute of Malaysia (SIRIM) under the Ministry of Science, Technology, and Innovation (MOSTI) in promoting the Cleaner Technologies. In the year 2002, the Malaysia DOE has abroad the technologies in Cleaner Production at many projects to selected Small and Medium Enterprises (SMEs) in Malaysia (Yusup, Wan Mahmood, Salleh, & Ab Rahman, 2015).

It has been called in Malaysia in various terms such as Kaizen, 5S and 3S. Cleaner Production emphasizes on pollution prevention. Any concept that has prevention components are basically a Cleaner Production concept/tool. Cleaner

Production is not only a matter of environmental issue only, but in term of economy and productivity aspect as well. So, it is a "win-win" situation impact between the manufacturer and the environment.

The construction sector in Malaysia where environmental practices are done such as Cleaner Production is still at a beginning stage. With less organizational support and the lack of awareness among the customers and also the perception of environmental practices will result in high costs. As a mitigation step to see the succession of the Cleaner Production, the organizational support should be increased with the knowledge of environmental practices, customer pressure by the increasing in environmental campaign and regulatory pressure by stringent force of implementation of the role (Yusof, Awang, & Iranmanesh, 2017). For the cement related sector, previous researchers mostly focus on utilization of other products as supplements of cement in concrete manufacturing without neglecting the concrete strength and improving the behavior. None of the studies are yet to be done in quantifying the carbon footprint at cement related premises.

2.3.2 Benefits of Cleaner Production

Various studies have come out with proof of implementing Cleaner Production option in getting a significant profit and advantages in various cases. A study done on magnesia refractory plant has proven that energy conservation and emission reduction can be realized by working on 28 cleaner production options related to raw material and energy substitution, technology improvement, facility maintenance and updates, process optimization and control, waste utilization, management, and staff training and motivation. It benefits by increasing the magnesite tailing powder, saving of magnesite ore annually, reduced stripped rocks, reduce comprehensive energy consumption, electricity savings, improved wastewater consumption and reduced SO_2 and NOx emission. The consequences bring a huge economic gain and environmental preservation(Li, Zhang, Shao, Zhang, & Ma, 2016).

The study on "better cotton" farmer at Ahmadpur, Bahawalpur, and Yazman in Pakistan by Zulfiqar, Datta, and Thapa (2017) has reached the target for resource use efficiency by optimizing the inputs such as seed quantity, irrigation, inorganic and organic fertilizer and pesticides. The potential for input reduction is by 52.9% from biofertilizer and 43.9% from irrigation application. The overall cost can be reduced by 44%. The farmers are also advised to use soil testing to identify suitable fertilizer to optimize the crop yields. The education also added an advantage in providing a knowledge to the farmers.

Waste utilization usually used in the study of concrete making as partial replacement of cement is tested by few types of materials. For example, the usage of industrial by-product, glass powder, and glass sludge waste are tested and successfully to be used as a part of cement and the cement reduction can reach to 20% by weight. This industrial by-product usage shall improve sustainable development by reducing carbon footprint especially from the cement itself and lower production cost(Lee, Hanif, Usman, Sim, & Oh, 2018). Tiwari, Singh, and Nagar (2016) and Hemalatha et al. (2016)provedCP option can be generated through using industrial by-product as partial replacement for fine aggregate in concrete, reducing waste by recycle it back as aggregate, reduce pollutant emissions, optimization of water and energy use.

2.4 Greening the cement casting premise

The construction site and related activities about concrete production generate a huge of pollution and carbon footprint(Mehta, 2001). Transportation is among the main activities in the construction sector, especially in loading the concrete and building materials. So, it's important to give a solution in remedying the environment issue. The impact will transfer to the overall cost of the project due to the cost of wastage is included.

2.4.1 Reducing fuel consumption

Fuels saving technologies are already available in the market. Generally, it increased an early cost, thus the purchaser must weigh the additional cost against the fuel saving. The fuel consumption method can be classified as behavior modification and technical application. The behavior modification usually no need money investment as it just needs the drivers to skills themselves in driving while the technical application usually needs to invest the money before getting the saving benefit. However, for the long-term period, it’s worth it due to great saving. It is depending on the company to choose which technology suitable for the budget and the company's business type. The companies that use more transportation in their business are encouraged to implement the methods. It's just not a matter of money-saving only but also an environmental concern and health matter. Diesel engine emits a wide range of gaseous and particulate phase organic and inorganic compound such as HC, CO, CO_2, and NOx. The composition of emission varies with operating condition, engine type, fuel, present of emission control system and lubricating oil. Too much exposure to the emission by exceeding the maximum incremental reactivity can affect to lung cancer (Rahman et al., 2013).

For a technical application, the studies and recommendations of reducing fuel at diesel vehicles conducted at various method could be considered as below:

1. Developing an innovation of low Rolling Resistance (RR)

Rolling resistance is defined as "energy dissipated by the tires per unit of distance traveled."(Joint EAPA/Eurobitumine Task Group Fuel Efficiency 2004). The rolling resistance is influenced by the tire factors itself. The higher air pressure, tire composition, and higher ambient temperature will reduce the rolling resistance and save fuel.

The previous study on truck tires has found 20% reduction of rolling resistance which can reduce 5% of fuel consumption and CO_2 emission. Such study in achieving the value is conducted by designing new tire improvement with new design features combined with innovative compound recipes. The scientific evaluation methods are run for new tread pattern, development of advancement nano-structured truck type compound, enhancement characterization through tools, assessment & modelization at tire performance. However, the study results 9% improvement in rolling resistance and 20% improvement in Wet Grip for longer tire durability (Duez, 2016).

2. Idling reduction strategy

The idle time is just producing no value for the owner and waste the fuel. Every hour of idle time in long-haul operation can save 1% of fuel consumption. The saving can be more if that time is at a higher temperature, especially in the afternoon(Park, 2012). The drivers usually idle their engine to obtain the required power for the accessories such as air-conditioners and lights. However, fuel consumption and emissions during idling are very high compared to driving cycle due to a rich mixture of air and fuel during that time. During the idling period, the fuel consumption rate can reach the maximum of 1.85 g/h, 16,500 g/h CO_2 emission, and 3-11% engine efficiency. Idling period by 10 min/day can generate the fuel consumption more than 27 gals/year. It can be concluded that idling just increases fuel combustion cost, decrease time interval between oil changes, increases maintenance and repair cost. The emission and fuel consumption rate depend on idling speed, accessory loading, truck model, fuel injection system and ambient temperature(Rahman et al., 2013).

The technical application studies are conducted in idle reduction technologies to reduce fuel consumption and emissions for varies duration and condition. The studies have suggested a few methods and available in the market as below(Rahman et al., 2013):

a) APU (auxiliary power unit)
b) TSE (Truck stop electrification)
c) Thermal storage systems (not commercially popular because of excess weight and space for accumulator)
d) Fuel cells
e) DFH(Direct fire heaters)

Among this method, Shancita et al. (2014) conclude the DFH technique as the best performance in reducing fuel wastage. The cost of installation can reach about RM12,000.

There are a few easy ways to reduce fuel consumption that can be used at the premise without having to spend the investment of money, just use the technique of handling(Park, 2012).

1. Progressive shifting

   The way the truck is geared can determine the fuel consumption. The truck itself has to maintain the gear to reduce the fuel usage.

2. Road speed and following distance

   The fuel consumption increased by the speed of the truck. For speed above 55 mp, each mph increases the fuel consumption by 0.1 mpg which equal to 0.425 km/L. Thus, moving slowly added an advantage on the fuel savings(Park, 2012).

3. Well maintenance

Maintained the vehicles as scheduled and early detect the problems can avoid the severe failure of the vehicle's operation.

4. Better organization of routes

By using the shortest distance and better pavement, it will reduce the mileage and fuel consumption.

2.4.2 Energy Efficiency Improvement

1. Use high efficient light emitting diode

Improving energy efficiency is a valuable near-term step along the road to sustainability. It makes both senses of environmentally and economically by increased productivity, a reduction in pollution, lower consumption of natural resources, and improved financial performance - all this without affecting the benefits that are derived from energy use. Low-cost energy efficiency measures include turning off equipment and lights that are not in use, switching to LED bulbs, and using more fuel-efficient vehicles.

In reducing the electricity, the LED bulb use less electrical consumption compared to the other bulb types as shown in Figure 2.4(AlFaris, Juaidi, & Manzano-Agugliaro, 2016). By replacing the lamp and bulb to a highly efficient light emitting diode (LED) and with lower voltage, the saving is about 50% to 70% (Ryckaert, Smet, Roelandts, Van Gils, & Hanselaer, 2012). Furthermore, the average LED lamp benefits on life-span, durable, cool, mercury-free, more efficient, cost-effective and less heat release (Cyr, 2016). The average life of a T8 LED is 50,000 hours while T8 fluorescent is only 20,000 to 30,000 hours (Program, 2006).

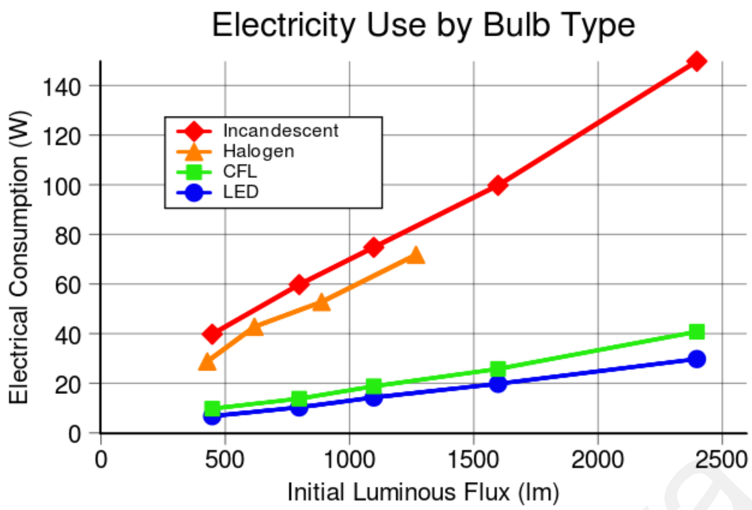

Figure 2.4 : Electrical consumption by various type of lamp(AlFaris et al., 2016)

2. Increase up the air-conditioner temperature from 16^0C to 20^0C

The energy saving also relates to ambient temperature and the humidity(Wang, Zhang, & Xia, 2013). The lower ambient temperature will reduce the energy consumption as less energy required to cool and dehumidify the inlet air. The energy consumption reduces by increasing the air-conditioner setting temperature, with maximum 10% reduction or saving per one degree Celsius. Thus, by increasing the temperature 4 degrees will result in about 40% energy saving.

2.4.3 Housekeeping

Housekeeping is one of cleaner production tools that need minimum or no need money investment, just the motivation of the staff. Occupational Safety and Health Administration US define it as “a workplace that kept in an organized, uncluttered, and hazard-free condition”. Housekeeping practices benefit in many ways such as:

1. Enhance worker safety

   Protect the workers from slippery and injuries due to spillage, obstacles at the walkway and far reaching.

2. Support workers health

   Regular cleaning and proper sanitation accommodations can reduce hazardous exposure to workers and prepare a healthy and safe working environment.

3. Improved productivity

   The comfortable workplace with nice arrangement will reflect the worker's motivation and spirit to work productively.

4. Reduced cost

   The tools and materials that are well kept usually are longer lasting, in turn, will reduce the operating cost.

5. Faster track the information

   The well-organized filing will help the process of searching information efficiently. Sometimes, the information need urgently due to some crucialcondition. So, good inventories is very helpful.

6. Good image of company

   Good arrangement and inventories might help to portrait the company image and enhance the company business input. This tool includes in ISO 9000 implementation on quality management and the quality standard by considering the regulations. The standard brand itself has to give a brand to the company.

2.5 Summary of Literature Review

The construction sectors contribute to global warming. This is due to the emission of carbon footprint at various processes during the cement production process, concrete casting and construction of buildings. In Malaysia, it is found that construction sectors do not apply the CP method during their operations due to their lack of awareness on such method. The enforcement regulations in Malaysia should be more stringent. The department concerns should take serious action by educating the sectors involved in building and also promote environmental awareness stating that emission of CO_2 into the environment is wrong and unhealthy to the living things.

Meanwhile, at the casting premise, it is found that carbon footprint is mostly contributed by the high volume of concrete waste and also the high fuels consumption used during transportation. Previous researchers have found many CP methods for reducing fuel consumption such as the use of better technology and the used of behavior modifications. At the same time, the recycling of the waste concrete can be a method of improving the fuel efficiency and that is by improving the road pavements/surfaces. The use of high efficiency of lamps and optimize the air-conditioner usage can be the ways to reduce the electricity consumption.

However, the CP being a way to prevent pollution can help in reducing carbon footprint. It also helps those involve in building construction to manage their investment well and the cost of repairs incurred during operations. And, at the same time the environment improves thus, able to sustain all living things. So, it can be concluded that a cement premise can be operated using the “Green” concept by using the CP strategy.

CHAPTER 3:

RESEARCH METHODOLOGY

3.1 Introduction

This chapter describes the process manufacturing method and CP methodology used to achieve the CO_2 reduction in cement casting production by using data collection strategy and feasibility studies.

3.2 Company background

The company was incorporated in Malaysia in 1993 and located at Petaling Jaya, Selangor. It is a specialist in the design, supply, and construction of its own patented proprietary retaining wall system which is Anchored Earth (AE) walls. Now, the company has nominated the market leader in Malaysia and expanding their market into other countries like Singapore, Indonesia, Sri Lanka, Bangladesh, and India. Other than Anchored Earth Walls, the company is also involved in the slope stabilization work using Greenmur which is a type of geotextile reinforced soil system.

In line with the objective of providing aesthetically pleasing and structurally sound reinforced soil structures at reasonable prices to ensure maximum customer satisfaction, the company strives to continuously improve the work system and product quality through the innovation of research development. On 29th June 2001, the company awarded the coveted prestigious ISO 9001:2000 Quality Management System Standards by Llyod's Register Quality Assurance.

To keep maintain the market by fulfilling the consumer and business, the company is expanding its scale by adding the subsidiaries and the employees also. Currently, there are four subsidiaries and 90 employees in Headquarters, branches and casting yard. The office operates 5 days a week with one half-day working on Saturday while 6 days a week for site personnel.

The casting yard where the selected premise of cement castings are casted is located at Jalan Kuari, Kampung Baru Kuang, Selangor. There are two locations that situated opposite each other. Figure 3.1 shows the two casting yards layout plan which area 8 acres and 3 acres respectively.

Figure 3.1 : Casting Yards layout plan

There are 20 employees working here. Within the space area of 11 acres, the daily production is 157 panels of various type and thickness depending on the demand of the projects. There are one cement mixer plant and three mixer trucks operating there on contract basis to the company. This research will focus on the respectivepremise only as the main production site. Certain projects are casting the panels at site due to the fardistance from premise and have a space to do casting works. The temporary casting area will stopwork once the project is completed.Therefore, it is not much significant to do the CP strategy at that temporary location.

3.3 Overall Research Activities

This study covers five main methodologies in CP strategies:

1) Identification of resource consumption and emission in the cement casting premise.

2) Conduct an initial audit to identify and assess the entire production processes in the cement casting premise using standard CP audit methodology.

3) Generate CP options by conducting a process-based approach CP to estimate the carbon footprint generated in per unit product.

4) Evaluate and prioritize CP option for resource saving and emission reduction by using the estimation result of the feasibility study.

5) Evaluating environmental and economical viability of the options

This study implements the CP methodology suggested by United Nations Environmental Programme and United Nations Industrial Development Organization(UNEP, 1996) as shown in Figure 3.2.

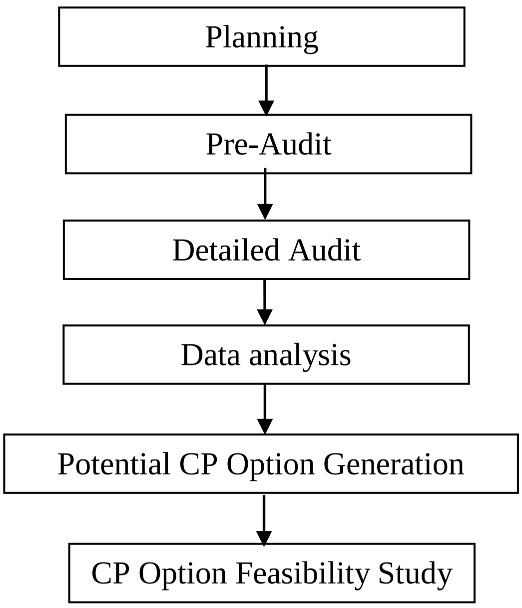

Figure 3.2 : Overall Research Methodology Steps

3.3.1 Planning

The objective of this phase is to obtain commitment from the project management team, allocate resources and plan the work details. The first step is to seek permission from the management of the company to do the research at company's casting yard and briefly explain about the CP initiatives which results in both environmental improvements and better economy performance. This is in line with one of the Company Management Philosophy: "To strive for continuous innovation and improvement". The casting yard is chosen due to its established operation, good housekeeping and record keeping system whereby they have a stock take several times in a year before ISO audit. These will ease the data collection for CP assessment.

A CP team is formed, member by Project Manager, Project Coordinator from Implementation Department and Accounts Manager from Account Department. They are selected as they could assist in giving inputs on data implementation of CP strategy.

3.3.2 Pre-Audit

An internal audit is required to access the entire production processes. A preliminary site visit was lead to observe the yard layout (selected premise), mainly the ready-mix concrete plant, location of raw material storage, precast concrete product, waste generation and onsite facilities. The visit is guided by the yard coordinator and ready-mix concrete plant operator to better understanding the process flow of cement casting and the process of the concrete mixer. The process is referred to the concrete mix stage until these panels are delivered by lorries to its destination. The transportation by lorries outside the premise gate is not covered as the research boundary is confined.

3.3.3 Detailed Audit

For detailed CP audit, data were collected by reviewing inventories on material and utility purchases, interviews with ProjectCoordinator, and measurement of process streams. The audit for the entire production processes is run to attain the quantitative and qualitative information of resource consumption, waste generation, emissions and CO_2 emission per unit of the concrete panel (kg CO_2/unit panel). The resources used and types of waste generated will be used as a basis to generate CP option. The data is gathered based on company record keeping, observation, and interviews with personnels.

3.3.3.1 Safety Requirement at Cement Casting premise

There are few points of safety aspects that need attention during CP audit at the premise.

1. To wear safety boot and safety jacket when entering the premise.
2. To wear the inhalation mask at cement batching and concreting area as it is dusty.
3. To be careful while stepping the staircase to operation office as the staircase is at improper condition and has no hand railing is provided.
4. To be careful while walking within the premise as the road has some potholes at many areas and the vehicles are moving around.
5. To ensure the timber absorbers are being used between the panels during stacking at the storage area and in the lorries to prevent chipping panel.
6. The crawler crane is being used to move the panels destination and have possibilities to drop the loading accidentally. Thus, minimize the workers standing at crane area to avoid the unnecessary event happen.

7. The vehicles must be moving at slow and medium speed within the premise to minimize the accident occurs.

3.3.4 Data Analysis

The entities like raw materials, fuels, electricity, waste generated and other entities that consume and generate the processes are identified and analyzed to generate CP options. Data analysis is the final stage of CP assessment in order to identify the CP option and to calculate the CO_2 emission and the overall production cost. The CO_2 emission of an entity is calculated using factor-based approach by multiplying the component data (consumption or generation rate) with the component of Malaysian emission factors(Rahim & Abdul Raman, 2015) following the Intergovernmental Panel on Climate Change (IPCC) method. The total CO_2 emission is gained by summing the individual CO_2 emission of the components.

Total CO_2 emission (kg CO_2) = $\sum$ (Entity data x Entity Emission Factor) ..Equation 3.1

3.3.5 Potential CP option generation and feasibility study

From the CO_2 emission calculation, the CP options for reducing CO_2 emissionis generated and calculated the overall production cost. Then, a brainstorming session will be held with the project coordinator, site supervisor and the operators to identify the improvement needed along the process flow. The improvement includes the operation SOP, equipment handling, inventories, waste management, training, house-keeping and time management. Subsequently, the feasibility studies are then executed to prioritize the most beneficial options, considering the environmental and economic aspects.

For economic aspect, the return on investment method (ROI) is used for the purpose of cleaner production option. ROI measures the profits based on the investment relative to the amount of money invested.

ROI is calculated as follow:

$$ROI = TI/TS \quad \text{…………………………………………………….….} \textit{Equation 3.2}$$

Where;

ROI = Return on Investment (year)

TI = Total Investment

TS= Total saving

CHAPTER 4:

RESULTS AND DISCUSSION

4.1 Introduction

This chapter discusses about the quantification of CO_2 emission, CP options and the feasibility study of the options. The suggestion for improvement in reducing CO_2 also presented here. At the end, amount of carbon footprint reduction and money saving is calculated to prove the success of the CP options.

4.2 Audit Result

A detailed audit has been conducted at the premise to identify the entities that contribute to CO_2 emission. The process flow in translated into Figure 4.1 which shows the input, output, and waste generated along the cement casting production. The cement casting produced here is mentioned as a panel.

There are some entities that involve in the process. The probability of each entity to contribute CO_2 emission is studied.The results found out that there are three entities identified as the contributor to CO_2 emission. The entities are concrete waste , fuel and electricity that referring to the resources and wastes generated.

The detailed processes are as follows:

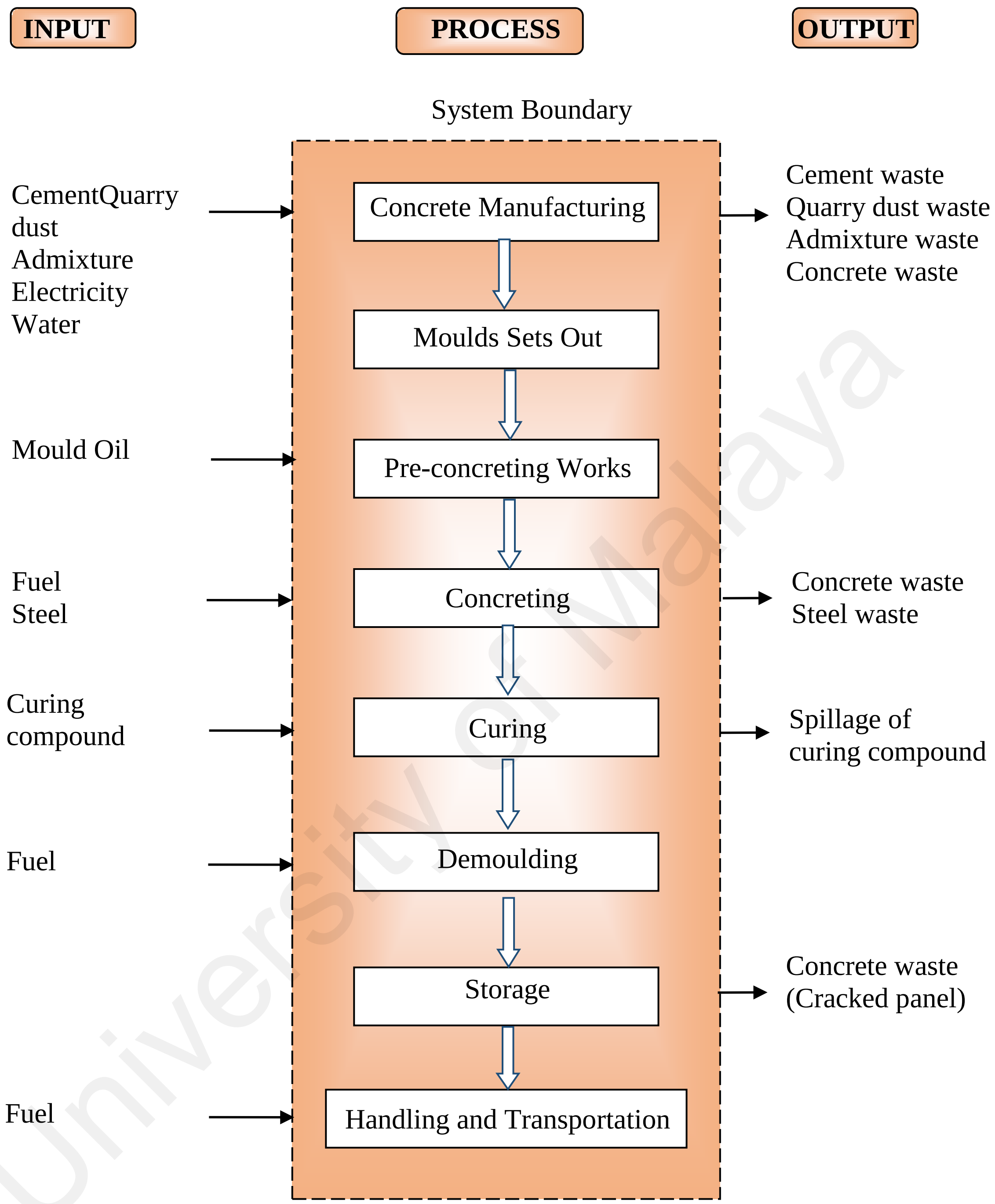

Figure 4.1 : Concrete Panel manufacturing method flow diagram

4.2.1 Concrete Manufacturing

All standard procedures for concreting and concrete strength requirements shall be applied to the concrete supply. The concrete is supplied by the readymixed concrete plant which operates in the casting yard itself as shown in Figure 4.2. The concrete produces is G30 and it takes seven days to demould the panels.

Figure 4.2 : Concrete mixer plant

The ready mixed concrete plant is owned by another party. All payments are made by the number of lorry trips per day. It operates from 10am to 2pm from Monday to Saturday with loading of between 60 to 90m^3 per day. This means about 10 to 15 trips of concrete trucks are required to transfer the concrete from plant to moulds. After 2pm, the plant and the operator of the concrete truck will do the housekeeping by cleaning the concrete waste.

A concrete mixer plant uses Boring water which is underground water to reduce the cost of water bills. The bill is charged twice a year by Syarikat Bekalan Air Selangor which amounts toRM1000 per bill. Boring water is the most suitable water to use as it has no taste and odor, and fewer impurities. Excessive impurities in mixing water may affect the setting test, concrete strength, efflorescence, corrosion of reinforcement, volume instability and reduced durability. The water is also used for drinking and sanitary.

4.2.2 Mould sets out

Moulds are supported preferably by timbers or concrete blocks. Spirit level is used to check and ensure that the moulds are leveled. For proper casting, mould shall always be maintained level. The number of moulds to be used is calculated to be fixed not more than $5m^3$as per concrete volume ordered per trip truck.

4.2.3 Pre-concrete works

All sideforms, dividing plates and base plates of moulds shall be cleaned and free the moulds. Thereafter, side formworks are fixed and tightened to the base plates. Should dividing plates be required, the position of the plates shall be checked on its verticality and dimensions.

4.2.4 Concrete works

The concrete truck shall be poured the fresh concrete into the steel moulds and a poker vibrator is placed to vibrate it thoroughly as shown in Figure 4.3.A poker vibrator is used to agitate fresh concrete so as to eliminate gross voids entrapped air and to produce intimate contact with form surfaces and embedded materials. There are 157 number of moulds that are ready to be filled every day with certain thickness and shape which depend on the project request. The concrete is finally leveled to the desired thickness of panels; 140mm, 180mm or 220mm. However, if raining in the morning, no concreting work will be done.

Figure 4.3: A poker vibrator use at fresh concrete

4.2.5 Curing

Half an hour after the pouring and trowelling of concrete in the mould, curing compound (Flow 601N) shall be sprayed onto the surface of the exposed panel until the entire surface is evenly covered. The curing compound is used as a retarder to stabilizes the concrete extending the hydration process of the cement so that the concrete continues to gain strength. The concrete will be stronger and long lasting by keeping the concrete moist for a longer period and will be more hardened by time. The Portland Cement Association mentioned that "most of hydration and strength gain take place within the first month of the concrete life cycle, but hydration continues at a slower rate for many years"(APA, 2017). This characteristic is important in the use of the panels to retain the soil and with certain loading on top of the panels such as slopes, roads, and housing.

4.2.6 Demoulding

The panels are ready for demoulding after concreting for 14 hours. All the side formworks are loosened and detached from the base plates before demoulding by a crane or forklift.

4.2.7 Storage of panels

All panels cast shall be leveled horizontally during stacking. Anchor blocks are used at a proper position as dunnage for the stacking of panels. No single stackof panels would be more than five pieces high. The panels should be at least 7 days old before fully loaded.

4.2.8 Handling and transportation

All panels shall be handled with care and timber absorbers are to be used toprevent damage and chipping. Only those panels with a minimum of 7 days strength are allowed to be transported out of the factory. During transportation which is from 11 am to 7 pm, no panels shall be allowed to be stacked more than three panels high. The lorry should not be overloaded. To minimize damage and chipping off during transportation, timber should be placed beside the RC panels to act as impact absorbers and to prevent detach among the panels and also with the lorry bucket.

4.3 Quantification of CO_2Emission Generation

Total CO_2 emission of these three entities is calculated by using IPCC methodology as Equation 4.1. The emission factors are summarized in Table 4.1.

$$\text{Total } CO_2 \text{ emission } (kgCO_2) = \sum (\text{Entity data x Entity Emission Factor})..\text{Equation 4.1}$$

The indicative measurement is based on one unit of the panel with thickness 140mm and weight 800kg. The calculation is based on the 26 working days and the total panel cast is at average 4082 units per month.

Table 4.1: Emission factors

Resources and wastes	Emission factor	Unit	References
Electricity	0.67	kg CO_2/kWh	(Rahim & Abdul Raman, 2017)
Fuel (Diesel)	2.69	kg CO_2/L	("IPCC, Guidelines for National Greenhouse Gas Inventories," 2006)
Solid Waste (Concrete)	3.7	kg CO_2/kg	(Rahim & Abdul Raman, 2017)

1. Concrete Waste

The concrete waste quantity is taken from the company data inventory.

$$CO_2 \text{ emission for concrete waste} = 70{,}850 \frac{kg}{month} \times 3.7 \frac{kgCO_2}{kg}$$

$$= 262{,}145 \frac{kgCO_2}{month}$$

2. Electricity

The electricity consumption is based on the bill from TNB.

$$CO_2 \text{ emission for electricity} = 2{,}710 \frac{kWhr}{month} \times 0.67 \frac{kgCO_2}{kWhr}$$

$$= 1{,}809 \frac{kgCO_2}{month}$$

3. Fuel

The diesel is usually bought from a supplier at an average of four drums a month which consist of 8,200 L amounting to RM 17,384 at the factory rate of RM 2.12 per liter. The price rate fluctuates and depends on the negotiation with the supplier. Diesel is used by three units of concrete lorries, one unit of bulldozer, two units of Manitou and two units of crawler crane. The diesel consumption of these vehicles is tabulated in Table 4.2and shows thatconcrete truckscontribute the biggest percentagein diesel usage. Mitigation in reducing diesel usage will benefit the company in terms of cash. The other three vehicles consume diesel at quite an equal portion.

Table 4.2: Total of Diesel Consumption per month

Vehicles Type	Unit (Nos.)	Diesel Usage per unit (L/month)	Diesel Consumption (L/month)	Diesel Cost (RM/month)	% of total
Concrete Truck	3	1,300	3,900	8,268	48
Bulldozer	2	780	1,560	3,307.20	19
Manitou	2	671	1,352	2,866.24	16
Crawler Crane	2	694	1,388	2,942.56	17
Total	**9**	**2,878**	**8,200**	**17,384.00**	**100**

** The calculation is based on diesel factory price RM2.12 per liter.
The operating days are 26 days.

$$CO_2 \text{ emission Fuel (Diesel)} = 8{,}200 \frac{L}{month} \times 2.69 \frac{kgCO_2}{L}$$

$$= 22{,}058 \frac{kgCO_2}{month}$$

The total CO_2 emission before implementing the CP options= $1{,}809 \frac{kgCO_2}{month}$ +

$$22{,}058 \frac{kgCO_2}{month} + 262{,}145 \frac{kgCO_2}{month}$$

$$\mathbf{= 286{,}462 \frac{kgCO_2}{month}}$$

CO_2 emission per unit panel = $286{,}462\,\frac{kgCO_2}{month} \div 4082\frac{pieces}{month} = 70\ \frac{kgCO_2}{piece}$

Therefore, the CO_2 emission per unit panel before implementing CP options is 70 $\frac{kgCO_2}{piece}$.

4.4 Cleaner Production Generation and Carbon Footprint

From the interviews with the staff along this process study, it was found that they do not really understand about the Cleaner Production even though some activities are already taking in action. The investigation of the premise has suggested some CP options for improvement which some only require good practices without cost implications.

4.4.1 Recycle of concrete waste

The concrete waste can be more valuable when crushing to a smaller parts. It can be used for build-up the road pavement, panel platform pavement and as a panel backfilling during installation. The crushed concrete waste will substitute the granular fill which is currently used at the project site. Thus, the waste concrete can be reduced to approximately zero waste.

4.4.2 House keeping

For this cement casting premise, concrete panel cast is arranged in five pieces per stack at a flat surface. More than five pieces will increase the chances for the panel to crack or damaged. The panels should be group by their thickness and type in order to ease in moving out by lorries and the inventories record process. Figure 4.4 shows the panel storage with an improper arrangement and messy with concrete waste and plastic cover. Meanwhile, Figure 4.5 shows the improvement whereby the panels are being arranged properly, clean and on a flat surface. Any wastage produce is placed at the suitable storagelocation and properly labels. The wastage can be from scrap and damaged steel, concrete scrap and empty containers.

Figure 4.4: Panel storage before housekeeping

Figure 4.5: Panel storage after housekeeping

4.4.3 Increase fuel efficiency

1. Improve road pavement

This panel casting premise use a lot of transportation in loading the fresh concrete from the batching plant to moulds area, transferring the panels from the moulds to the storage area and transferring the panels at storage area to the lorries. The vehicles are operated at an average of 15km/hr only due to a lot of potholes along the road and some destination is quite near to reach. By always maintaining road pavement at routine route will smooth the vehicle journey as the road flatter. Here, the crush concrete waste can be used as a pavement. By improving the condition of the vehicles road pavement, the fuel consumption will decrease by up to 7% (Joint EAPA/Eurobitumine Task Group Fuel Efficiency 2004).

Diesel saving = 0.07 x 8,200 L = 574 L

Diesel usage after CP option = 8,200 L- 574 L

= **7,626 L**

By improving the road pavement only can reduce the diesel usage to 7,626L which the value is RM 16,167 per month in monetary value, and equal to 20,514 $kgCO_2$/month carbon footprint.

2. Using a tire with Rolling Resistance Technology

The current market already has tires with this development but with a quite demanding price. The manufacturer of the tires states that the fuel saving can go until 6.7% and 37% longer wear life than the conventional tire. The Manitou's tire is suggested to be replaced with these new tires as it only uses four numbers of tires per vehicle. However, the replacement better to be done when the tires are really at a time to change.

Diesel saving = 0.067 x 7,626 L = 511 L

Diesel usage afterfurther CPoption = 7,626 L- 511 L

= **7,115 L**

The calculation assumes that the road pavement has been done. Further diesel usage after further CP optionis 7,115 L which is valued at RM 15,084 per month and equals to 19,140 kgCO_2/month carbon footprint.

3. Progressive shifting

The vehicles should gear smoothly and maintain the gear within the journey. The geared can be accelerated by not too fast and use the minimal engine revs for each gear change will be better for fuel economy, more quiet, smoother and also emit less of CO_2(Park, 2012).

4. Well maintenance

All of the vehicles at the premise are more than 5 years of usage and not properly maintain. For example, the concrete truck might have a crooked blade inside that can keep the concrete wastage inside and not mix the concrete very well. Maintain the vehicles as scheduled and early detect the problems can avoid the severe failure of the vehicle's operation. The tire should also be inflated suitable to the manufacturer's recommendation. 10% underinflated will decrease 1% in fuel efficiency and 15%

shorter tread life. For severe condition, the tire will damage and need to remove early(Criswell, 2017).

4.4.4 Energy Efficiently Improvement

The electricity only consumes at the Operation Office and workers cabin. Some recommendations that should be considered as below:

1. Improvement of lighting systems

The office is currently using twenty numbers of 22 Watt fluorescent lamp, also known as T8 and the worker's house use four numbers of 14 Watt compact fluorescent light bulb, known as CFL bulb. By replacing lamps and bulbs with 8 Watt of LED lamp (T8 LED), the average saving is about 53%.

Electric usage (maintenance office) = 0.022kW x 20 units x 10.5hr x 26days

= 120 kW

Electric usage (Workers' cabin) = 0.014kW x 4 units x 10.5hr x 26days

= 15 kW

Thus, total electric usage for lighting = 135 kW per month

$$\text{Electricity saving} = 0.53 \times 135 \frac{kW}{month}$$

$$= 72 \frac{kW}{month}$$

$$\textbf{Electricity usage afterCP option} = 135 \frac{kW}{month} - 72 \frac{kW}{month}$$

$$= 63 \frac{\boldsymbol{kW}}{\boldsymbol{month}}$$

By replacing the fluorescent lamps and the bulbs to LED T8 lamp, the electricity usage can be reduced to 63kW per month which valued at RM 28 and equal to 43 $kgCO_2$/month carbon footprint.

The installation of motion detectorsis also recommended in helping to reduce the total energy consumption by controlling lighting operation. Small cost investment can bring a huge amount of future saving. Subsequently, the energy usage will reduce as the duration is less.

2. Increase up the air-conditioner temperature from 16^0C to 20^0C

By increasing the temperature, the electricity will reduce to about 40%. There are two units of 1 HP air-conditioner which equal to 0.746 kW of energy per unit.

Total electric usage for air-conditioner = 0.746kW x 2 units x 10.5hr x 26 days

= 407 kW per month

$$\text{Electricity saving} = 0.40 \times 407 \frac{kW}{month}$$

$$= 163 \frac{kW}{month}$$

Electricity usage afterCP option $= 407 \frac{kW}{month} - 163 \frac{kW}{month}$

$$= \mathbf{244} \frac{\boldsymbol{kW}}{\boldsymbol{month}}$$

By increasing 4 degree Celsius of the air-conditioner temperature, the electricity usage can be reduced to 244 kW per month which valued at RM 106 and equal to 164 $kgCO_2$/month carbon footprint.

The implementation of good practices like cleaning the filter when dirty and always close the door to maintain the room temperature also helps in significant energy saving.

The total CO_2 emission after CP options

$$= 1{,}684\,\frac{kgCO_2}{month} + 19{,}140\,\frac{kgCO_2}{month} + 0\,\frac{kgCO_2}{month}$$

$$= \mathbf{20{,}824\,\frac{kgCO_2}{month}}$$

Therefore, CO_2 emission per unit panel $= 20{,}824\,\frac{kgCO_2}{month} \div 4082\,\frac{pieces}{month}$

$$= \mathbf{5.1\,\frac{kgCO_2}{piece}}$$

The CO_2 emission per unit panel after the improvement done for all the selected entities is 5.1 $kgCO_2$/piece. For 49,000 units of panels which produce within one year will emit 249,900 $kgCO_2$/year.

4.5 Feasibility Studies of Cleaner Production

4.5.1 Increase Fuel Efficiency

Total investment to improve road pavement is zero as the material is taken from the in-house source (concrete waste). The price of the tire taken from the manufacturer is RM 840.00 per unit. Thus, the total investment to buy 8 units of tires for two units of Manitousis RM 6,720.00. The cost of maintenance and installation is at the average of RM 200 per month. Hence, the total investment is RM 6,920.00 per month.

Previous diesel usage was RM 17,384 per month and after improvement, the result shows in RM 15,084 per month. The savings is up to RM 2,300.

$$\textit{Return on Investment, ROI (month)}=\frac{Total\ investment}{month} \div \frac{Total\ saving}{month} \text{.....} \textit{Equation 4.2}$$

ROI = RM 6,920/month÷ RM 2,300/month = 3 months

Thus, the ROI is 3 months. Meanwhile, the progressive shifting method and good maintenance need no cost of investment and immediate ROI.

4.5.2 Energy Efficiency Improvement

1. Improvement of lighting systems

Cost of equipment for LED lamp T8 is RM 30.00 including the lamp and additional casing. Total cost for 24 units with no installation cost is RM 600.00. Previous lamp electricity usage was RM 59 per month and after 53% saving is RM 28.

*Electric usage (maintenance office)=0.022kW x 20 units x 10.5hr x RM0.435 x 26days

= RM 52

Electric usage (Workers' cabin) =0.014kW x 4 units x 10.5hr x RM0.435 x 26days

= RM 7

Total = RM 59

ROI = RM 600.00/month ÷ RM 28/month = 22 months

Thus, the ROI is 22 months. The LED T8 lamp life span will extend until 15 years compared to fluorescent lamp T8 at approximately 6 years only. This is due to the average life of a T8 LED is 50,000 hours while T8 fluorescent is only 20,000 to 30,000 hours.

2. Maintain the air-conditioner temperature to 20^0C

No investment is required as only behavior modification needed. The total electricity usage for two units of the air-conditioner is RM 177. By 40% reduction will result in RM 106 per month and savings is RM 71 per month. The ROI is in immediate effect.

* Electric usage = 0.7457kW x 2 units x 10.5hr x RM0.435 x 26days

= RM 177

4.5.3 Housekeeping

Regular housekeeping is suggested at the premise. The panels should be immediately arranged properly in their storage once demoulding. The concrete waste is accumulated at a suitable place before sending it for crush. The empty container and rubbish are burned at premise itself. The hazardous empty chemical containers should be sent to a specialist contractor to dispose of. Thus, the ROI is immediate because no cost is required in the implementation.

4.5.4 Concrete waste management

The concrete waste accumulated for a month will be crushed by the existing bulldozer to smaller parts and ready to be used as road pavement. No outside equipment required for this method. Thus, the ROI is immediate because no cost is required in the implementation.

4.6 Safety Improvement

During the audit, it was identified that the place is dusty, noisy,and accident prone due to lack of space. Furthermore, the workers do not comply to any Personal Protective

Equipment (PPE) while working except for wearing thesafety boots. By working in the concrete area, the workers are exposed to silica which contains concrete and cement. Long-term exposure to dust containing crystalline silica can lead to lung disease (silicosis).

4.6.1 PPE awareness

The workers who are working in a high-risk area should be provided respiratory protection. They also must attend a short training on using PPE and the awareness. The premise coordinator must observe the use of PPE among the workers.

4.6.2 Put proper signage and labeling

There is no signage route for the incoming lorries. It is just monitored by workers only. This surrounding is dangerous and can cause an accident. Proper signage that easy to see and understandable signage should be put at the premise to avoid confusion by lorries' driver. For the storage of material, it is advisable to place a direction and labeling at the storage.

4.7 Summary of Results and Discussion

From the audit that was done at the selected cement casting, concrete waste, fuel and electricity have been chosen as the entities to be implemented the CP options. The audit result before CP options implementation is shown in Table 4.3. From the calculation, the CO_2 emission per unit panel is 70 $kgCO_2$/month and for 49,000 units panel produces within one year will emit 3,433 tonnes CO_2/year.

The amount of CO_2 emission at each entity for one unit panel is summarized in Table 4.3. The table shows that concrete waste, fuel, and electricity waste were contributing 64.2 $kgCO_2$, 5.4 $kgCO_2$ and 0.4 $kgCO_2$ respectively.

Table 4.3: Before CP Options Implementation

Entities	Quantity	CO_2 emission (kg/month)	kg CO_2/unit panel	Total Cost (RM)
Concrete Waste	70,850 kg/month	262,145	64.2	8,800
Fuel (Diesel)	8,200 L/month	22,058	5.4	17,380
Electricity	2,710 kWhr/month	1,809	0.4	1,350
Total		**286,462**	**70.0**	**27,530**

During CP options implementation, concrete waste which produced during concreting and demoulding process is fully recycled as pavement at the premise. The fuel was consumed by vehicles in mobilizing the fresh concrete to the moulds and the panels to the storage area and uploading into lorries. It was found that less maintenance of vehicles and road surface condition contributes to the increase of fuel consumptions. Two options have been selected to reduce the fuel consumption whereby by improving the road pavement and use of better technology of tires. The drivers' behavior in driving also helps to improve. For electricity consumption, lamps and air-conditioning are the crucial target for CP options, whereby the LED lamp is introduced to replace the existing fluorescence lamps. Meanwhile, the air-conditioning temperature should be increased from 16^0C to 20^0C. By just increasing the temperature and always close the door, the savings give a huge impact too.

By using CP options at the three entities, the CO_2 emissions per unit panel is reducing up to 5.1 kgCO_2/month as tabulated in Table 4.4. The total cost is reducing from RM 27,530 to RM14,575 per month and give a total savings by RM 155,460 per year. The 49,000 units of panel which produce within one year will emit 250 tonnes kgCO_2.

Table 4.4: After CP Options Implementation

Entities	Quantity	CO_2 emission (kg/month)	kg CO_2/unit panel	Total Cost (RM)	ROI
Concrete Waste	0 kg/month	0	0	0	Immediately
Fuel (Diesel)	7,115 L/month	19,140	4.7	13,324	3 months
Electricity	2,476 kWhr/month	1,660	0.4	1,251	22 months
Total		**20,824**	**5.1**	**14,575**	

CHAPTER 5:

CONCLUSION AND RECOMMENDATION

This study has achieved the research objectives to propose and evaluate a CP options at selected cement casting premise at Kuang, Selangor. The CP tools such as on-site reuse and recovery, the efficiency usage of energy resources and housekeeping should be carried out in this premise to target three entities (concrete waste, diesel and electricity) to reduce the CO_2 emission and to provide the cost and environmental benefits. The CO_2 emission per unit panel is reduced from 70 kgCO_2 to 5.10 kgCO_2 per month (93% reduction). Thus, the CO_2 emission reduction per year of panel productioncan be reduced from 3,433 tonnes to 250 tonnes.With estimated investment is RM7,190, the payback period can be gain within 3 years.

From this study, it shows that there areseveral options to reduce carbon footprint at the selected cement casting premise. Concrete waste and fuel consumption is the main contributors to the carbon footprint. Nowadays, there are many options in reducing the fuel consumption. It depends on the owner of the company to considerwhich one is suitable for the condition and budget. The highest reduction usually needs the company to invest before getting the benefits. The electricity usage can also reduce a lot of expenses by just changing the lamp type and adjust a bit the air-conditioning temperature. By changing the behavior more to saving concern, it merely helps a lot in waste reduction. In the construction sector, many companies are not really concern about the environment and lack of regulations enforcement give a very disappointing situation. The mind thinking of losing the money as the action has made them see the environment with a blind eye.

The scope of this study is focus on cement casting premise for retaining wall in Malaysia situation only. Another purpose of cement casting may give varies results. Thus, the research should be attempt for another purpose of cement casting premises also and at different countries to provide the opportunities for data comparison.

A recommendation of the further studies in the options of cement substitution is advisable to be done at this premise by fulfilling the concrete specification requirement of the company. The substitution material to consider is the industrial waste and is preferably to be cheaper, more environmental friendly and easy to get the source. For example, the fly ash and plastic waste can be tested. Hence, the overall cement quantity shall be reduced. It also reflects the objectives to reduce cost and the carbon footprint.

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