*Journal of BIMP-EAGA Regional Development* Volume 2. No 1. 2016
ISSN 2232-1055

# SUSTAINABLE CONSTRUCTION AND $CO_2$ EMISSIONS

Nik Nurul-Hidayah N.Y.[1*], Shamzani Affendy M. D.[2] , Alias Abdullah[3], T. Sugiyama[4] and Hadi Purwanto[5]

[1]Kulliyyah of Architecture & Environmental Design, International Islamic University of Malaysia, Malaysia.
[2]Department of Applied Arts & Design, Kulliyyah of Architecture & Environmental Design, International Islamic University of Malaysia, Malaysia.
[3]Department of Urban & Regional Planning, Kulliyyah of Architecture & Environmental Design, International Islamic University of Malaysia, Malaysia.
[4]Center for Engineering Education, Faculty of Engineering, Hokkaido University, Japan
[5]Department of Materials, Kulliyyah of Engineering, International Islamic University of Malaysia, Malaysia.

E-Mail: shamzani@iium.edu.my

## ABSTRACT

*Both Green Building Index (GBI) and Comprehensive Assessment System for Built Environment Efficiency (CASBEE) sustainable construction certification acknowledged the atmospheric emissions, hence signify the importance of the $CO_2$ emissions measurement for every construction project in the world. Gross Domestic Products of Japan and Malaysia both resultant to 10 and 18.6% in 2012, from the construction industries and believes to increase by years due to rapid urbanisation demand of both countries. Therefore, propagate the strategic stakeholders of the project to play challenging roles in combating the $CO_2$. This paper supports by contributing several numbers of strategic plans in mitigating this issue. In addition, this paper also provides a fundamental evaluation to $CO_2$ as the environmental performance indicator for a project. This research investigates on the $CO_2$ emissions in bore piling concrete structure construction. Malaysian 2014 $CO_2$ inventory data that were developed by this research are being adopted in the analysis. The life cycle assessment of bore piles- construction and transportation resultant to 20,910.54 kg-$CO_2$/$m^3$. Comparisons were made with Japanese findings. It is found that the volume of concrete is not the significant factor of $CO_2$ emissions, but amount of combustions from machineries and transportation contributes to the $CO_2$ emissions. This paper enhances the strategic environmental planning in order to reduce the $CO^2$ emissions that were ground from the construction activities.*

**Keywords:** carbon dioxide ($CO_2$), concrete, construction, life cycle assessment, inventory analysis, strategic environmental planning

## 1.0 INTRODUCTION

The ambient of the globe has faced climate change since 21st century. Various sources of air pollutants and energy had been recognizes become the contributor of climate change process. Anthropogenic sources from human activities are being identified and construction industry is among one of those. However, nowadays the impact is to be seen turning back to the construction industry itself.

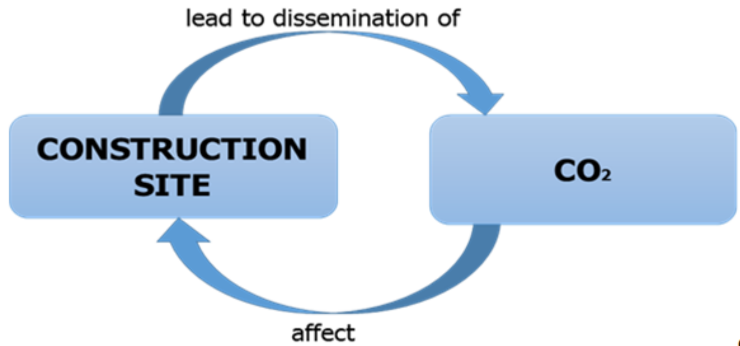


**Figure 1:** The Link between $CO_2$ sources and impact of Constructions Site

When the temperature increases, especially in a tropical weather like Malaysia, the weather may become hotter and the construction workers whom work at the outdoor site without sheds to cover them, it then decrease their productivity and indirectly lead to the delay and surplus in project. Demand of concrete infrastructure works are concurrently raising with the urbanisation of a country. These represent the declination of quality of ambient air. It is a huge challenge to the construction industry player to sustain the environment from degradation.

In this research, the carbon emissions are provided throughout the delivery of materials and construction of concrete infrastructure. As the massive concrete work found through the construction of piling, bore piling work had been chosen for the purpose of this paper. The control of this environmental pollutant in construction site is believed to affect the strategic environmental planning of this project. Significantly, this paper provides the basis for environmental performance evaluation as a part of life cycle assessment for concrete work in Japan and Malaysia. Hence, it is vital in order to provide the construction team player in any countries with the proposed mitigation measures from the environmental impact due to the concreting work.

This study targets to review the infrastructure construction carbon emissions and its control during planning activity. This aims are being accomplished through the following objectives that are to identify and understand the environmental impacts, specifically the $CO_2$ emissions that releases from the construction of concrete infrastructure and to investigate on the strategic environmental planning implemented in those construction sites.

## 2.0 LITERATURE REVIEW

Green Building Index (GBI) and Comprehensive Assessment System for Built Environment Efficiency (CASBEE) are the sustainable construction certifications that acknowledged the atmospheric emissions, hence signify the importance of the $CO_2$ emissions measurement for every construction project in the world.

The environmental performance of building and built environment are being evaluate and rate in Japan with the method namely CASBEE. Since 2001, this system was established through the cooperation between stakeholders include, academia, industrial and governmental officer. This system than lead to the found of the Japan Sustainable Building Consortium (JSBC) under the support of the Ministry of Land, Infrastructure, Transport and Tourism (MLIT).

This environmental performance evaluation and rating system of Japan has acknowledged the significant of $CO_2$ since 2008. Therefore, Lifecycle $CO_2$ ($LCCO_2$) assessment that evaluates $CO_2$ emission during the entire building life cycle from construction and operation to demolition and disposal had been introduced. A new free standard calculation method had been developed. The user just need to enter the data into the CASBEE spreadsheet, thus the result of $LCCO_2$ estimation will be shown automatically.

In CASBEE 2016, a building that satisfies the energy standards for building owners according to the Japanese Energy Conservation Law has been appointed as a reference. $LCCO_2$ performance is indicated through level 1 until 5 green stars awards that were evaluated on $LCCO_2$ emissions rate for the assessment target is evaluated relative to the $LCCO_2$ emission level of the reference building.

In, Malaysia, the GBI has been established by Malaysian Institute of Architects and the Association of Consulting Engineers Malaysia. GBI meant for environmental rating system for buildings. Environmental design and performance of Malaysian buildings are being rated under the six main criteria include the energy efficiency, indoor environmental quality, sustainable site planning and management, materials and resources, water efficiency and innovation. For this specific paper evaluating the bore pile concrete construction work for rapid train structure, the GBI, 2009 assessment criteria involved are the Non-Residential New Construction Part 3, under the Criteria of Sustainable Site Planning & Management in SM5 that listed the Earthwork, Construction Activity Pollution.

The insight of Japan for concrete-making materials viewing cement as the highest contributor at 784 kg-$CO_2$/ton, while aggregates and other admixture materials at low level (Henry,2010). This is supported by IPCC, 2007 statement indicating fossil fuel and cement production is the main contributor of $CO_2$. Supported by the recent United Nation Copenhagen 15 Conference, Malaysia government has pledged a voluntary 40% reduction of carbon dioxide ($CO_2$) emission intensity by 2020. Hence, under the Eleventh Malaysia Plan (2016-2020), government has strengthened effort to reduce $CO_2$ emission by climate adaptation and mitigation measures.

Viewing into the geotechnical concrete structure constructions, bored pile that act as the foundation to transfer the loads to a deeper layer of soil had been found contributing highest carbon dioxide ($CO_2$) emissions in comparison with other ground foundation systems Ong and Choo, 2014. Thus, sandwiching with the bore pile structures are the sustainability challenges that each of its process, materials, machineries and mobiles own.

Health impact that can be seen from the emission of $CO_2$ are, in a scenario of acute high level $CO_2$ exposure supported by the reduction of $O_2$ lead to the headaches, attacks of vertigo, poor memory, poor concentration, insomnia, tinnitus, double vision, photophobia, loss of eye movement, visual field defects, enlargement of blind spots, deficient dark adaptation and personality changes (Susan,2004).

**Table 1:** Health Impact of $CO_2$

| **Acute high $CO_2$ exposure** | **Long term $CO_2$ exposure** |
|---|---|
| 1. Headaches<br>2. Attacks of vertigo<br>3. Poor memory<br>4. Poor concentration<br>5. Insomnia<br>6. Tinnitus,<br>7. Double vision,<br>8. Photophobia<br>9. Loss of eye movement<br>10. Visual field defects<br>11. Enlargement of blind spots<br>12. Deficient dark adaptation<br>13. Personality changes | 1. Benign<br>2. Alterations in bone mentalism<br>3. Alterations in related blood calcium concentrations. |

*Source: Susan,2004.

Furthermore, multiple manner, metrics and systems had been identified in measuring the sustainability quantitatively. The environmental impact of life cycle assessment (LCA) is one of them O'Brien & Gere, 2004. From this Figure 1, it can be seen that there are the input of concrete raw materials are the extraction and processing of steel, cement, course and fine aggregate. Then, there are system boundaries involving the manufacturing of ready mixed concrete, construction of concrete structure, use of concrete infrastructure that involve rehabilitation process of making good in maintaining the facilities, demolition of the concrete structure loading it for the landfilling or recycling it to become the recycle aggregate type III. Various types of energy and electricity are included in this process in order to transport, and operates the vehicles and machineries. These processes lead to various atmospheric emissions, waterborne wastes and solid wastes. This paper scope only to the machineries and transportations of construction for bore pile concrete structure and their respective $CO_2$ emissions. The highlighted dashed line in the diagram identifies the system boundaries and scoping of LCA for this study that are elaborated in the section 3.

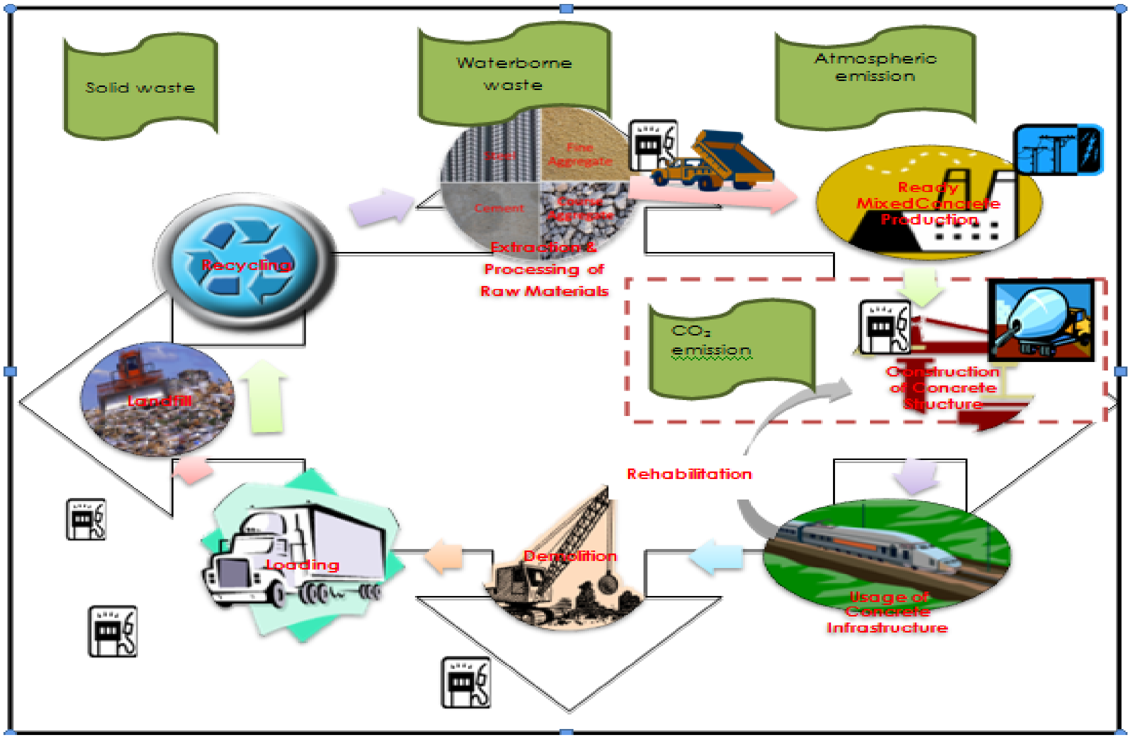


**Figure 2:** Life Cycle of Concrete Structure adopted from Kawai (2005), University of Michigan (2008), Rebitzera (2004), USEPA (2006), Whitelaw (2004), Pennington (2004), International Standard Organization (1997).

## 3.0 RESEARCH METHODOLOGIES

To understand better the overall concrete structural construction $CO_2$ emissions factor, a mixed type of research strategies is being applied. Both quantitative and qualitative methods were adopted systematically. The benefits of having these two types of research strategies are that they can complement each other and results in comprehensive data collections.

Through the literature review, the subject of civil engineering concrete structure construction, sustainability, life cycle assessment, laws regulating both environment and LCA, atmospheric pollutant emission and implication towards exposure of $CO_2$ emissions had been literally described based upon two sources. Those are searched from the primary and secondary literature sources. The first sources, are reviewing the previous research paper from academic journals, papers from conference, related dissertations and government publications. The researcher also uses secondary types of literature sources for instance searching related textbooks, trade journals.

Quantitative research as described by Cormack, 1991 is a research strategy that is formal and has certain objective, which involves systematic process and utilizing the numerical data in order to get information about the world. Thus, four (4) infrastructure construction sites had been selected from Japan and Malaysia as case studies area. For the purpose of this paper discussion, concrete structure from retaining wall, tunnel lining, pre-stressed concrete bridge, and bore piling were investigated and compared. However, only concrete bore pile constructions were elaborated in detail as the site was in Malaysia and the new findings of this research.

The principal tool adopted in this quantitative method is life cycle assessment of the concrete construction. These tools consist of scoping, inventory analysis, impact assessment, interpretation and direct application phase. The scope of this paper are being limited to the LCA of manufacturing of ready-mixed concrete, construction of concrete structure and the environmental impact of atmospheric emission specifically the $CO_2$ only and the energy consumed by these projects.

Furthermore, the inventory analysis was held by conducting the bottom up based method. The bottom up is a process analysis. For Japan, the inventory analyses are obtained from data collections gain from the literature survey and hearing to the institute that are already established by Kawai, 2005 and adopted in Japan concrete construction industry reference. On the other hand, the Malaysia inventory data are obtained from the GreenTech Malaysia, 2010 but it is adopted from IPCC Guideline, 2006, thus both were read together. The approaches used are the top down based method. This methodology uses both the reference and sectorial approach; this is based upon economic input-output based method. For Malaysia inventory data are not yet established for the concrete construction industry, thus this paper is also to provide the inventory data for $CO_2$ emitted by the Malaysia energy in 2014. The main reference is the National Energy Statistical Handbook, 2014. The methodologies are being adopted as accordance to IPCC 2006 Guideline. Therefore identification of sector for combustion types of fuel from stationary sources and mobile sources are being selected as follows: -

**Table 3:** The Sector for Concrete Work Fuel Combustion

| **Sector Reference No.** | **Description of Sector** |
|---|---|
| 1A2 | Construction |
| 1A1c | Steel Coke Oven |
| 1A3b | Transport by Industry (On Road) |
| 1A3b iii | Heavy Duty Truck & Buses, seperate |
| 1A3b ii | Light Duty Trucks<br>• With 3-way catalyst<br>• Without 3-way catalysts |
| 1A5 other | Other: Not elsewhere specified all remaining emissions from non-specified fuel combustion include. (Off road)<br>a. Stationary<br>b. Mobile |

*Source: IPCC Energy Combustion, 2006

Among those four (4) case studies, $CO_2$ were analyzed statistically. Based on the statistical results, supported by the qualitative research strategies the literal interpretation of the environmental management plan that had been applied in all case studies are being described. Detailed case studies on peak values of emissions and energy usage during the construction of the concrete structure, indicating the source characters of different energy consumed being interpreted. This is in order to diagnosis a situation, screening alternatives and to discover new ideas. Mitigation/prevention measure adopted in these concrete infrastructure constructions are being discussed in order to complement the LCA direct application steps for strategic planning.

## 4.0 RESULTS AND FINDINGS

This section is being distributed into four subsections that are the inventory data, impact assessment, interpretations and direct application in strategic planning. A concrete bore piling structure had been constructed as in the following schematic Figure 3. As shown in the image, the total amount of concrete had been use in this bore piling are 114m$^{3.}$

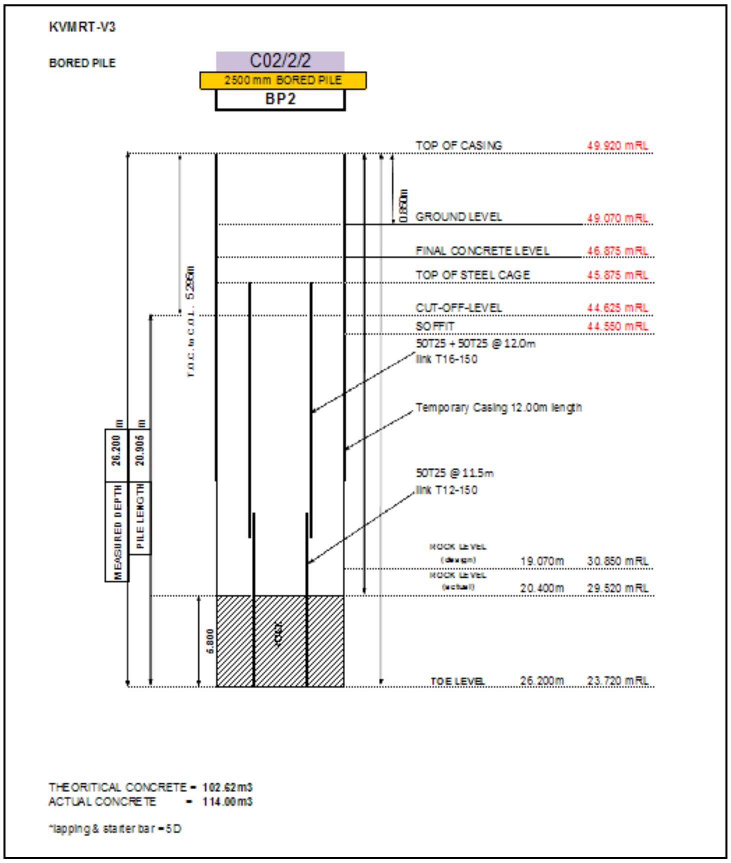

**Figure 3:** Schematic view of bored pile.

### 4.1 $CO_2$ Emissions Assessment

The following Table 4 summarized the $CO_2$ emissions inventory data according to energy used in Japan and Malaysia. It can be seen that the inventory data from Japan were found in the unit of kg-$CO_2$/unit while Malaysian found in kg-$CO_2$/MJ. These data inventories for Malaysian were developed in this unit as the limitation of resources found from bore piling only, hence no average can be summed up for the use of civil infrastructure project. In addition, the conversion factor is at constant of 41.84 MJ/unit as accordance to instruction of Malaysian GreenTech, 2010 that were adopted from the IPCC Guideline,2006.

As clearly indicated in the following Table 4, the highest $CO_2$ emissions in Malaysia can be found from the fuel oil at 76.59 kg-$CO_2$/GJ while the lowest emissions calculated are from the electricity at 2.26 kg-$CO_2$/GJ. In contradiction, the highest emissions in Japan can be found from the acetylene gas at 3.38 kg-$CO_2$/* and the lowest emissions is also from electricity at 0.407 kg-$CO_2$/*.

**Table 4:** The $CO_2$ Emissions Inventory Data According To Energy in Malaysia, 2014.

| Energy Types | Malaysia | | Japan | |
|---|---|---|---|---|
| | Conversion Factor (MJ/unit) | $CO_2$ emission (kg-$CO_2$/GJ) | Calorific value (MJ/*) | $CO_2$ emission (kg-$CO_2$/*) |
| Crude Oil (local) | 41.84 | 72.60 | n.a. | n.a. |
| Natural Gas Liquid | 41.84 | 62.44 | n.a. | n.a. |
| Refinery Gas | 41.84 | 0 | n.a. | n.a. |
| ATF (Jet Kerosene) | 41.84 | 70.79 | n.a. | n.a. |
| Kerosene | 41.84 | 71.15 | 36.7 | 2.5 |
| Gas/Diesel Oil | 41.84 | 73.33 | 38.2 | 2.64 |
| Fuel Oil | 41.84 | 76.59 | n.a. | n.a. |
| LPG | 41.84 | 62.44 | 50.2 | 3.03 |
| Gasoline | 41.84 | 68.95 | 34.6 | 2.31 |
| LNG | 41.84 | 0 | 54.5 | 2.79 |
| Acetylene Gas | 41.84 | n.a | 50 | 3.38 |
| Coke Oven/Gas Coke | 41.84 | 46.71 | n.a. | n.a. |
| Natural Gas Dry | 41.84 | n.a | n.a. | n.a. |
| Electricity | 41.84 | 2.26 | 9 | 0.407 |
| Heavy oil Type A | n.a. | n.a. | 41.7 | 2.77 |

*Source: Malaysia Energy Statistical Handbook (2014), GreenTech (2010), IPCC Energy Combustion Guideline (2006), and Kawai (2005).

Japan had established their own concrete infrastructure $CO_2$ emission since 2005, this can be seen as in the Kawai, 2005 and updated by Kawai,2010. However, for the purpose of this paper, for the Malaysia case, only $CO_2$ emission from the construction of concrete structure of bore piling were displayed in the results and findings section.
From the data collection conducted, emission amount from the bore piling concrete infrastructure had been established as indicated in the following Table 5. This table was form through the calculation of amount usage of transportation of materials and machineries in construction commissioning; the following formula also had been adopted from Kawai, 2005.

$$\textit{Fuel consumption} = \frac{\textit{Engine power x Specific fuel consumption}}{\textit{Max Capacity x Ave. Speed}}$$

For all four (4) cases, the average speed was assume to be 30km/h and engine power and specific fuel consumption were obtained from the Equipment Cost Calculation Chart (JCMA, 2001), and Malaysia Energy Statistics: Handbook, 2014 and data collected from contractor.

**Table 5:** $CO_2$ emissions for transportation of ready mixed concrete, case study of bore piling.

| Material | Unit | Amount | | Transportation Method | No. of Truck | Distance from Supplier to Site (km) | Total Transport Distance (km) x 2 [Include return trip] | Type of Energy Used | Unit | Fuel Consumption Amount | Engine Power (kW) | Maximum Capacity (m3) | Average Speed (km/h) | Total Energy Consumption (J) | CO2 emissions kg-$CO_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ready mixed concrete | m³ | 114 | 60 | Agitator Truck (10m3) | 6 | 15 | 180 | Diesel | L | 25.7 | 206 | 10 | 30 | 17.6473 | 1.29 |
| | m³ | | 54 | Agitator Truck (9m3) | 6 | 15 | 180 | Diesel | L | 22.5 | 206 | 10 | 30 | 15.4500 | 1.13 |
| *Total* | | | | | | | | | | | | | | 33.0973 | 2.43 |

**Table 6:** Bore Piling Construction $CO_2$ Emissions in Malaysia.

| Method | Machine | Unit | Amount | Types of Energy used | Unit | Fuel Consumption Amount | Engine Power (kW) | Maximum Capacity | Unit | Total Energy Consumption (J) | $CO_2$ emissions kg-$CO_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Coring/Boring | Boring Plant | h | 37.5 | D | L | 1875 | 433 | 72500 | kg | 11.1983 | 0.82 |
| | Hydraulic Crane 80t Capacity | h | 37.5 | D | L | 937.5 | 208 | 80 | t | 2437.5000 | 178.73 |
| | Kelly Bar | h | 37.5 | - | L | 0 | 0 | 0 | - | 0 | 0 |
| Installation of Temporary Casing | Hydraulic Crane 80t Capacity | h | 0.5 | D | L | 12.5 | 208 | 80 | t | 32.5000 | 2383095 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Temporary Casing | m | 12 | - | L | 0 | 0 | 0 | - | 0 | 0 |
| | Vibro hammer | h | 0.5 | D | L | 4.6875 | 315 | 6800 | kg | 0.2171 | 0.00 |
| Base Cleaning | Boring plant | h | 0.5 | D | L | 25 | 433 | 72500 | kg | 0.1493 | 0.00 |
| | Hydraulic Crane 80t Capacity | h | 0.5 | D | L | 12.5 | 208 | 80 | t | 32.5000 | 2.38 |
| | Cleaning bucket | h | 0.5 | - | L | 0 | 0 | 0 | - | 0 | 0 |
| Installation of Steel Cage | Hydraulic Crane 80t Capacity | h | 2 | D | L | 50 | 208 | 80 | t | 130 | 9.53 |
| | Steel Cage | tons | 8.23 | - | L | 0 | 0 | 0 | - | 0 | 0 |
| | Temporary Casing | m | 12 | - | L | 0 | 0 | 0 | - | 0 | 0 |
| Concrete Placing | Agitator Truck (9m3) *total hours on site for 6 trucks | h | 2 | D | L | 150 | 206 | 10 | $m^3$ | 3090.0000 | 226.58 |
| | Agitator Truck (10m3) *total hours on site for 6 trucks | h | 2 | D | L | 150 | 206 | 10 | $m^3$ | 3090.0000 | 226.58 |
| | Hydraulic Crane 80t Capacity | h | 4 | D | L | 300 | 208 | 80 | t | 780.0000 | 57.19 |
| | Tremie Pipe 2m dimension, 8”-12”, 1-4m length | h | 4 | - | L | 0 | 0 | 0 | - | 0 | 0 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Uninstall Temporary Casing | Hydraulic Crane 80t Capacity | h | 0.5 | D | L | 12.5 | 208 | 80 | t | 32.5000 | 2.38 |
| | Temporary Casing | m | 12 | - | L | 0 | 0 | 0 | - | 0 | 0 |
| | Vibro Hammer | h | 0.5 | D | L | 4.6875 | 315 | 6800 | kg | 0.2171 | 0.02 |
| Compaction | Self-compact Admixture | h | 24 | - | - | 0 | 0 | 0 | - | 0 | 0 |
| Curing | Natural | h | 24 | - | - | 0 | 0 | 0 | - | 0 | 0 |
| **Total** | | | | | | | | | | **9636.7819** | **2383799.22** |

Note: Energy Type, D=Diesel

As indicated in the above Figure 3, it can be viewed that the total length of pile for this case study is 20.905m at 114m$^3$. Hence, the total emission of $CO_2$ for the transportation of materials to site per cubic meter is 0.0213 kg-$CO_2$/m$^3$, while the total emission of $CO_2$ for the combustion of machineries during construction of bore piling is 20,910.52 kg-$CO_2$/m$^3$. These amounts to the sum of 20,910.54 kg-$CO_2$/m$^3$. For both construction and transportation of materials in the case of a number of concrete bore piling in Malaysia at 114m$^3$, the total amount is 2,383,801.65 kg-$CO_2$.

## 4.2 Total $CO_2$ Emissions of Each Case Study

Comparative study of Malaysian and Japan infrastructure construction had been done. Data obtained from Japan are as indicated in Table 7. It is to be acknowledged that this result that is meant per unit of each case study, thus the calculation of $CO_2$ emissions per unit can be derived through the division of the volume of concrete. The designs of these infrastructures were typical, as indicated in the Kawai, 2005.

**Table 7:** Total $CO_2$ Emissions of Each Case Study

| Types of Civil Infrastructure | Unit | Total Concrete Construction | $CO_2$ Emissions (kg-$CO_2$) | $CO_2$ Emissions (kg-$CO_2$/unit) |
|---|---|---|---|---|
| PC bridge | $m^3$ | 240.40 | $3.51x10^3$ | 14.60 |
| Retaining Wall | $m^3$ | 943.92 | $2.56x10^5$ | 271.21 |
| Secondary Tunnel Lining (500m) | $m^3$ | 3225.00 | $7.91x10^5$ | 245.27 |
| Bore Piling | $m^3$ | 114.00 | $23.84x10^5$ | 20,910.54 |

The following Figure 4 illustrate the results of the emission from the combustion of transportation of material and combustion of machineries use in the construction activities according to the types of concrete infrastructure construction. From the figure below it can be seen that the highest $CO_2$ emissions is bore piling construction with 20,910.54 kg-$CO_2$/unit while the lowest is PC bridge with 14.60 kg-$CO_2$/unit.

Scanning the scenario strictly, concrete bore pile construction in Malaysia used agitator truck of 9-10$m^3$ capacity, boring plant, hydraulic crane, and vibro hammer. On the other hand in Japan, PC bridge construction and transportation used agitator truck of 4.5 $m^3$, nos. of truck at 10 tonnes, 4 tonnes and 2 tonnes were used. Hence, indicating that the types of machineries and transportations used, twinning with distance, engine power, types of energy, and duration of usage influence these results.

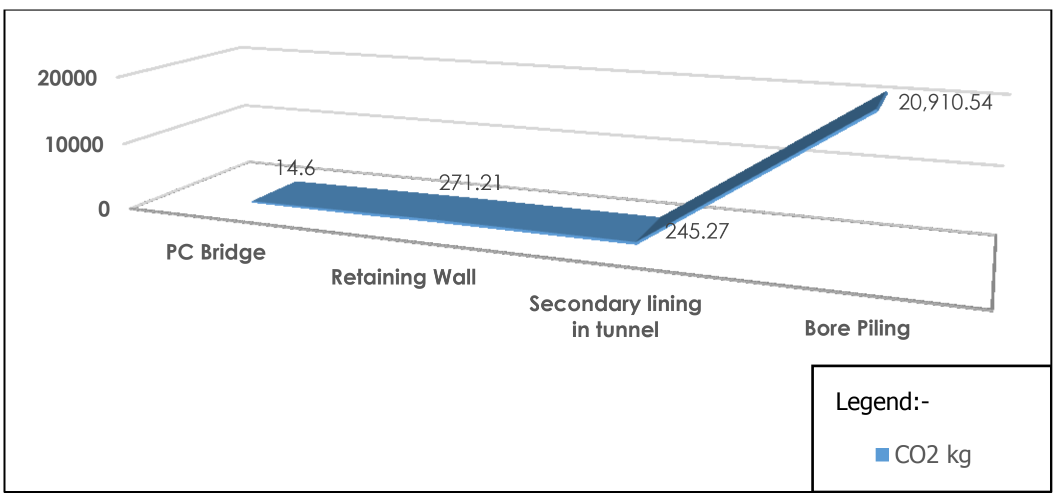


**Figure 4:** $CO_2$ emission according to concrete civil infrastructure per $m^3$

## 4.3 The Control of $CO_2$ and Site Management Planning

From the results, it shows that the strategic planning for the control of $CO_2$ is vital in a concrete infrastructure construction. Therefore, through this study, it is proposed at three different levels that are in the aspect of planning design and site management plan. All four (4) projects are constructed by using the considering and verifying environmental performance design method. Mixture of concrete and proposed alternative materials are being designed and calculated.

In the case of PC bridge, it can be seen the reduction of 5.10% of $CO_2$ emissions due to the modified mix proportions and amounts of ready mix concrete due to the use of high range water reducing admixture, beside nearest supplier of other materials. Moreover, findings from the retaining wall grasp that the hollow block surpass the in-situ retaining wall construction $CO_2$ emissions. In this case, the hollow blocks are being piled up before connecting them with ready-mix concrete and steel bars, soils from site being treated and filled in the hollow blocks later. Hence, reduction in amount of transportation concrete product. Thus, evolving secured concrete quality.

In the secondary lining in tunnel, the heating and rubbing method of recycling fine and coarse aggregate offers the lowest $CO_2$ emissions at $7.91x10^5$ that is reduction of 19.90%. For the bore piling case, the concrete mix is being designed with super plasticizing admixture that improves the pumpable concrete, no vibration and compaction needed during placing. The supplier of this concrete also plays important role by reducing the amount of concrete mix transported not exceeding the capacity of the truck, resultant to low emissions of $CO_2$ during the transportation of materials and reduction of water usage to clean off the truck from dust. This blended cement is obtained from fly ash coal burning power station and slag obtained from the steel industry blast furnaces.

The site management planning that had been established and implemented in this project is listed in the following list:-

i. stop the machineries/equipment at the point of not using
ii. scheduled maintenance of machineries and vehicles
iii. practice energy saving
iv. using diesel to generate electricity
v. materials are not to be loaded to a higher level than the side and tail boards
vi. materials should be dampened or covered before transport
vii. water sprays are being applied to maintain the worksite wet
viii. all dusty materials are being sprayed with water prior to any loading
ix. unloading or transfer operation so as to maintain the dusty materials wet
x. where every vehicle leaving a construction site is carrying load of dusty materials are being covered by clean impervious sheeting to ensure that the dusty materials do not leak from the vehicle
xi. post and enforced speed limits to reduce airborne fugitive caused by vehicular traffic
xii. train workers to handle construction materials and debris during construction and dismantlement to reduce fugitive emissions
xiii. tighten gate seals on dump trucks
xiv. immediately before leaving a construction site
xv. every vehicle shall be washed to remove any dusty materials from its body and wheels
xvi. all spraying of materials and surfaces should avoid excessive water usage
xvii. any stockpile of dusty materials shall be either:
    (a) covered entirely by impervious sheeting
    (b) placed in an area sheltered on top and the 3 sides or

(c) sprayed with water or a dust suppression chemical so as to maintain the entire surface wet

xviii. preparation of exact types of facemasks and goggles.

## 5.0 CONCLUSIONS

There are 5 key conclusions has been derived from this study includes: 1) Combined with qualitative result on some specific $CO_2$ specifies with high detection rate the listed materials/vehicle/equipment/machineries used were proposed as $CO_2$ sources in concrete structure construction project 2) the highest value resultant out of the bore pile construction 3) The lowest emissions are found during PC bridge construction 4) types of machineries and transportations used, twinning with distance, engine power, types of energy, and duration of usage influence the $CO_2$ emission towards the environment 5) proposed strategic environmental plan that had been practiced in the case studies are being established in order to mitigate this issue. This study could help to better understand the climate change impact by the concrete infrastructure construction and its mitigation measures that shall be adhered to the future concrete construction work in every part of this world.

Moreover, this paper is written to complement the student exchange program between International Islamic University of Malaysia and Hokkaido University. Due to limited time, only $CO_2$ emissions from construction process are environmentally evaluated in this paper. It is believed, as the boundaries of studies expand, *supra* optimal solutions may emerge. Hence, it is highly recommended to be further explored in Malaysian studies covering all environmental aspects and processes involve in the concrete construction operations.

## ACKNOWLEDGEMENT

Greatest appreciation to Kulliyyah of Architecture & Environmental Design, Kulliyyah of Engineering, Research Management Centre (RMC), International Islamic University of Malaysia (IIUM) grant no.: EDW B13-045-0930 and Centre for Engineering Education, Faculty of Engineering, Hokkaido University, Japan for the funding assistant of this research.

## REFERENCES

Cormack,(1991). *Quantitative Research*, p. 140.

Department of Statistics, Malaysia (16th May 2014). Annual Gross Domestic Product 2005 2013, Department of Statistics, Malaysia: Malaysia, pp.2

Department of Statistics, Malaysia (2014). Quarterly Construction Statistics, Third Quarter 2014, Department of Statistics, Malaysia: Malaysia, pp.8.

Economic Planning Unit, (2015). Eleventh Malaysia Plan 2016-2020: Anchoring Growth on People, May 2015, Malaysia.

Eggleston,S., Buendia, L., Miwa, K., Ngara, T., and Tanabe K., (2006) Intergovernmental Panel on Climate Change Guidelines for National Greenhouse Gas Inventories, Vol.2: Energy, IGES, Japan.

Energy Commission (2014), Malaysia Energy Statistics: Handbook, Malaysia.

G. Rebitzera, T. Ekvallb, R. Frischknechtc, D. Hunkelerd, G. Norrise, T. Rydbergf, W.-P. Schmidtg, S. Suhh, B.P. Weidemai, D.W. Penningtonf (2004). Life cycle assessment Part 1: Framework, goal and scope definition, inventory analysis, and applications, Environment International, Vol. 30, pp.701– 720

GreenBuilding Index (2009), GBI Assessment Criteria for Non-Residential New Construction (NRNC), First Edition, April 2009, Ver.1, Malaysia.

GreenTech Malaysia, (2010). Methodology for greenhouse gases inventory, Malaysia.

Henry, M. (2010). Formation and evaluation of sustainable concrete based on social perspectives in the Japanese concrete industry, Doctoral Dissertation, Department of Civil Engineering, The University of Tokyo: Japan.

Institute for Building Environment and Energy Conservation (2016), Comprehensive Assessment System for Built Environmental Efficiency (CASBEE), March,2016, Tokyo, Japan.

International Standards Organization [ISO], (1997). Environmental Management – Life Cycle Assessment- Principles and Framework ISO 14040.

Japan Construction Machinery and Construction Association (JCMA), 2001. Equipment Cost Calculation Chart, Japan.

Kawai K., Sugiyama T., Kobayashi K. and Sano S., (October 2005). Technical report: Inventory Data and Case Studies for Environmental Performance Evaluation of Concrete Structure Construction, Journal of Advanced Concrete Technology ,Vol.3, No. 3, pp. 435-456.

Kawai, K., Fujiki, A., Aoki, Y. Iwatani, Y. (2010). Preparation of Inventory Data for Environmental Performance Evaluation of Concrete and Concrete Structures, Proceedings of Honouree sessions ed., The University of Wisconsin Milwaukee Centre for By-Products Utilization Second International Conference on Sustainable Construction Materials and Technologies, June 28-June 30, 2010, at Universita Politecnica delle Marche, Ancona, Italy. Retrieved on 11 April 2016 from http://www.claisse.info/2010%20papers/p26.pdf

Najib,.R. (2009).Najib Razak Speech Archive, U.N. Climate Change Conference 2009, "15th Conference of Parties (COP 15)",17th Disember 2009, Copenhagen, Denmark. Retrieved from http://www.pmo.gov.my/home

O'Brien & Gere, (2004). Strategic Environmental Management for Engineers, John Wiley & Sons, Inc.:United States.

Ong, D. E. L. and Choo, C. S., Sustainable construction of a bored pile foundation system in erratic phyllite, Proceedings of 'Engineering for sustainability', the ASEAN Australian Engineering Congress, Kuching, Sarawak, Malaysia, 25-27 July 201, Swinburne University of Technology. Sarawak Campus, Malaysia. Retrieved on 26th November 2014 http://hdl.handle.net/1959.3/222120

Pennington D.W., Potting J., Finnveden, G., Lindeijer E., Jolliet, O., Rydberg, T., Ribetzer, G. (2004). Life cycle assessment Part 2: Current impact assessment practice, Environmental International, Vol. 30, pp. 721-739.

Statistics Bureau Ministry of Internal Affairs and Communications Japan (2014). Statistical Handbook: Gross Domestic Product by Type of Economic Activity, pp.31, Retrieved 15 October 2014, http://www.stat.go.jp/english/data/handbook/index.htm

Susan A. R., (2004). Human Health Risk Assessment Of Co2: Survivors Of Acute High-Level Exposure And Populations Sensitive To Prolonged Low-Level Exposure, Third Annual Conference On Carbon Sequestration Rice - 5 May 3-6, 2004, Alexandria, Virginia, USA. Retrieved from http://www.alrc.doe.gov/publications/proceedings/04/carbon-seq/169.pdf

University of Michigan, (2008). Sustainable Concrete Infrastructure Materials and Systems Retireved on 15 November 2014 from http://sitemaker.umich.edu/muses/home

USEPA (May, 2006). Life Cycle Assessment: Principles and Practice, EPA/600/R-06/060, United

States of America.
Whitelaw K. (2004). ISO 14001 Environmental Systems Handbook: Great Britain.

**BIBLIOGRAPHY**

Alexandre J., Azevedo A. R. G., Silva C. L. A. P., Vieira C. M. F., Candido V. S. , Monteiro S. N., Technical Feasibility of Using Lightweight Concrete with Expanded Polystyrene in Civil Construction, Materials Science Forum, Vol. 798 – 799,2014,pp. 347-352, Retrieved 14 november 2014 from 10.4028/www.scientific.net/MSF.798-799.347.

Construction Industry Development Board Malaysia, (2008). Compilation of Environmental Acts, Laws and Regulations Related to Construction Industry, CIDB: Malaysia.

GRID-Arendal (2014). The Greenhouse Effect, Retrieved 25 November 2014, http://www.grida.no/publications/vg/climate/page/3058.aspx

Harrison, J., Pickering, C.A.C., Faragher, E. B., Austwick, P.F.C., Little, S.A., and Lawton L., (1992). An Investigation of the Relationship Between Microbial and Particulate Indoor Air Pollution and The Sick Building Syndrome. Respiratory Medicine. 86 (3) May 1992: 22-235.

Huth, M. W., (1997). Construction Technology.USA: Mc Graw Hill.

IPCC, (2007). Climate Change 2007: Impacts, Adaption And Vulnerability. Report of the Working Group II, Cambridge University Press, UK. pp. 973

Izyan, Y & Nazirah, ZA 2013, Commitment of Malaysian contractors for environmental management practices at construction site. International Journal of Sustainable Human Development, vol.3, no.1, pp. 119-127.

Japan Construction Occupational Safety and Health Association (2007), Construction Occupational Health and Safety Management System Guidelines & External System Evaluation (External Audit), Definitions: Construction Worklace, pp. 6.

JSCE (2004). Assessment for Environmental Impact of Concrete (Part 2), Japan Society of Civil Engineers, Concrete Engineering Series 62

Khairuddin, A.R., (2002). Construction procurement in Malaysia : processes and systems : constraints and strategies. Gombak, Selangor : Research Centre, International Islamic University Malaysia.

Oxford Dictionaries, 2013, Definition of construction in English. Oxford University Press. Retrieved 13 January 2013, www.oxforddictionaries.com

Sakai, K. (2008). Environmental Management of Concrete & Concrete Structures-Towards Sustainable Development in Construction Industry, Architecture Civil Engineering Environment, No. 3/2008, The Silesian University of Technology, Japan. Retrieved 26 November 2014 from
www.acee-journal.pl/cmd.php?cmd=download&id=dbitem:article:id=40&