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CO$_2$ EMISSIONS FOR CONCRETE BORE PILING CONSTRUCTION

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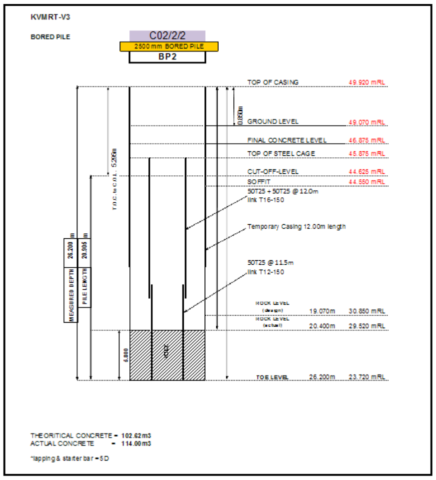
Graphical abstract



Abstract

Japan and Malaysia are among the sustainable countries in the world ranking 26 and 51 in the Environmental Performance Index (EPI), accordingly. Recent data obtained from the statistical department shows that both countries GDP contributed by the construction industries amounting 18.6% in Malaysia while Japan at 10% contribution in 2012. Malaysia and Japan are the countries that depend on the concrete infrastructure construction. As the development demand of the countries increase rapidly, it is a huge challenge to the construction industry player to sustain the environment from degradation. Hence, this paper offer strategic plans mitigation measures in resolving those issues. CO$_2$ is the environmental performance indicator to be evaluated in this paper, specifically on bore piling concrete structure construction. Construction site from Malaysia had been investigated. These data are then being analysed by using the 2014 Malaysia inventory data that was developed through this study. The key finding of this research is the 2014 Malaysian energy CO$_2$ emission inventory data, the concrete bore pile life cycle analysis for the scope of construction and transportation of materials of CO$_2$ emissions found at 20,910.54kg-CO$_2$/m^3. In comparison with Japanese concrete infrastructure, this amount is the highest thus proven that volume of concrete did not affect the amount of disseminated CO$_2$ to the environment but the amount of combustion from machineries from and transportation affect the CO$_2$ emissions. Another significant finding of this paper is the strategic mitigation measure that was done in the planning stage and imposed on site. Hence, CO$_2$ emissions ground from the concrete construction activities are turning back its cycle by affecting construction industry itself.

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.

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 paper, 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. Hence, this study targets to review the infrastructure construction carbon emissions and its control during planning activity. Thus, objectively to identify and understand the environmental impacts, and specifically focusing on the of CO_2 emissions that has been releases from the construction of concrete infrastructure. It is also to investigate on the strategic environmental planning implemented in those construction sites.

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.

2.0 BACKGROUND OF RESEARCH

Theoretically, construction is the contracted project that involved processes of building physical structures and related activities [1; 2; 3]. This explains the process of commissioning the development or demolition of any building, civil, external, service work and its related work by the agreed parties. Civil constructions are activities that develop structures closely linked with the land than other areas of construction [4]. This type of construction benefits public as a whole directly. Airport runways, railways, highways, dams and bridges are categorised into this type of construction.

Staring it in the Malaysian construction industry scenario, a recent government report [5] shows a growth of 21.2 per cent (%) amounting to RM25.0 billion work done in between 2013 to 2014. Recent data obtained from the statistical department shows that Malaysia and Japan GDP contributed by the construction industries amounting 18.6% in Malaysia while Japan at 10% contribution in 2012 [6,7]. Malaysia and Japan are the countries that depend on the concrete structure building and infrastructure construction. Expressing 17.1% of booming residential house construction in Malaysia in 2014 and 11.7% of civil work inclusive both Oil and Gas and Infrastructure construction activities.

Moreover, concrete infrastructure can be in the form of many elements at massive amount of concreting work and being conducted at an open outdoor ambient area. Thus, it is to be recognised as among the most polluting to environment for the large wastage amount generated through its process. This is supported by Alexandre *et al.,* [8]. Today's sustainability involves complex definition from various fields of studies. However, in concern with sustainability in concrete structure, the consultants are to complement the clients end needs, hence sustainability awareness among the end-client are crucially vital. Shen *et al.,* 2002 in Izyan and Nazirah 2013 [9] claimed that this rapid economic and social growth has reduced the attention towards environmental impact. Although Japan and Malaysia are among the sustainable countries in the world ranking 26 and 51 in the Environmental Performance Index (EPI) respectively but the unsustainable ways of construction in Malaysia had been practiced since previous two (2) decades. These imposed adverse direct and irreversible impact towards the environment extended up to 67.5% impact on the ecosystem, 21% on the natural resources and the remaining 11.5% on the public [9]. Besides it is also found that certain phases of construction emits certain air pollutants and in different amounts. Overall, the emission of air pollutants in the atmosphere is mainly due to material but with the additional factors of the activities; lack of legal enforcement; negligence of mitigation and control; and machinery uses.

Furthermore, 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 [10]. Thus, sandwiching with the bore pile structures are the sustainability challenges that each of its process, materials, machineries and mobiles own. 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 [11]. This is supported by IPCC 2007 [12] statement indicating fossil fuel and cement production is the main contributor of CO_2. Supported bythe 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 Tenth Malaysia Plan (2011-2015), government has strengthened effort to reduce CO_2 emission by climate adaptation and mitigation measures.

Moreover, global warming occurs as an effect of the increase in CO_2, and other greenhouse gases (i.e methane, CFCs) [13]. The characteristic of carbon dioxide is transparent to light. But, it is opaque to heat rays. Consequently, CO_2 in the atmosphere retards the radiation of heat from the earth back into space. This phenomenon as shown in the Figure 1 is known as the greenhouse effect. This increment of CO_2 also causes the inclination of the average temperatures. It is found that there is an increment of ~0.6°C in the last century. It affects both ocean and land temperatures, glaciers and ice sheets are receding, barren wood shrubs in areas of northern Alaska, early flowering of angiosperms in the spring, birds and butterflies are moving north and breeding earlier in the spring. It is forecasted that by the end of this century, the earth will warm in the range of 2.5–3.5°C. 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.

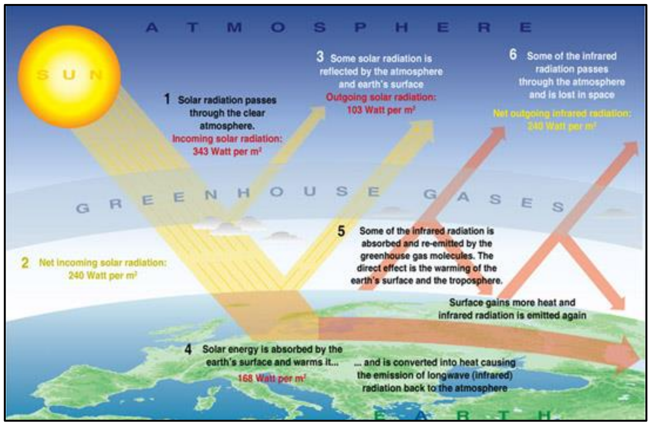


Figure 1 Diagrams of Greenhouse Gases Reactionsfrom the Carbon Cycle[14]

Besides, 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 [15]. In addition, in a scenario where long-term exposure towards CO_2 («3%) towards a young adults causes benign, alterations in bone mentalism and related blood calcium concentrations. In consequence, a poor concrete construction site management lead to this exposure of health impact causes lower productivity on site that to the overrun of cost and time of a construction project.

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. Its implementation is guided in each country. For the specific case of Japan and Malaysia, there are numbers of rules, acts and guidelines to be adhered pertaining the air pollution control, in this paper specifically referring to CO_2, in concrete construction transportation of materials and project implementation. The summary of these regulated laws are as listed the following Table 1.

Table 1 Malaysia & Japan Environmental Legislation Related to Concrete Structure Construction Planning & Commissioning

JAPAN		
No	Legislation	Description of Legislation
1	ISO 14020	General Principles of Environmental Management
2	ISO 14021	Self-declared environmental claims (Type II environmental labelling)
3	ISO/F DIS	Type III environmental declaration – principles and procedures
4	ISO 14040	Principle & Framework of LCA
5	ISO 14041	Goal & scope definition & inventory analysis
6	ISO 14042	Life cycle impact assessment
7	ISO 14043	Life cycle interpretation
8	1997 EIA Law	Environmental Impact Assessment Law
9	Japan Society of Civil Engineers	i. Recommendation of Environmental Performance Verification for Concrete Structures ii. JSCE Standard Specification for Concrete Structures: To the environment
MALAYSIA		
No	Legislation	Description of Legislation
1	Environmental Quality Act 1974	Prohibition on open burning
2	Environmental Quality (Clean Air) Regulations 1978	i. Burning of trade waste in incinerator only ii. Every asphalt concrete & bituminous plant shall not emit or discharge dust or solid particles iii. Portland Cement Plant standards for any dust/solid particles iv. Declared activities in construction site due to restrictions of open burning
3	Environmental Quality (Prescribed Activities) (Environmental Impact Assessment Order 1987)	i. Construction of hospitals with outfall into beachfronts used for recreational purposes ii. Industrial estate development for medium & heavy industries covering an area of 50 hectares or more iii. Construction of expressways iv. Constrction of national highways v. Construction of new townships vi. Construction of steam generated power stations burning fossil fuels and having capacity of more than 10megawatts vii. Construction of dam and hydro-electric power schemes with either or both of the following :

		a) dam over 15 meters high and ancillary structures covering a total area in excess of 40 hectares b) reservoirs with a surface area of 200 hectares or more viii. Construction of combined cycle power stations ix. Construction of nuclear fueled power station x. Groundwater development for industrial, agricultural or urban water supply of greater than 4,500 cubic meters per day
4	Environmental Quality (Scheduled Wastes) Regulations 2005	Construction of Mass Rapid Transport projects
5	Public Work Department Integrated Management System Manual	All types of construction projects
6	Management System ISO 14001:2004	Environmental management system that to be adhere with:- i. ISO 14040:1997 Environmental Management – Life Cycle Assessment – Principles and Framework, Principles for carrying out and reporting of LCA studies. ii. ISO 14041:1998 Environmental Management – Life Cycle Assessment –Goal and Scope Definition and Inventory Analysis- Methodology for definition of goal and scope, performance of LCA, interpretation and reporting. iii. ISO 14042:2000 Environmental Management – Life Cycle Assessment iv. ISO 14043:2000 Environmental Management – Life Cycle Assessment , Life Cycle Interpretation v. ISO 14048:2002 Environmental Management – Life Cycle Assessment – Data Documentation Format vi. ISO 14044:2006 covers life cycle assessment (LCA) studies and life cycle inventory (LCI) studies.
7	GreenTech Malaysia	Methodologies for Greenhouse Gases Inventory
8	2006 IPCC Guideline	Greenhouse Gases inventory that to be adhere with:- i. Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventory Work Book ii. IPCC Good Practice Guidance or iii. Uncertainty Management in National Greenhouse Gas Inventory

**Source:* CIDB[16], GreenTech Malaysia[17], and 2006 IPCC Guidelines[18], Japan Society of Civil Engineers [19], Sakai[20]

As discussed above, life cycle assessment (LCA) is one of those that holistically analysed the environmental problems [21]. The general view of environmental impact of life cycle of concrete structure is as illustrated in the following diagram. From the Figure 2, 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 of this paper.

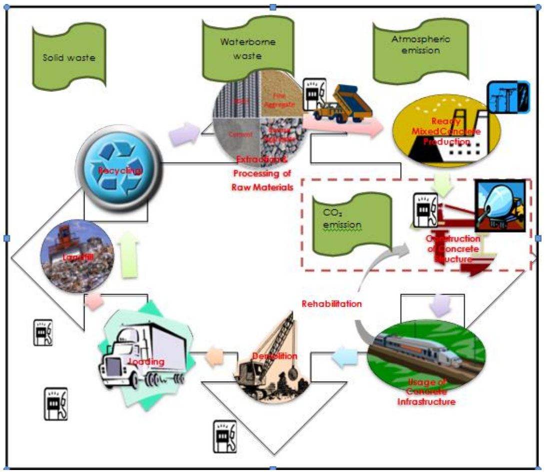


Figure 2 Life Cycle of Concrete Structure adopted from Rebitzer *et al*. [22], University of Michigan [23], USEPA [24], Whitelaw [25] Kawai *et al.* [27] International Standard Organization [28], Pennington *et al.* [29]

3.0 RESEARCH METHODOLOGY

In order 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. Some internet articles also utilized in order to complement this literature part.

Quantitative research 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 [29]. 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 construction 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 analysis are obtain from data collections gain from the literature survey and hearing to the institute that are already established and adopted in Japan concrete construction industry reference [26]. On the other hand, the Malaysia inventory data are obtain from the Greentech Malaysia, 2010 [17] but it is adopted from 2006 IPCC Guideline [18], 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 listed in Table 2:

Table 2 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 • With 3-way catalyst • Without 3-way catalysts
1A5 other	Other: Not elsewhere specified all remaining emissions from non-specified fuel combustion include. (Off road) a. Stationary b. Mobile

**Source*: IPCC Energy Combustion, 2006[18]

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 Figure 3. As shown in the image, the total amount of concrete had been use in this bore piling are 114m$^{3.}$

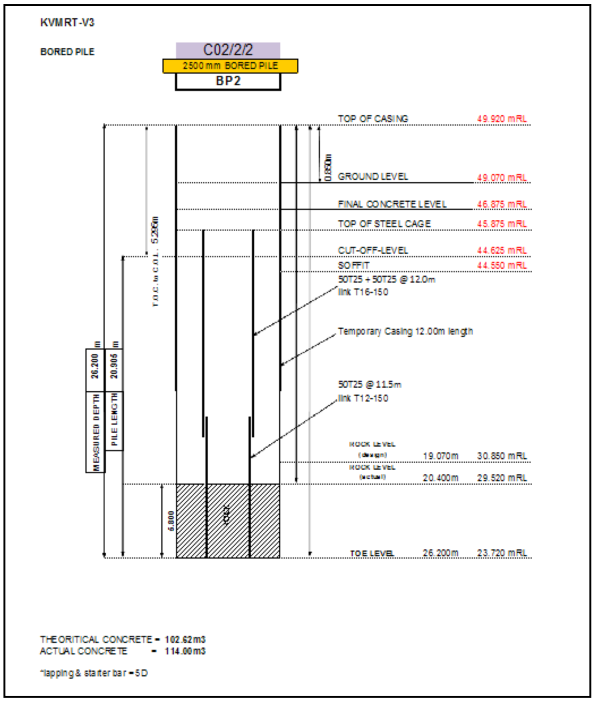


Figure 3 Schematic view of bored pile

4.1 CO_2 Emissions Assessment

The following Table 3 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 [17] that were adopted from the IPCC 2006 [18].

Table 3 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-CO2/*)**
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: Kawai *et al.* [27]; IPCC Energy Combustion [18], GreenTech [17] and Malaysia Energy Statistical Handbook [5].

Japan had established their own concrete infrastructure CO_2 emission since 2005, this can be seen as in the Kawai *et al*. in 2005 [27] and updated by Kawai *et al*. [30] in the year 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 of CO2 emission from the transportation and the bore pile concrete infrastructure had been established as indicated in the following Table 4 and 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 *et al*. [27].

Fuel consumption = Engine power x Specific fuel consumption
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 Statistical Handbook [5] and data collected from contractor.

Table 4 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 5 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	m³	3090.0000	226.58
	Agitator Truck (10m3) *total hours on site for 6 trucks	h	2	D	L	150	206	10	m³	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 114m3. 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 2,383,801.65kg-CO_2.

4.2 Interpretation of Obtained Data

Comparative study of Malaysian and Japan infrastructure construction had been done. Data obtained from Japan are as indicated in Table 6. 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 *et al.*, 2005 [27].

Table 6 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 is bore piling construction, while the lowest is PC bridge. Scanning the scenario strictly, concrete bore pile construction in Malaysia used agitator truck of 9-10m^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 10tonnes, 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.

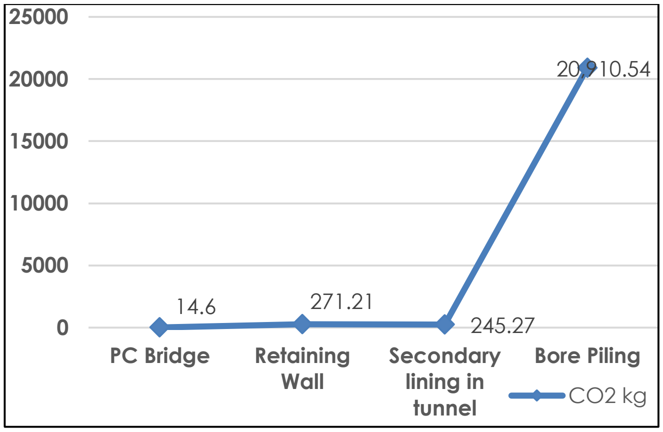


Figure 4 CO_2 emission according to concrete civil infrastructure per m^3

4.3 Direct Application in Strategic 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 $7.91 x 10^5$ that is reduction of 19.90%. For the bore piling case, the concrete mix is being designed with super plasticizing admixture that improves the pumpability of 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 are stop the machineries/equipment at the point of not using; scheduled maintenance of machineries and vehicles; practice energy saving; using diesel to generate electricity; materials are not to be loaded to a higher level than the side and tail boards; and should be dampened or covered before transport; water sprays are being applied to maintain the worksite wet; all dusty materials are being sprayed with water prior to any loading; unloading or transfer operation so as to maintain the dusty materials wet; 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; post and enforced speed limits to reduce airborne fugitive caused by vehicular traffic; train workers to handle construction materials and debris during construction and dismantlement to reduce fugitive emissions; tighten gate seals on dump trucks; immediately before leaving a construction site; every vehicle shall be washed to remove any dusty materials from its body and wheels; all spraying of materials and surfaces should avoid excessive water usage; 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 (3) sprayed with water or a dust suppression chemical so as to maintain the entire surface wet; and preparation of exact types of facemasks and goggles.

5.0 CONCLUSION

Key conclusion derived from this study include: 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 CO2 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 every concrete construction site 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.

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