Application of Low Carbon Concrete on Reinforced Earth Wall

Norman M H Lee*, Yassine Bennani Braouli

Reinforced Earth Pacific Limited, Hong Kong, China

*Corresponding author

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ABSTRACT

Global warming is one of the big issues all over the world. Continued global warming could bring a series of damaging effects. Many countries are now pursuing a broad range of strategies to reduce emissions of greenhouse gases, such as reducing the vehicle use, development of renewable energy etc. Minimize the use of cement is one the method to reduce the emission of carbon dioxide. Comparing the concrete volume used between Reinforced Earth Wall and traditional R.C. wall, Reinforced Earth Wall is an environmental friendly and more economical solution with less concrete consumption. Apart from this, the carbon dioxide emission can be reduced by minimizing the cement ratio in concrete. Low carbon concrete consists of industrial cement combined with mineral compounds, such as ground-granulated blast furnace slag, calcined clay and fly ash. With only 12% dosage in weight of concrete, the cement is responsible for 85% of carbon dioxide emission. By using the low carbon concrete, there will be a high possible reduction of carbon dioxide emission. Concrete facing panel is one of the three main components of Reinforced Earth Wall. The emission of carbon dioxide is mainly caused by the production of concrete panel. Using low carbon concrete can help to minimize the carbon dioxide emission.

Keywords: Reinforced Earth Wall, Low Carbon Concrete

1 Introduction

Over the past few centuries, the world has been moving towards urbanization as human beings have advanced and developed technologically and economically. The global population is growing every year. More and more people are migrating from rural and suburban areas to cities, so the size and the number of cities is expanding and increasing and many countries having most of their population living in cities increasing the various environmental problems associated with urban living. We have been paid for the price of the environment and creating a lot of pollution due to the rapid development.

Climate change is one of the big issues for environment due to the rapid development. The emission of greenhouse gases into the earth's atmosphere produces a greenhouse effect and thus contributes to global warming which has caused many problems such as more frequent heat waves, changes in rainfall, rising sea levels, reduced agricultural production, spread of diseases, depletion of water resources, environmental and ecological imbalances etc. Greenhouse gas emissions from human activities strengthen the greenhouse effect and the major sources of greenhouse gas emissions from human activities in Hong Kong are electricity generation, transportation and waste management. The Paris Agreement entered into force on 4 November 2016 and is applicable to the Hong Kong Special Administrative Region. The parties to the agreement will work to promote carbon reduction policies that will limit global temperature increases to no more than 2 degrees Celsius this century, set a more ambitious target of 1.5 degrees Celsius and achieve carbon neutrality by 2050.

Apart from the climate change, another environmental issue is finite resources. Besides water, sand is the most widely used natural resource by humans on the planet. Sand is an important ingredient in most construction projects. The main reason for the sand supply crisis is the rapid global urbanization. Building high-rise buildings and construction for road works for the world's growing urban population requires huge amounts of sand and other construction materials. The sand we need is relatively coarse

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and dry sand mined which is from riverbeds, riverbanks, and shores. The demand for this sand material become higher and higher that the world's riverbeds and beaches are being mined out of sand. Most of the sand mined by humans is used to make concrete.

There are two ways to minimize the impact. 1. Consuming less construction material or minimize the usage of machine is one of the methods to minimize the greenhouse gas emission. 2. Using the materials that are less emissive. (e.g., low carbon concrete).

2 Concrete

2.1 Advantages of using Concrete

Concrete is the most common material used for infrastructure purposes. It is a mixture of several other materials like cement, water, sand and gravel. Ready-mix concrete has become popular in recent years to accelerate the construction process and make it more reliable.

Concrete is used to provide strength, durability, and versatility during the construction of a structure. These excellent properties have made concrete a reliable and long-lasting choice of construction companies for both commercial and domestic types of constructions.

Different types and qualities of concrete are available on the market and some of the properties of concrete that make it important in construction are:

2.1.1 Strength

Concrete is a solid material that can withstand tensile and compressive stresses easily without getting affected. The strength of concrete has made it essential in the infrastructure, construction of buildings, foundations, civil works and many other types of structures for many years. The strength of the concrete is adaptable to the specific requirements of the construction project by making changes in the mixture, for example, by increasing or decreasing the ratio of the quantity of water, cement and crushed stone. Moreover, concrete can increase in strength over time.

2.1.2 Durability

Concrete can last for ages as it can survive harsh weather conditions and natural disasters and it is resistant to abrasion, rusting, chemical reactions, fire and any other deterioration and will retain its original form, quality and serviceability when it is exposed to the environment. As a result, the structural integrity of the concrete will not be undermined for an extended period which makes it suitable for every other place in the world.

Some concrete structure which was built in ancient times are still found. The longevity of this popular material has made it important for the construction of permanent buildings and strong structures like bridges and dams.

2.1.3 Versatility

Concrete is one of the most versatile materials used for construction of many structures due to its strength and ability to modify its according to the construction requirements, shape and size and its high durability and fire resistance.

2.2 Environmental Impact of using Concrete

The advantages of the concrete are undeniable. However, some environmental impacts are given out by manufacturing concrete cannot be ignored.

2.2.1 Shortage of Natural Resources

Concrete is a mixture of cement, water, sand and aggregates. Sand is one of the most versatile natural materials used in construction. In addition to construction, sand is highly used in land reclamation, water filtration and glass making. According to the data from United Nation, the demand of sand resources is rising and we are now need 50 billion tons per year, an average of 18kg per person per day. And another problem is we are running out of sand at a much faster rate than its natural renewal. Sand takes thousands of years to form through erosion.

At the same time, the loss of sand threatens the fragile ecosystem. Most of the sand is dredged from the river and it will harmful the fisheries, aquifers and protected areas. Uncontrolled mining can greatly threaten biodiversity. Moreover, sand carriers can carry invasive species and placing a huge burden on species habitats and ecological communities. Over exploitation can lead to an unstoppable decline in the ability of eroded coasts to defend and repair themselves from natural disaster. It can also exacerbate drinking water and food problems and there will be the risks for human health and regional security.

2.2.2 Emission of Greenhouse Gas

The manufacturing process of cement produces about 5% to 8% of global man-made carbon dioxide. The production of cement releases greenhouse gas emissions both directly and indirectly. Approximately 50% of these emissions come from a chemical process called calcination. Calcination occurs when limestone is heated and breaking down into calcium oxide and CO_2. Around 40% comes from the energy by burning fossil fuels to heat the kiln which is usually heated by coal, natural gas, or oil. The final transportation of cement represents another 5-10 percent of the industry's emissions. (Madeleine Rubenstin, 2012)

Around 30 billion tons of concrete are produced worldwide every year and this production is not expected to slow down in the near future. Therefore, modification on the concrete mix may be a powerful solution to prevent the greenhouse gas to entering the atmosphere.

2.2.3 Low Carbon Concrete

Low carbon concrete consists of the cement combined with mineral compounds such as fly ash, slag etc to minimize the carbon footprint. In order to reduce the carbon footprint from concrete, reduce the ratio of the cement in concrete and replaced by supplementary cementitious materials is one of the solutions. The composition and CO_2 emission are shown in Figure 1.

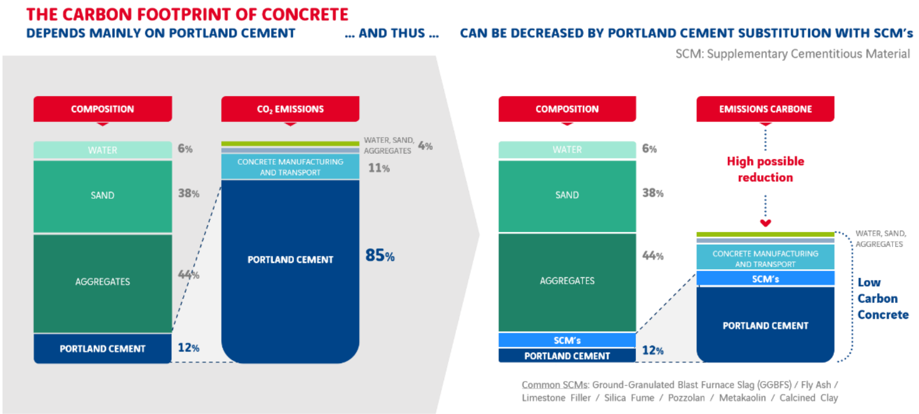

Figure 1: Carbon footprint of concrete

With only 12% dosage in weight in concrete, cement is responsible for 85% of CO_2 emissions. By reducing around 50% of usage of Portland cement, more than 40% CO_2 emissions can be reduced.

VINCI Construction evaluate and classify a concrete formulation according to their emissions (kg CO_2e/m3) and compressive strength (MPa). They evaluate the concrete with the prism of environmental performance and to classify it into three levels: low carbon, very low carbon, ultra-low carbon which is shown in Figure 2.

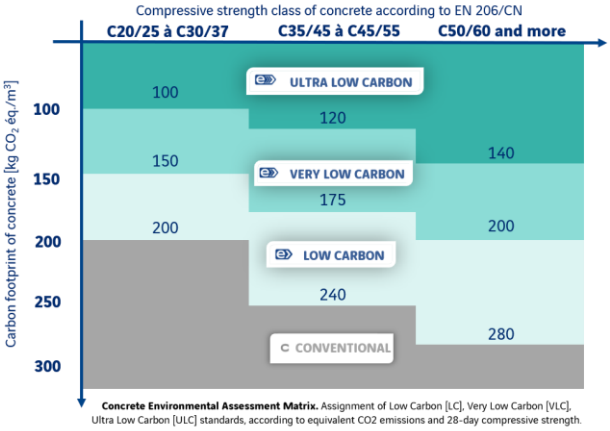

Figure 2: Concrete Environmental Assessment Matrix

The pros of using low carbon concrete are easy and practical and some trials by using around 50% SCM had been done. But the cons are the early strength of the concrete is reduced. It may limit the use for the site work. But for the Reinforced Earth wall, the concrete panel is precast and it will minimize the influence of the early strength.

3 Application of Concrete on Retaining Wall

3.1 Comparison of Material used between the Reinforced Concrete Wall and Reinforced Earth Wall

In order to minimize the embodied carbon of concrete, reduce the volume of concrete using is one of the methods to reduce the carbon footprint. The benefit of using the Reinforced Earth retaining wall by comparing with the R.C. retaining wall is not only the cost saving, but also the environment friendliness. Figure 3 shows the ecological parameters for a typical 6m high Reinforced Earth Wall and an equivalent reinforced concrete retaining wall. Even though it is an optimized design of the reinforced concrete retaining wall, the different of the efficiency in ecological terms of both walls is significant (Geoguide 6, 2002).

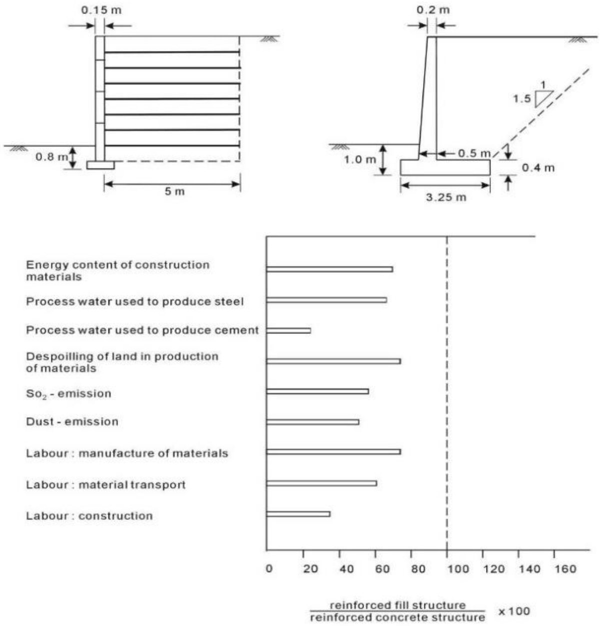

Figure 3: Ecological Parameters for a 6m High Reinforced Earth wall and an equivalent Reinforced Concrete Retaining Wall

Below is an example showing the difference of the material and greenhouse gas emission between two different types of retaining wall. The original design of abutment is a Reinforced Concrete (R.C.) retaining wall supported by socketed H-pile with 1.5m combined pile cap (Figure 4). The design has been revised to Reinforced Earth True abutment with a L-shape R.C. seating as an alternative (Figure 5).

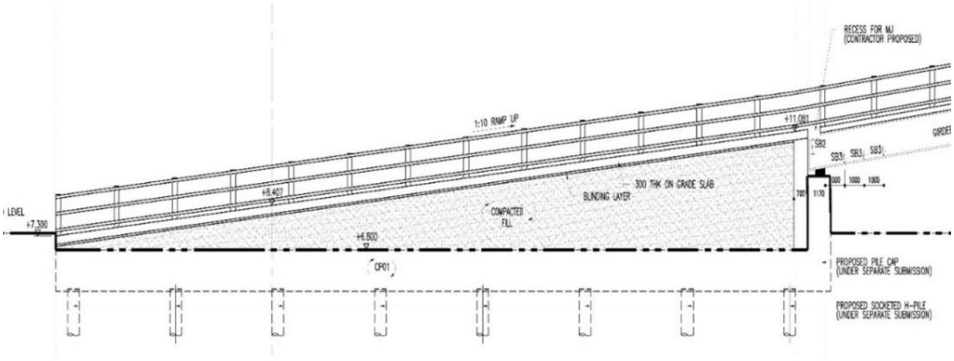

Figure 4: Original Design

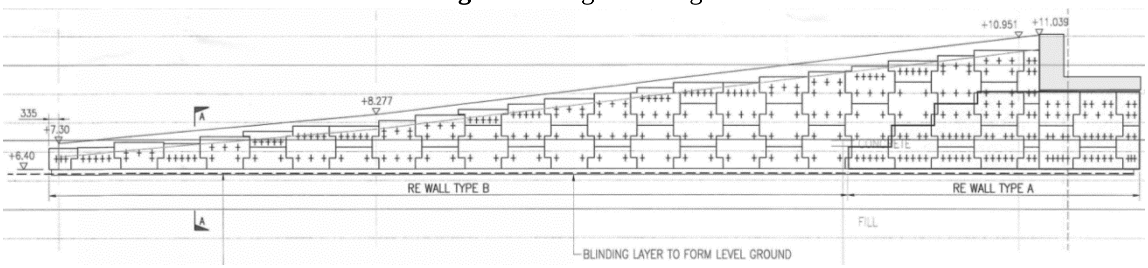

Figure 5: Reinforced Earth Wall Design

The summary of the material used on both schemes are illustrated in Table 1.

Table 1: Comparison of Material Used

Scheme	**Element**	**No. of pile (nos.)**	**Concrete (m^3)**	**Structural Steel / Rebar / Strip (ton)**
Reinforced Concrete wall with Piling Scheme	Foundation	24	-	245
	Cap	-	535	130
	Wall	-	100	6
Total		**24**	**635**	**381**
Scheme	Element	No. of pile (nos.)	Concrete (m^3)	Structural Steel / Rebar / Strip (ton)
Reinforced Earth Wall Scheme	Panel	-	33	2
	Levelling Pad	-	6	0
	L-shape RC wall	-	35	4
Total			**74**	**6**

The table above reveals that the consumption of concrete, structural steel, and reinforcement / steel strip of Reinforced Earth retaining wall with L-shape R.C. seating is far below than the original piling and pile cap with R.C. retaining wall scheme. Carbon footprint could be reduced by this proposal. By

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eliminating the piling, construction waste can further be reduced and clean underground could be allowed for future development in case.

3.2 Life Cycle Analysis of the Reinforced Concrete Wall and Reinforced Earth Wall

Life cycle analysis is a method to access the environmental impacts of all stages of the work (from material production, construction, use and maintenance and end of usage/reconstruction) and the life cycle assessment of CO_2 emission of this project is shown in Figure 6.

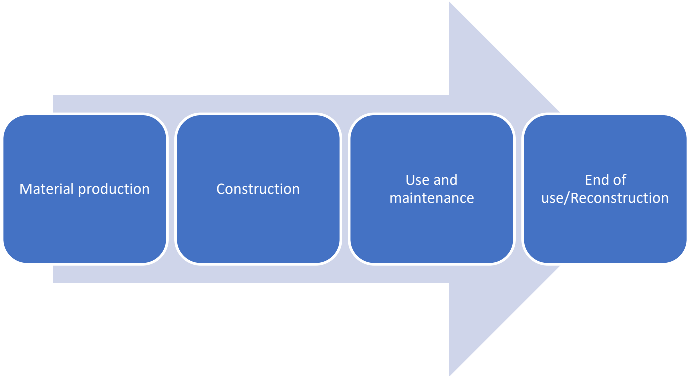

Figure 6: Life Cycle Analysis

In this study, the first two stages which are related to the construction process (material production and construction) of CO_2 emission will be compared. Table 2 shows the CO_2 emission from the material production and also for the equipment of construction.

Table 2: Comparison of CO_2 emission between R.C. wall and Reinforced Earth Wall

Scheme	kg of CO_2 emission			
	Concrete	Steel	Operation equipment	Total
Reinforced Concrete wall	260,350	724	7,770	268,844
Reinforced Earth Wall	30,340	11	2,590	32,411

For the analysis, the production process of concrete had the big influence on the emission of CO_2, the difference is significant since the volume of concrete usage on the reinforced concrete wall is much higher than that for the reinforced earth wall. Moreover, due to the duration of work is longer and the number of construction machine are more than reinforced earth wall. The high consumption of fuel leads to the high emission of CO_2.

3.3 Life Cycle Analysis of Reinforced Earth Wall with GGBS used in the Precast Concrete Panel

Design the concrete with the addition of an appropriate proportion of Ground-Granulated Blast Furnace Slag (GGBSS) can help to reduce carbon footprint. The cement content of the panel is around 400kg per m3 of concrete and the cement content can be reduced to 220kg by mixed with GGBS. Table 3 shows the emission of CO_2 by using GGBS in the concrete mix.

Table 3: Comparison of CO_2 emission between R.C. Wall and Reinforced Earth Wall (with and without using GGBS)

Scheme	kg of CO_2 emission			
	Concrete	Steel	Operation equipment	Total
Reinforced Concrete wall	260,350	724	7,770	268,844
Reinforced Earth Wall	30,340	11	2,590	32,410
Reinforced Earth wall with GGBS	25,142	11	2,590	27,212

Although the characteristic strength of the concrete made by mixing the cement with GGBS is low in early stage. It does not mean that we have to sacrifice the strength, on the contrary, the strength is much higher on 28 days and it is more durable and environmental friendly. The typical example of the strength of the concrete up to 150 days is shown in Figure 7 (source by Greentex Construction Materials Ltd).

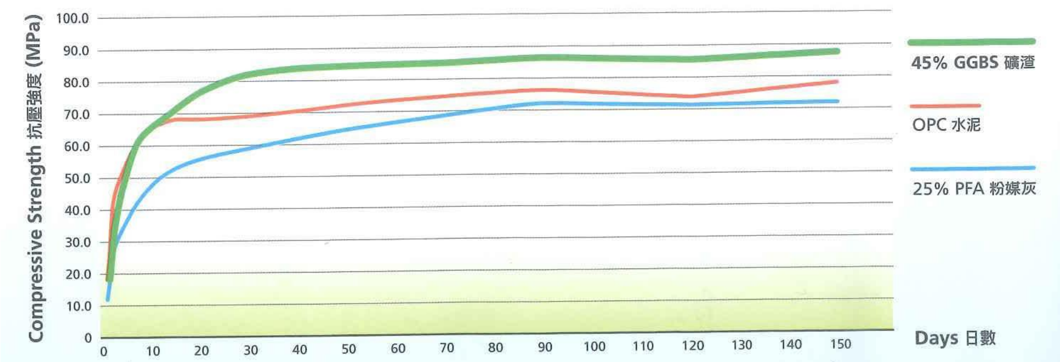

Figure 7: Typical example of concrete strength

3.4 Advantages on Construction of Reinforced Earth Wall

From the ecological point of view, the construction method of Reinforced Earth Wall has its significant advantages. First of all, formwork is eliminated as the precast concrete panels interlocked each other. Formwork is not required since the installation and the backfilling are all on the inner side of the structure. No scaffolding and moulds mean that the site space require for the construction can be reduced significantly and can be constructed to the existing structure closely. Likewise, trees and vegetations can be retained in front of the Reinforced Earth Wall.

Construction sequence of R.C. wall including setup of formwork and scaffolding, fixing up the rebar, concrete pouring, demoulding and backfilling. Different from the traditional method, construction time of the Reinforced Earth Wall is based on the time for the backfilling. Therefore, the construction time of the Reinforced Earth Wall is much less than the R.C. wall and easier to control. On the other hand, construction of Reinforced Earth Wall requires neither scaffolding nor heavy weight machine. By comparing to the traditional method, only a light crane and a roller is necessary for the panel installation and compaction. It also a great advantage in terms of safety since less machine will be used.

In terms of economical benefit, Reinforced Earth wall have been found on the sloping ground without using the pile foundation. When constructed on sloping ground, the relatively rigid reinforced concrete retaining wall generally imposes higher bearing stress at the wall toe and may require piles for support. The alternative solution involving the use of the reinforced fill technique could be much more economical and environmental friendly. An example is shown in Figure 8. Another example to show

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the Reinforced Earth wall offer technical and economical benefits over the conventional concrete viaducts which have been used in some projects in Hong Kong (Geoguide 6, 2002). The major saving is the viaducts are generally sensitive to differential settlement and are usually supported on piled foundations, whilst reinforced fill structures can accommodate differential settlements and do not require expensive foundation support (Figure 9).

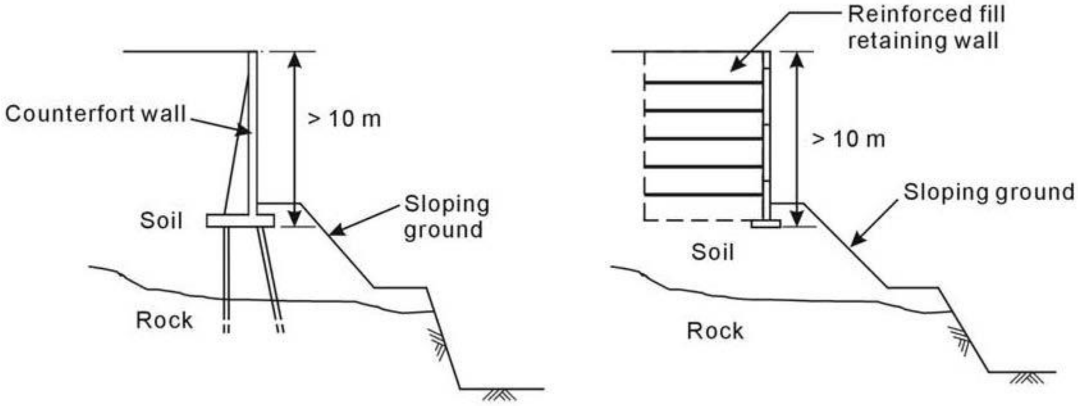

Figure 8: Example of the retaining wall on sloping ground

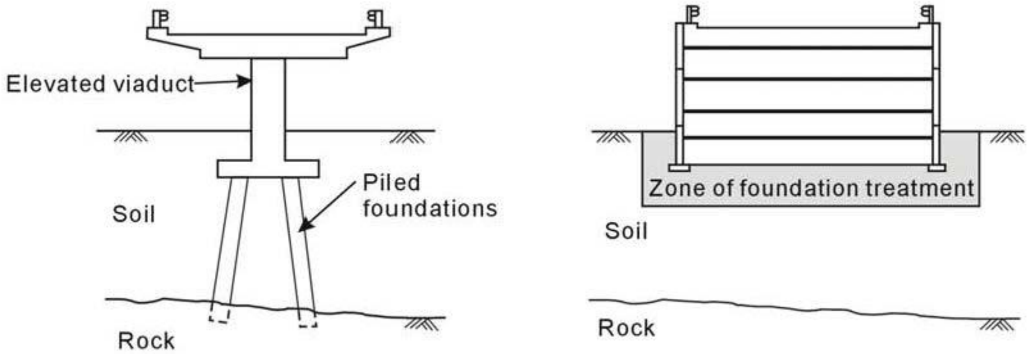

Figure 9: Example of the retaining wall on elevated road

4 Conclusion

Concrete works is playing an important role in the construction industry. At the same time, it will be a very heavy burden to the society in the future. Reinforced Earth structures provide great strength and flexibility. Moreover, the ecological advantages of Reinforced Earth retaining wall are undeniable. The use of the technique results in saving materials and energy, reducing nuisance associated with the construction of a structure such as air pollution and traffic congestion and also reducing disturbances to the foundation soil. By using the GGBS in the reinforced concrete panel, the content of the cement will be decreased and the emission of greenhouse gas will be further reduced. Nowadays, one of the development directions of concrete is high performance mix concrete, and its basic feature is its durability. The strength and durability of the concrete will be improved by mixing with GGBS. The use of GGBS can be used rationally to replace part of the cement and will be the future "green" material.

5. Publisher's Note

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