CO_2 Uptake Model of Biomass Silica Foamed Concrete

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Abstract

The cement industry contributes about 5% to global anthropogenic CO_2 emissions. CO_2 is emitted from the calcination process of limestone, from combustion of fuels in the kiln, as well as from power generation. A model of CO_2 uptake by biomass silica foamed concrete is proposed as a potential mitigation strategy against CO_2-emission. The key parameters in the cement production process are defined and the total CO_2 emissions are reviewed. A comparison between CO_2 emission and CO_2 uptake by carbonation is made. The forecasting of CO_2 uptake by carbonation is modeled with the use of Microsoft Excel. The CO_2 emission mitigation options are discussed based on the modeling on CO_2 uptake by biomass silica foamed concrete. The proposed foamed concrete absorbs CO_2 42.7% faster than the normal Portland cement concrete, with a regression accuracy of 0.98. Successful deployment could contribute towards sustainable development while benefiting from the carbon credits.

Keywords: Biomass silica, CO_2 emission, CO_2 uptake, foamed concrete

1. INTRODUCTION

Over the last century, fossil fuel consumption, deforestation, and other unsustainable land use practices brought by land conversion and land use change (LCLUC) have resulted in a dramatic increase of carbon dioxide (CO_2) emissions into the atmosphere. Most scientists believe the increase of CO_2 emissions is the main cause of the human-induced climate warming. The Intergovemmental Panel from Climete Change (IPCC, 2007) reported that the concentration of atmospheric CO_2 had increased from a pre-industrial value of about 280 parts per million (ppm) to present level of 375 ppm. Atmospheric CO_2 concentration increased by only 20 ppm over 8000 years prior to industrialization, however since the 1750 the concentration has risen nearly 100 ppm. If this trend continues, climate change will be inevitable. The long-term effects of global temperature change include droughts, increased severity of storms and flooding.

The natural production and absorption of CO_2 is achieved through the earth's biosphere and oceans. However, increased use of fossil fuels (coal, oil, natural gas, and wood) for energy has altered the natural carbon cycle.

Since 1751 roughly 321 billion tons of carbon have been released to the atmosphere from the consumption of fossil fuels and cement production. Half of these emissions have occurred since the mid 1970s. The 2005 global fossil-fuel carbon emission estimate, 7985 million metric tons of carbon, represents an all-time high and a 3.8% increase from 2004 (CDIAC). The CO_2 emission by developed countries such as Norway and Canada are based on many factors such as cement manufacturing, fuel consumption and electricity exploitation. One way to address the issue is to use energy more efficiently and to reduce our need for a major energy and carbon source - fossil fuel combustion. Another way is to increase our use of low-carbon and carbon-free fuels and technologies such as renewable energy. Solar energy, wind power and biomass fuels are potential options.

Even though measures are being undertaken to curb CO_2 emission from the use of fossil fuels, its impact to climate change is continuously imminent due to the long lifespan of CO_2 in the atmosphere. Hence, together with the trend to shift to alternative clean energy, technologies are also being developed to absorb as much CO_2 from the atmosphere (i.e. the carbon capture storage.)

The probability of biomass silica foamed concrete as a viable mechanism for sustainable development and carbon sequestration is explored. It aims to provide long-term storage of carbon in the concrete surface in contact with the air to reduce the build-up of carbon dioxide concentration in the atmosphere. This is accomplished by enhancing the natural carbonation process as a new technique to reduce CO_2.

This study is focused on modelling the CO_2 uptake by carbonation of biomass silica foamed concrete using Microsoft Excel forecasting. The paper attempts to provide a conceptual framework of the issues and the problems associated with the production of foamed concrete block as carbon sequestration strategy. The issues and challenges related to the implementation the model based on unified volunteerism approach is discussed.

2. CARBONATION MODEL

The study is divided into two main parts; quantifications of the CO_2 emission and the predictive carbonation model on CO_2 absorption. Data for CO_2 emission during the cement production were cross examined via Environment Protection Agency (EPA) US, International Energy Agency (IEA) US, US Department of Energy (DOE), World Bank, Nordic Innovation Centre and Carbon Dioxide Analysis Centre (CDIAC).

Country	CO_2 Emission (metric tons per capita)
United States	20.5
China (mainland)	3.9
Russian Federation	10.6
India	1.2
Japan	9.8
Germany	9.8
Canada	20
Malaysia	7

3. CO_2 EMISSION

Table 1: Comparison of CO_2 Emission among top 7 countries and Malaysia

Table 1 shows that in the year 2007, United States of America contributed the most carbon emission per capita in cement manufacturing sector. Despite a high demand of cement for concrete construction US pledged to reduce its percentage of CO_2 by 7% in year 2010. The second main contributor is Canada, with an urban population of 80.1% out of 32.3 millions. The climate change affected Canada as the weather registered the warmest years since 1990 for 10 consecutive years. The storm that hit Canada which caused the melting of the ice and losses which cost $2.5 million/year. Japan, Germany and Russia have maintained CO_2 emission at nearly the same rate. Japan and Germany had ratified the Kyoto Protocol in 2002 and Russia in 2004.

Though China has the largest population in the world, and its industrial and construction sector is blooming, the urban population is only 40.4% out of 1.3 billions. 3.9 metric tons per capita is considered low compared to the rest of the developed nations. As Malaysia is aspiring to be a developed nation by 2020, there is an increasing demand for cement for concrete construction. Hence, Malaysia has relatively high per capita emission of CO_2 in cement production. As for India, it produced the least per capita CO_2 in the cement production compared to the rest of the world. India has a population of 1.1 billions but only 28.7% of their populations are urbanized. This shows that the structural buildings are less and the demands for cement are less too.

Based on 1kg of cement, the ratio of CO_2 emission released by clinker and fuel are quite clear. Ratio of clinker is always much more smaller if compared to the fuel, despite of the types of process used (wet/dry). At 55% clinker ratio is at 0.28, 75% is at 0.38 and 95% is at 0.49. This increment of ratio between the three percentages is due to the increment of heat in the process. A complex succession of chemical reactions take place as the temperature rises. The peak temperature is regulated so that the product is less sintered. Sintering consists of the melting of 25-30% of the mass of the material. The resulting liquid draws the remaining solid particles together by surface tension, and acts as a solvent for the final chemical reaction.

On the other hand, different types of homogenizing causes different amount of CO_2 being emitted. CO_2 being released at dry processing is slightly less compared to the wet processing. This happens due to wet processing requires more fuel to dry the clinker, due to higher moisture content. As fuel consumption increases, the CO_2 released also increased. Therefore, we can say that the highest emission of CO_2 in cement production is at the raw blending and calcining stage (clinker).

4. CO_2 UPTAKE

Fig. 1 shows the uptake of CO_2 emission of Malaysia since year 1970 till 2005. Fig. 2 to 8 show the trend line of the forecast system for both foamed concrete and Portland cement concrete. It is shown that the exponential trend is a more batter trend line to forecast the CO_2 emission by having a regression (R^2) of 0.98 for both foamed concrete and Portland cement concrete. The nearer the regression reaches 1 the more accurate the forecast will be. As for power trend and linear regression, both of the forecasts are only able to achieve the regression of 0.83 and 0.89.

Fig. 9 shows that foamed concrete tends to absorb carbon dioxide (CO_2) at a faster rate. It is estimated that foamed concrete absorb 43% more than Portland cement concrete.

While, the trend line shows a faster rate of 20% absorption by foamed concrete over Portland cement concrete. The validation of the accuracy by using Mean Percentage Absolute Error (MAPE) shows an average of 0.006 till 0.02 which is approximate to 0 in 3 decimal places, achieving less than 10% difference. This shows that the forecasted model is very good and accurate.

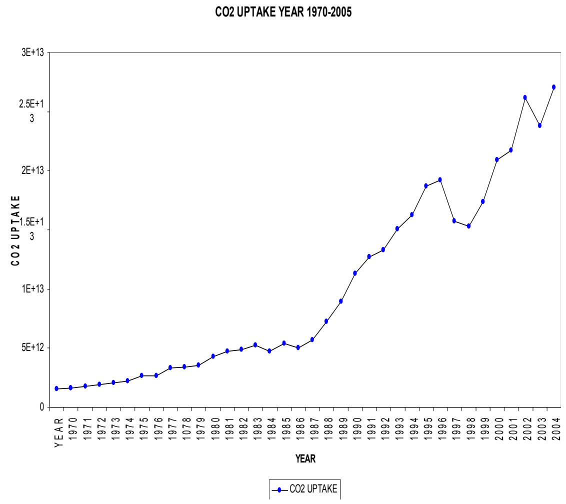

Fig. 1: CO_2 Uptake in Malaysia 1970-2005.

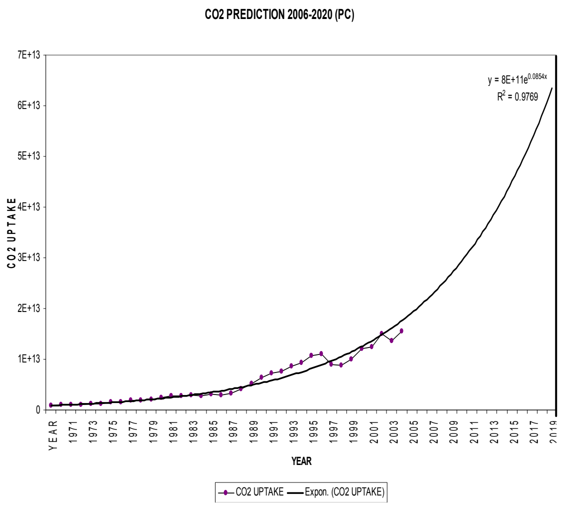

Fig. 2: Exponential smoothing trend forecasting of foamed concrete

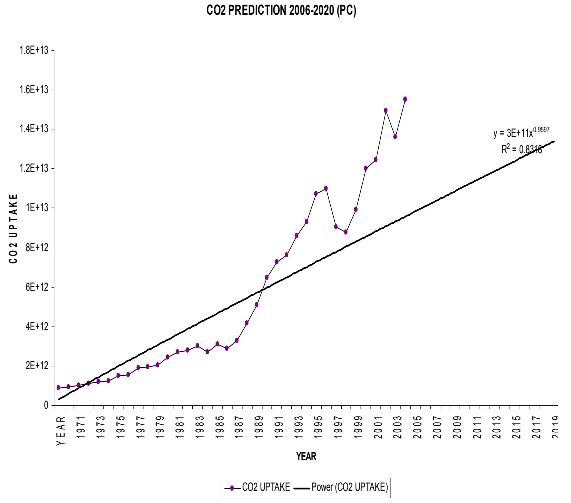

Fig. 3: Power trend forecasting of foamed concrete

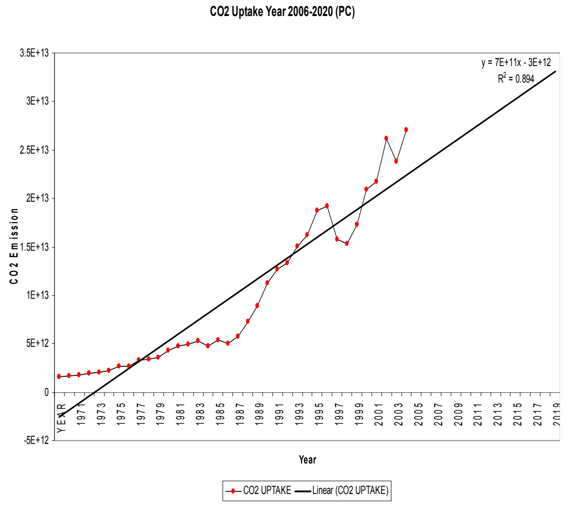

Fig. 4: Linear regression trend forecasting of foamed concrete

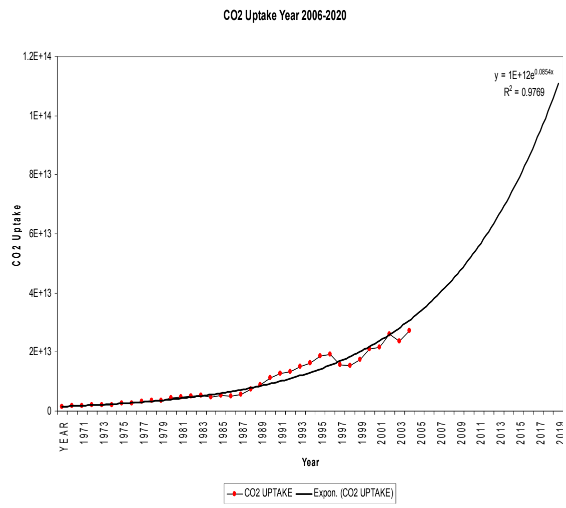

Fig. 5: Exponential smoothing trend forecasting of Portland cement concrete

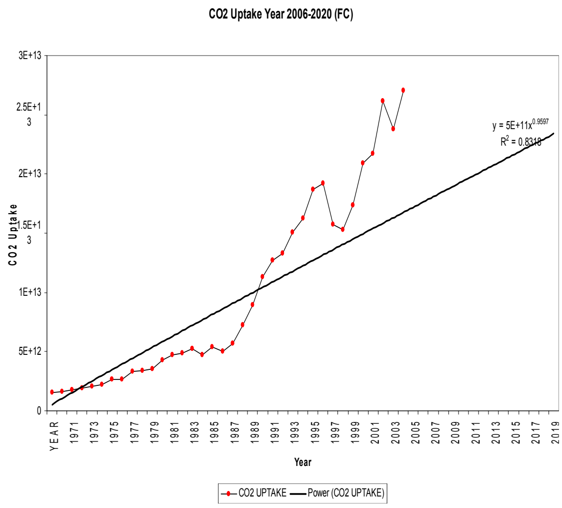

Fig. 6: Power trend forecasting of Portland cement concrete

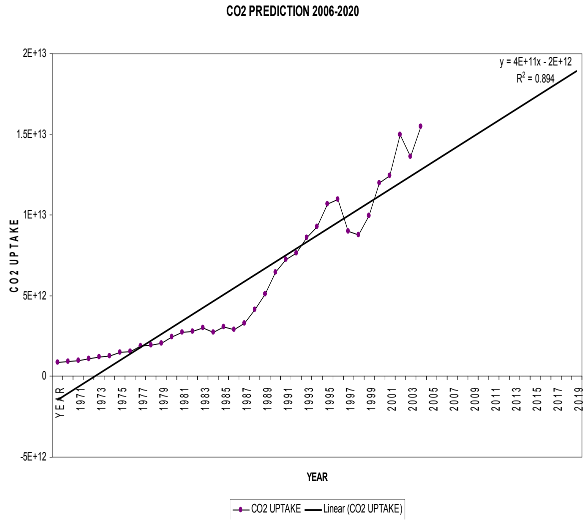

Fig. 7: Linear regression trend forecasting of foamed Portland cement concrete

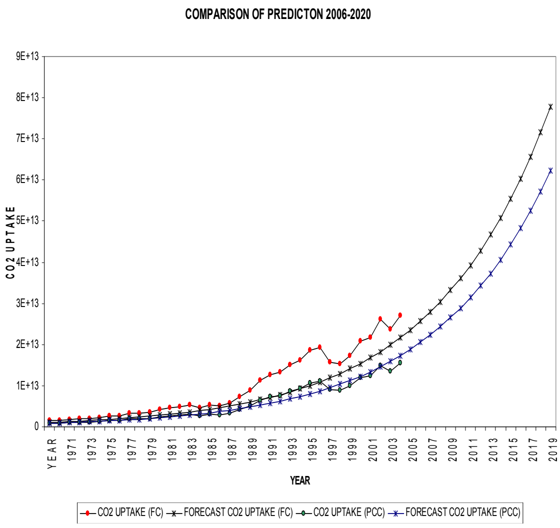

Fig. 8: Comparison of foamed concrete and Portland cement concrete forecast (MYS)

5. CO_2 UPTAKE WORLDWIDE

Fig. 10 shows the uptake of CO_2 emission worldwide from year 1750 till 2005. Fig. 11 to 16 show the trend line of the forecast system for both foamed concrete and Portland cement concrete. It is shown that exponential trend is more accurate and suits the trend of the CO_2 emission forecast by having a regression (R^2) of 0.92 for both foamed concrete and Portland cement concrete which is approximately 1. The nearer the regression reaches 1 the more accurate the forecast will be. As for power trend and linear regression, both of the forecasts are only able to achieve the regression of 0.68 and 0.88.

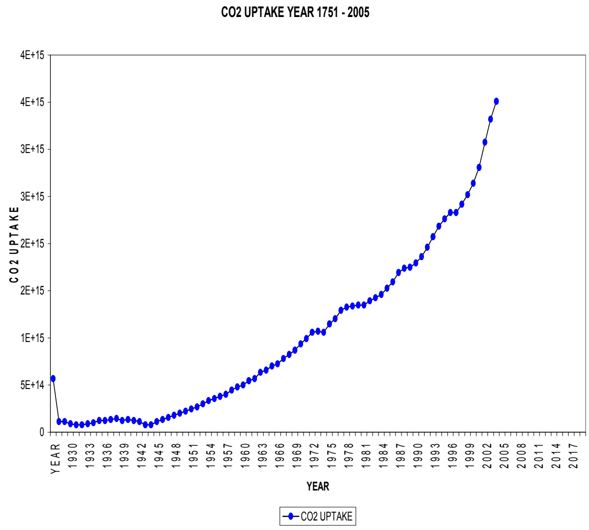

Fig. 9: CO_2 Uptake Worldwide from Year 1970 – 2005

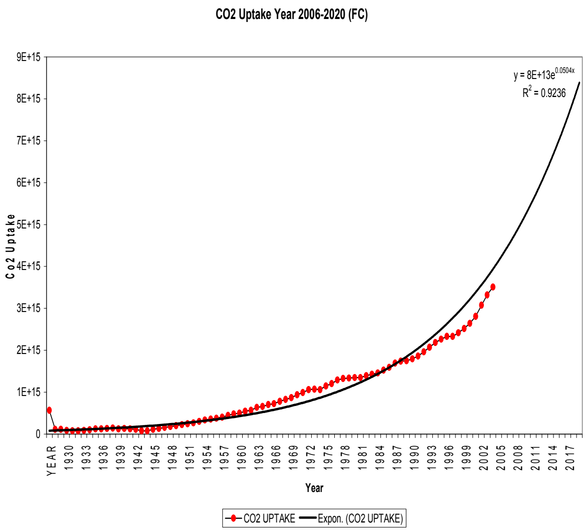

Fig. 10: Exponential smoothing trend forecasting of foamed concrete

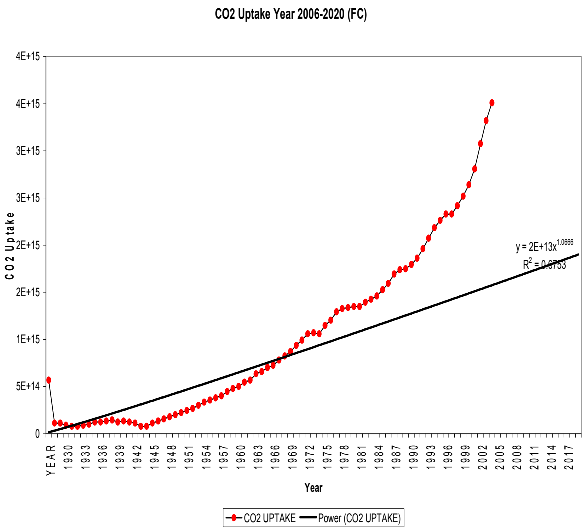

Fig. 11: Power trend forecasting of foamed concrete

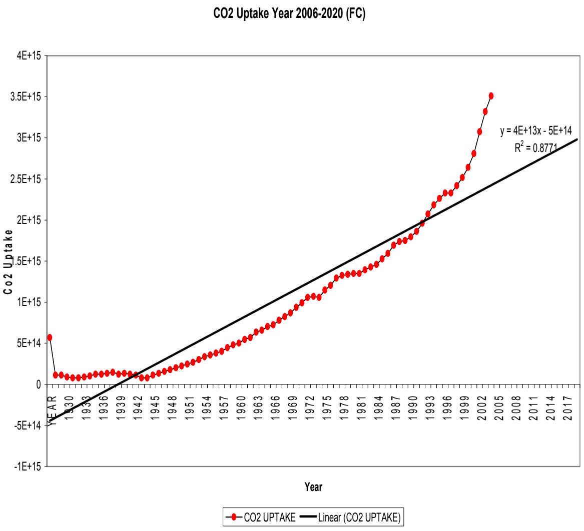

Fig. 12: Linear regression forecasting of foamed concrete

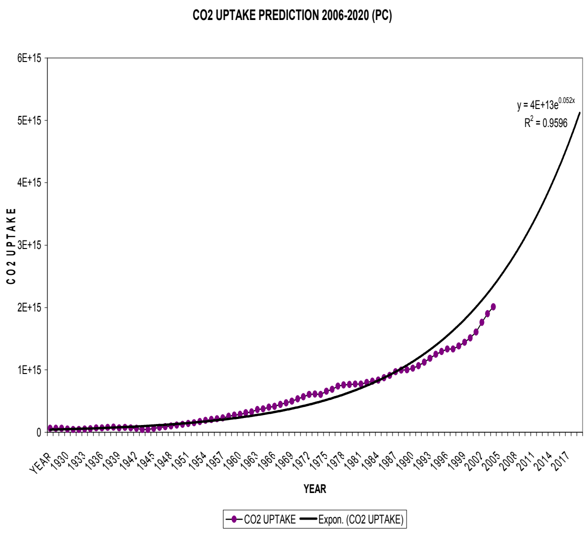

Fig. 13: Exponential smoothing forecasting of Portland cement concrete

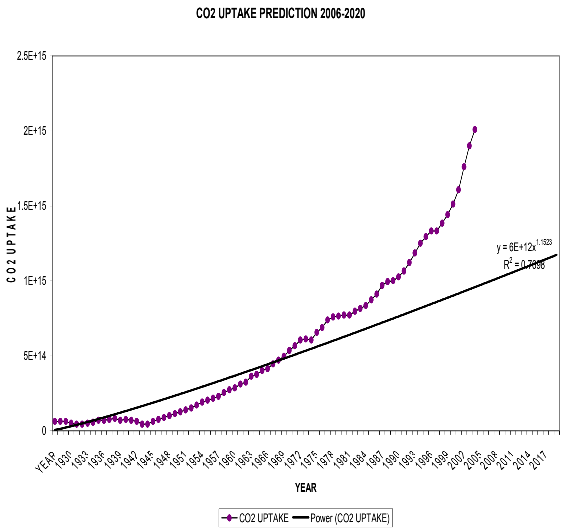

Fig. 14: Power trend forecasting of Portland cement concrete

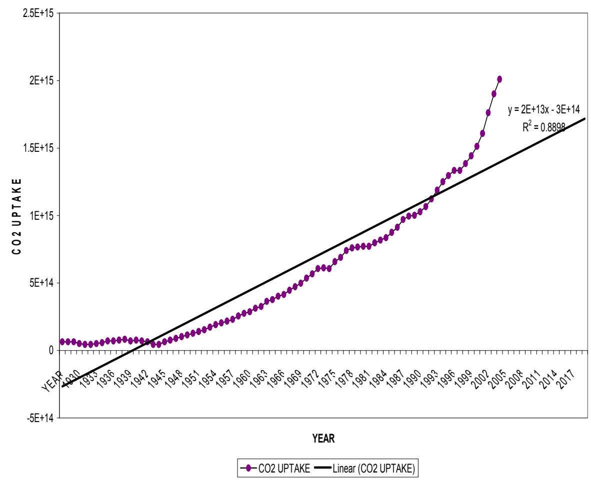

Fig. 15: Linear regression forecasting of Portland cement concrete

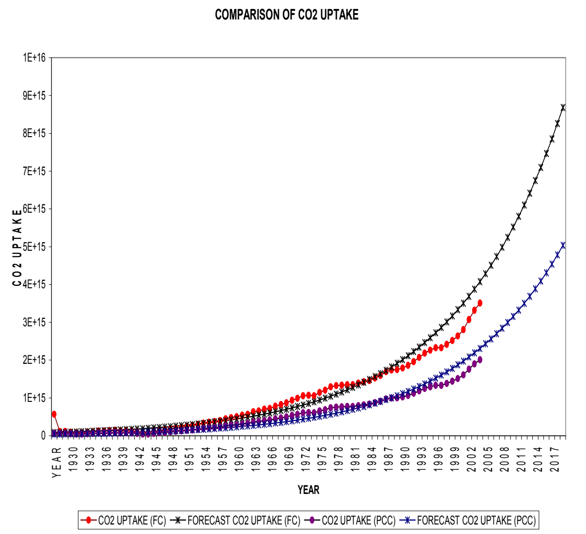

Fig. 16: Comparison of foamed concrete and Portland cement concrete forecast (Worldwide)

7. CONCLUSION

In 2007, the main contributions of carbon dioxide emission in the cement sector was US which produced 20.5 metric tons per capita, followed by Canada 20 metric tons per capita and then Russia, Japan, Germany, China then India. As for Malaysia, the emission of CO_2 was about 7 metric tons per capita.

The highest contributions of carbon dioxide emission during the cement production is found to be in the calcination process, where fuel and the raw material both release a high amount of CO_2 with a ratio of 0.5-0.95 depending on the types of clinker and fuel usage.

From the forecasted results of Malaysia and worldwide, we can see that an actual faster CO_2 uptake rate of 42.7% if foamed concrete is used. Foamed concrete is a lightweight construction material produced by incorporating pre-formed foam into a base mix of cement paste or mortar, using standard or propriety mixing plant. The entrapped air bubbles reduce the density of the base mix. The use of foamed concrete as sustainable construction material is expected to increase the CO_2 uptake towards mitigating global warming in the near future. Foamed concrete is also one of the sustainable strategy for carbon credits and USGBC LEED. It contributes to sustainable sites, materials and resources as well as innovation in the design and construction process.

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