Virtuous Concrete: Concrete Technology Innovation for Carbon Footprint Reduction

Rr. M. I. Retno Susilorini

Department of Civil Engineering, Faculty of Engineering, Soegijapranata Catholic University, Jl. Pawiyatan Luhur IV/1, Bendan Dhuwur, Semarang 50234
E-mail : retno_susilorini@yahoo.com

ABSTRACT

Cement and concrete industries are important players of CO_2 emission in the world. It is the obligation of cement and concrete industries to create and develop technologies to reduce the CO_2 emission. A very crucial problem nowadays is how to make carbon foot print reduction by developing concrete technology innovation. The model of "Triangle of Virtuous Concrete Principle" becomes a solution to get better life. The purpose of the model is to develop virtuous concrete as carbon footprint reduction for sustainable development that is supported by infrastructure development. "The Triangle of Virtuous Concrete Principle" should be developed and adjusted along the sustainable development.

Keywords
Virtuous concrete, concrete technology, innovation, carbon footprint

"*If you replace concrete with any other material, it would have a bigger carbon footprint. Many people have the idea that if you built in steel you'd make things better – but in fact you'd make things worse. The reason concrete has a big carbon footprint as a whole is that there are just such huge quantities used*"

(Karen Scrivener, Head of the Construction Laboratory at the Swiss Federal Institute of Technology, Lausanne, [2])

1. INTRODUCTION

The rising of super high tall buildings is big phenomenon in these last decades. Buildings construction has been an important factor in infrastructure development around the world. Unfortunately, those mega projects of super high tall buildings have been consuming most world supplies of materials, especially concrete, until several coming years. It is noted that in 2007, that world consumption of concrete is about 11 billion tons, or 1.7 tons for every living human being [1]. As consequences, big consumption of concrete as well as cement in infrastructure development drives the increase of carbon footprint. Due to the big number of concrete consumption, concrete production takes 5% of annual anthropogenic global CO_2 production [2]. The world likes concrete building very much. It is so popular because of its low impact characteristic. Even, if another kind of materials

used, then there will be bigger carbon footprint, because the great number of carbon footprint of concrete comes from the huge consumption of concrete in this planet.

After over than 20 centuries of concrete existence, since ancient Egypt to mega modern era, everybody shocked by the fact of global warming. The decreasing of live quality is very hard to cope because of the greenhouse gas and CO_2 emissions have ruin the human health and environment as well as sustainable development. Speaking of greenhouse gas and CO_2 emissions, cement and concrete industries are important players of CO_2 emission that contribute about 28 billion tons of worldwide CO_2 emission [3]. Kyoto Protocol United Nation Framework Convention on Climate Change [4] has agreed to implement many policies related to climate change. One policy is to "implement encouragement of appropriate reforms in relevant sectors aimed at promoting policies and measures which limit or reduce emissions of greenhouse gases not controlled by the Montreal Protocol"; another policy is also to "implement the research on, and promotion, development and increased use of, new and renewable forms of energy, of carbon dioxide sequestration technologies and of advanced and innovative environmentally sound technologies". Hence, the cement and concrete industries can create and develop technologies to reduce greenhouse gases emission as well as CO_2 emission.

A very crucial problem that has to be solved nowadays is how to make carbon foot print reduction by developing concrete technology innovation. Surprisingly, in every single day, there are many innovations implemented to carbon footprint reduction efforts. One of the innovations named 'virtuous concrete', an innovative concrete technology presented to carbon footprint reduction. The term of 'virtuous concrete' ('beton bajik', in Indonesian language) is rarely used. 'Virtuous concrete' is adopted from terms of '*the virtues of concrete*' [5-7] which describes all benefit of concrete performance. The benefits of 'virtuous concrete' are durability, sustainability, and smartness. Since the sustainable development has found many challenges, especially global warming and CO_2 emissions, then 'virtuous concrete' is expected to answer the challenges for carbon footprint reduction.

This paper wants to discuss about how the 'virtuous concrete' takes important role in carbon foot print reduction of concrete industry issues. A model of Triangle of Virtuous Concrete Principle is delivered as solution for carbon footprint reduction to get better life.

2. INFRASTRUCTURE DEVELOPMENT: A CHALLENGE

The infrastructure development is running very fast. Population growth has just only one reason to make development of facilities to support cities and human living. People tend to fulfill their needs of facilities for example high rise buildings, super tall tower, and transportation infrastructure. During the last century, people built towers higher and higher. This activity generates big consumption of construction materials, especially concrete. Sometimes the sustainability of infrastructure principal is not the top priority of development policy, but while the effect of global warming is getting worse, the carbon footprint left message very clear to cope the problem before everything is going to be late.

Sustainability of infrastructure is very important. The World Commission on Environment and Development [8] defined sustainability as meeting the needs of the

present without compromising the ability of the future generations to meet their own needs. Sustainability is an idea for concern for the well being of our planet with continued growth and human development". Therefore, sustainability of infrastructure could be defined as to design and to maintain buildings, structures, and other facilities, while still to keep resource conservation over the life of infrastructure [9]. It should be emphasized that infrastructure is a key factor of sustainable development that takes a very important role in determining stability and economic development. However, the rapid growth of infrastructure development has invited serious problems on CO_2 emission. According to The 2002 Economic Census *Industry Series* report, there are many subsectors in construction industry that contributed significant CO_2 emission in 2002 [10]. Construction of building subsector has contributed 36% of total of construction industry, while heavy and civil engineering subsector have contributed 26%. The calculation was defined by NAICS (North American Industrial Classification System).

The significant CO_2 emission in construction industry sector will increase carbon footprint along with huge consumption of construction materials, especially concrete. Concrete is a backbone of infrastructure development. As important resources used throughout the world, concrete took the second place after water [11]. It is also noted that the whole concrete industry networks in USA have involved over than 2 million works with concrete production and shipment cost more than 42 billion US dollars per year. The concrete itself costs more than 100 billion US dollars per year. While the concrete industry become promising sector, since 2005, Germany also has big number of investment in construction industry as much as 250 billion US dollars per year [12]. The rising of construction industry and concrete production also happened in Asia. For example, in Thailand, in 2007, the production of ready-mix concrete is about 22 million tons while the production of cement is about 40 million tons [13].

According to the big number of concrete consumption mentioned above, concrete industry is an important player in infrastructure development. From the ancient Egypt and Roman concrete buildings to Burj Dubai super tall building, concrete had proven as the most wanted and used materials around the world. In spite of its advantage, contains natural material and use no poisonous substances [14], concrete also has disadvantage such as contributes green house gases and CO_2 emissions which disturb the environmental balance. What people do to tackle the disadvantage of concrete is to develop concrete technology innovation for better life.

There are several issues which have been handled by on concrete production such as: (1) Manufacturing of cement consumes lots of energy, then substitution of other materials is necessity; (2) Sometimes, natural resources are scarce in certain areas, hence demolition waste of concrete and masonry rubble should be applied as substitute of natural materials; (3) There is water exploitation during concrete production, hence, water recycling should be done for eco-efficiency [15]. According to the issues, some efforts should be done [10] to reduce the impact of concrete production such as to reduce emissions by recycling and/or reusing materials, improving shipping methods, and/or selecting different materials. Truitt [10] delivered a new approach by including the full lifecycle emissions associated with an activity's supply chain and waste management. These efforts followed by innovations in concrete technology will be very valuable for carbon footprint reduction.

3. CARBON FOOTPRINT ISSUE IN CONSTRUTION AND CONCRETE INDUSTRIES

Carbon footprint, in general, can be defined as total amount of greenhouse gases produced directly or indirectly as a result of an activity [16]. European Commission [17] has a more detail definition of carbon footprint that is a measurement of GHG (greenhouse gas) that is individual produces and has a unit of ton (T), or kilogram, equal to carbon dioxide equivalent. Some methodologies were derived to measure embodied carbon (CO_2 e) due to carbon footprint analysis. Embodied carbon is carbon emissions associated with energy consumption (embodied energy) and chemical processes during the extraction, manufacture, transportation, assembly, replacement, and deconstruction, of construction materials or products [18]. It is also said by [18] that embodied carbon can be defined as the resultant emissions from all the activities in the creation and demolition of building.

Many countries, such USA, UK, New Zealand, Australia, etc., have endorsed carbon footprint policy in area of construction and concrete industry. Carbon footprint assessment becomes awareness to reduce environmental impact by industrial activities in the last years. There are standards for carbon footprint assessment. One of those standards has implemented widely, ISO 14040, ISO 14044 (2006), and ISO 14064-1 (2006) [19]. However, carbon footprint analysis (or commonly named as 'calculator') in construction and concrete industries still develop to find more appropriate methodology. Several perspectives can be used to make assessment of carbon footprint industries, in example, a calculator for measuring carbon footprint in construction building [16] will measure carbon emissions associated with the major steps associated with the construction process (manufacturing, transportation, and installation of building materials).

Strong efforts to reduce carbon footprint in concrete production aimed to make concrete be strong and durable. A workable concrete mixture with appropriate admixtures will absolutely support those efforts by implementing appropriate concrete technology innovation.

4. VIRTUOUS CONCRETE FOR CARBON FOOTPRINT REDUCTION

'Virtuous concrete', as defined in the first paragraph of this paper, has three characteristics for its advantage; they are durability, sustainability, and smartness. When those three characteristics work together to form 'virtuous concrete', there will be only one supreme character, it is virtuous, excellence.

Durability of concrete is defined by ACI 201.2R-08 Chapter 1 as the ability to resist from weather, abrasion, or any other processes that deteriorate the quality of concrete [20]. The concrete that has high durability during its service-life is called sustainable concrete [7]. Durable and sustainable concrete needs smartness to become 'virtuous concrete'. Generally, smart concrete is defined as concrete with added ingredients of conductors or semi-conductors (such as carbon fiber, black carbon, steel flakes, or nano materials) and has self ability to detect stress and strain better than conventional concrete [21]. In terms of 'virtuous concrete', smartness of concrete can be extend not only refer to carbon, fiber,

steel, or nano materials as added ingredients, but also another kind of material that generates ability to self-healing, earthquake-resistant, anti-blasting, etc.

Several efforts of carbon footprint reduction have been implemented in concrete production. One innovation mentioned above, the 'virtuous concrete', has also implemented in previous and ongoing researches of author. Concrete with sugar based admixture (Patent ID No. No. P0032950**)**, has proven its ability of durable and sustainable as 'virtuous concrete', while its smartness is still studied in ongoing research [22-25]. The sugar based admixture 'virtuous concrete' has high compressive and flexural strength, great ductility as earthquake resistant concrete element, and very good performance while it is exposed to aggressive environment (seawater environment).

It is a good idea to make connection between many aspects of carbon footprint reduction effort in construction and concrete industries by building a model. The model named as "Triangle Virtuous Concrete Principle" (Figure 1). The purpose of the model is to develop virtuous concrete as carbon footprint reduction for sustainable development that is supported by infrastructure development.

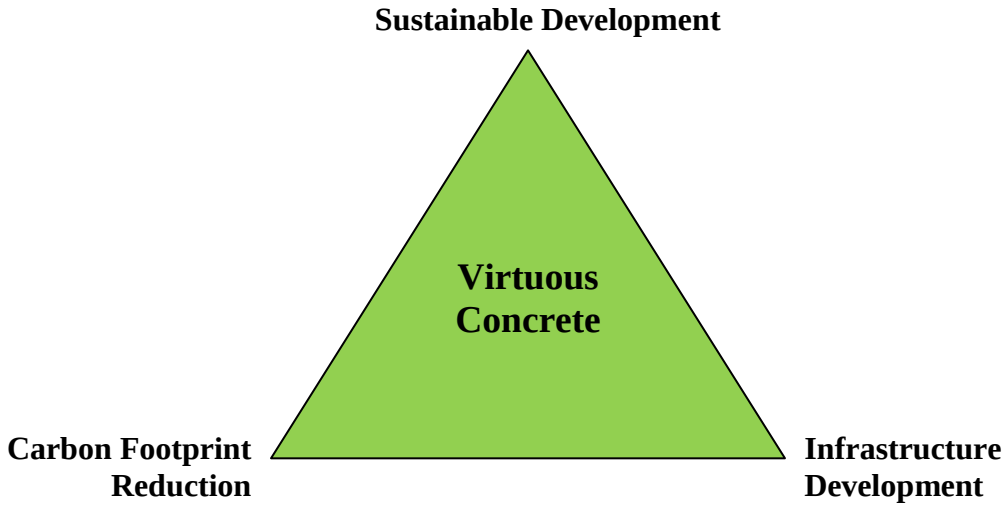

Figure 1. The Triangle of Virtuous Concrete Principle

The principle of "Triangle of Virtuous Concrete Principle" is connecting the 3 aspects of sustainable development, infrastructure development, and carbon footprint reduction as unity that becomes borders for 'virtuous concrete' to develop. The virtuous concrete itself has free access to the three aspects. One aspect will always be connected to two others aspect. For example, the aspect of carbon footprint reduction will always be connected to sustainable development. "The Triangle of Virtuous Concrete Principle" should be developed and adjusted along the sustainable development.

5. CONLUSION

Sustainable development has many challenges of global warming and CO_2 emissions that requires carbon footprint reduction efforts. A model of "Triangle of Virtuous Concrete Principle" becomes a solution to get better life. The purpose of the model is to develop virtuous concrete as carbon footprint reduction for sustainable development that is supported by infrastructure development. Towards the next coming years, "The Triangle of Virtuous Concrete Principle" should be developed and adjusted along the sustainable development.

ACKNOWLEDGMENT

The research of author in this paper is funded by Competence Grant, 2009-2011, Directorate of Research and Service to Community, Directorate of Higher Education, Ministry of Education and Culture, Republic of Indonesia.

REFERENCES

[1] Soroushian, Parvis, "Towards Broad Use of Recycled Glass Concrete in MSU Campus," *Innovation in Sustainability Seed Grant*, Michigan State University, Dec 2012.

[2] Crow, James Mitchell, "The Concrete Conundrum", *Chemistry World*, pp. 62-66, March. 2008.

[3] Naik, Tarun R, "Sustainability of Concrete Construction", Practice Periodical pp. 62-66, March. 2008.

[4] United Nations, *Kyoto Protocol to the United Nations Framework Convention on Climate Change*, 1998.

[5] Sika, "The Virtues of Concrete", Ambition, Customer Magazine, Issue no. 1, April 22, pp. 8-12, 2009.

[6] Susilorini, Retno, M.I. Rr., "Beton Bajik - Meningkatkan Daya Saing Bangsa Di Bidang Teknologi Beton Sebagai Wujud Kasih Akan Tanah Air" in "Bunga Rampai Kasih Akan Tanah Air: Upaya untuk Terus Menjadi", pp. 133-155, 2011.

[7] Susilorini, Retno, M.I. Rr., *Beton Bajik untuk Dunia Berkelanjutan*, Penerbit SPS, Semarang, 2012.

[8] McDonough, W. et al., "The Hannover principles: Design for sustainability", EXPO 2000, The world's fair, Hannover, Germany, 1992.

[9] ESCAP, United Nations, *Sustainable Infrastructure in Asia – Overview and Proceedings*, seoul Initiative Forum on Sustainable Infrastructure, 6-8 Sept 2006.

[10] Truitt, Peter, *Potential for Reducing Green House Gas Emissions in the Construction Sector*, United States, Environmental Protection Agency, Feb 2009.

[11] Concrete Research and Education Foundation, *Roadmap 2030: Concrete Industry Technology Roadmap*, Strategic Development Council, USA, 2002.

[12] Holschemacher, K., "Germany – Concrete Construction Industry – Cement Based Material and Civil Infrastructure (CBM-CI)", *Proc. CBM-CI International* Workshop, Karachi, Pakistan, pp. 143-153, 2007.

[13] Limsuwan, Ekasit, "Thailand – Concrete Construction Industry – Cement Based Material and Civil Infrastructure (CBM-CI)", *Proc. CBM-CI International* Workshop, Karachi, Pakistan, 2007.
[14] Pentalla, Vesa, "Concrete and Sustainable Development", ACI Materials Journal, Vol. 94., No. 5, pp. 409-416, 1997.
[15] Nielsen, Claus V., "Carbon Footprint of Concrete Buildings Seen in the Lifecycle Perspective", Proc. NRMCA Concrete Technology Forum, pp. 1-14, 2008.
[16] Harmouche, N., Ammouri, A., Srour, I., Chehab, G., and Hammade, R., "Developing a Carbon Footprint Calculator for Construction Building", *Proc. of Construction Research Conggress*, ASCE, pp. 1689-1699, 2012.
[17] European Platform on Life Cycle Assessment – EPA, *Carbon footprint - what it is and how to measure it,* JRC, Joint Research Centre Institute for Environment and Sustainability TP 460 Via E. Fermi 2749 I-21027, Italy, 2007.
[18] RICS, *Metholodogy to Calculate Embodied Carbon in Materials*, RICS QS & Construction Standards IP 32/2012, RICS Professional Information, UK, 2012.
[19] Lundie, S., Schulz M., Greg, P., Nebel, B., and Nedgard, S., *Carbon Footprint Measurement – Methodology Report*, Center for Water and Waste Technology, University of New South Wales, Fonterra, New Zealand, 2009.
[20] ACI 201.2R-08, *Guide to Durable Concrete*, Report, ACI Committee 201, American Concrete Institute, Farmington Hills, MI, USA, 2008.
[21] Li, Hui, dan Ou, Jinping, "Smart concrete, sensors, and self-sensing concrete structures", Key Engineering Materials, Vol. 400-402, pp. 69-80, 2009.
[22] Susilorini, Rr. M.I. Retno, *Pemanfaatan Material Lokal untuk Teknologi Beton Ramah Lingkungan yang Berkelanjutan*, Final Report, First Year, DP2M, Ditjen Dikti, 2009.
[23] Susilorini, Rr. M.I. Retno, dan Sambowo, Kusno Adi, *Pemanfaatan Material Lokal untuk Teknologi Beton Ramah Lingkungan yang Berkelanjutan*, Final Report, Second Year, DP2M, Ditjen Dikti, 2010.
[24] Susilorini, Rr. M.I. Retno, Sambowo, Kusno Adi, dan Santosa, Budi, *Pemanfaatan Material Lokal untuk Teknologi Beton Ramah Lingkungan yang Berkelanjutan*, Final Report, Third Year, DP2M, Ditjen Dikti, 2011.
[25] Susilorini, Rr. M.I. Retno, Sambowo, Kusno Adi, dan Santosa, Budi, "Pemanfaatan Material Lokal untuk Teknologi Beton Ramah Lingkungan yang Berkelanjutan", National Seminar of Grant Competence, DP2M, Ditjen Dikti, 2012.