Slovenská banícka spoločnosť ZSVTS
Základná organizácia pri Ústave geotechniky SAV, Košice

Slovakian Mining Society
a member of Association of Slovak Scientific and Technological Societies
a basic unit at the Institute of Geotechnics SAS, Košice

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Z B O R N Í K – P R O C E E D I N G S

XXVIII. vedecké sympózium s medzinárodnou účasťou
SITUÁCIA V EKOLOGICKY ZAŤAŽENÝCH REGIÓNOCH SLOVENSKA A STREDNEJ EURÓPY

The XXVIII Scientific Symposium with International Participation
SITUATION IN ECOLOGICALLY LOADED REGIONS OF SLOVAKIA AND CENTRAL EUROPE

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POTENTIAL WAYS TO LOWER CO_2 EMISSION FOR CEMENT PRODUCTION

Slavica Mihajlović[1] – Marina Blagojev[1]

Abstract
Rapid technological development leads to an improvement in the quality of life in all spheres of human activity, but at the same time it creates environmental degradation. Therefore, it is important to analyze the negative impact of technological processes, in order to adopt the strategy and define activities for implementation adequate environmental protection rates. One of the major problems in environmental protection is the emergence of greenhouse gas emissions. The world's organizations dealing with environmental protection provide a great stimulus for the development of innovative sustainable solutions in the construction industry. Thus, one of the priorities in cement industry is finding new ways to reduce energy consumption and CO_2 emissions with point on clinker production plants as the biggest CO_2 emitter (the product of the baking process during the portland cement process). In such a way new solutions reduce the amount of clinker, while at the same time, they encourage the use of alternative materials. Materials that can replace the use of cement (supplementary cementitious materials - SCM) as well as mixtures of cement, offer advantages in better characteristics, lower energy consumption and emissions of gases that produce greenhouse effect.

Keywords: *CO_2 emission, greenhouse effect, sustainable development, environmental protection*

Introduction

Implementation of environmental policy sets ecological economics as the best and most complete analytical framework for evaluating the success of production activities [Benson and Jordan, 2015]. The economic aspect of sustainable development lies in the more efficient use of available resources, while minimizing the negative impacts on the environment [ESDN, 2016]. One of the priorities is to eliminate all the contributing factors to the greenhouse effect [Gonçalves and Mil-Homens].

The essence of the problem of the greenhouse effect is the global warming of the Earth's surface. Namely, part of the heat radiation from the Earth's surface is reflected into the atmosphere where it is absorbed by certain gases (CO_2 and CH_4 which are found in the atmosphere as pollutants) and returned to the earth again, further warming it up [Gadea Rivas and Gonzalo, 2019]. Such effects are achieved in greenhouses, hence the name greenhouse effect that leads to global warming [Selin and Mann, 2019]. Furthermore, global warming is the onset of the steady rise of temperature of planet Earth [Breckned and Sunde, 2019].

The greenhouse effect is an expression for warming of the earth's surface caused by energy disbalance between the amount of radiation received from the sun and energy that get back toward space as infrared radiation, as shown in Fig. 1. The greenhouse effect causes part of energy to be waylaid in the atmosphere, absorbed and released by greenhouse gases such as carbon dioxide, water vapor, methane nitrogen suboxide and nitrous oxide [Le treut et al., 2007]. Nonetheless, when considering their individual impact, carbon dioxide, CO_2, is the most important because its emissions account for as much as three quarters of all anthropogenic greenhouse gas emissions [EPA, 2017]. Concentration of CO_2 in atmosphere is steadily increasing (Fig. 2) while two main sources of emissions of this gas to the atmosphere are: oxidation of fossil fuels and carbonate decomposition. For this study, it was of interest to investigate cement as the largest source of CO_2 emissions from the decomposition of carbonates. On Figure 3 it is shown CO_2 emissions from fossil-fuel use and cement production in the top 5 emitting countries and in European Union

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[Olivier et al., 2016; Kuba, 2018]. In addition, production of cement expanding rapidly worldwide, with current levels of global production equivalent to more than half a tonne per person per year (Fig. 3).

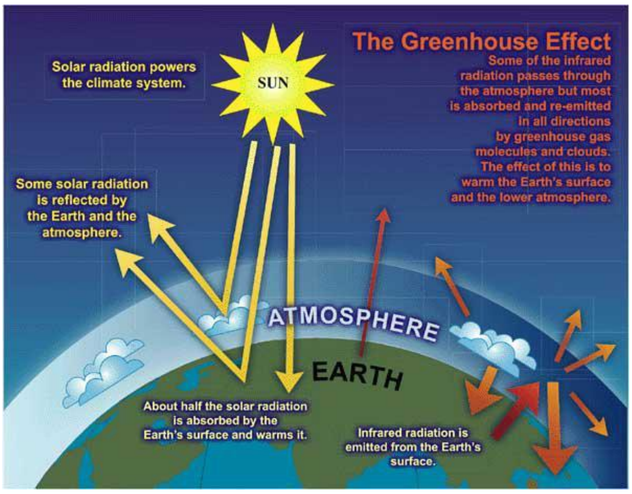

Fig. 1. Simplified diagram illustrating the greenhouse effect [Le Treut et al., 2007]

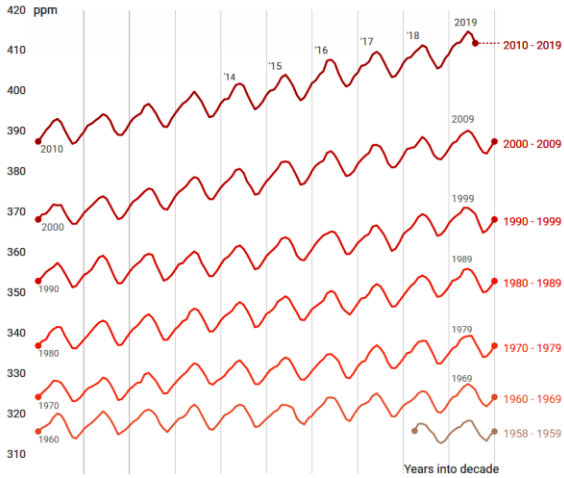

Fig. 2. Simplified diagram illustrating the greenhouse effect [Aisch, 2018]

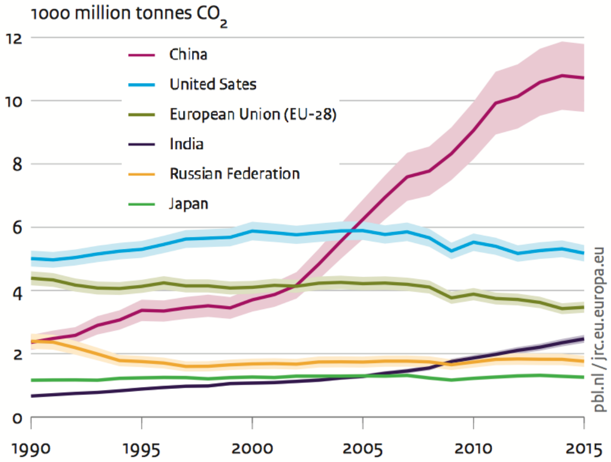

Fig. 3. CO2 emissions from fossil-fuel use and cement production in the top 5 emitting countries and European Union [modified from Kuba, 2017]

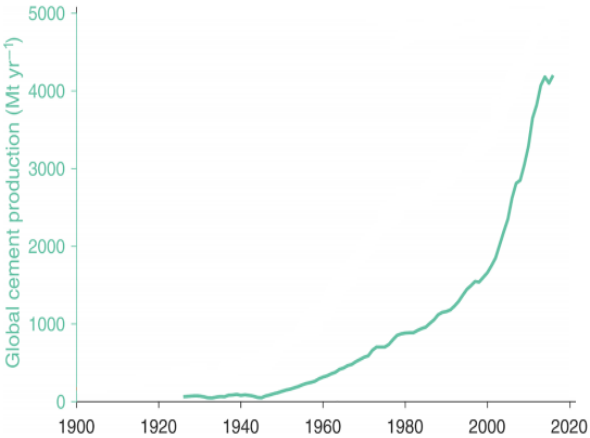

Fig. 4. Global cement production to 2016 [modified from Andrew, 2019; BP, 2019]

SCM (supplementary cementatious materials) as possible way to reduce CO_2 emission in the atmosphere

Portland limestone cement

Total emissions from the cement industry could contribute as much as 8% of global CO_2 emissions [IEA, 2017]. Global warming gas is released when the raw material of cement, limestone and clay is crushed and heated in a furnace at high temperature (± 15000°C). Each year, approximately 1.89 billion tons of cement (which is a major component of concrete) have been produced worldwide. One way to reduce greenhouse gas emissions per ton of cement produced is to use limestone from the quarry. Specifically, mixing Portland cement clinker and limestone (5% to 15% limestone) produces portland limestone cement (PLC) [Barrett et al., 2013; Mrema, 2010]. Production of Portland limestone cement leads to reduced levels of CO_2 emissions and reduced energy consumption when compared with the production of the same quantity of Portland cement, thus contributing towards more sustainable construction materials [Nisbet 1996]. This represents a promising approach for the world market. First application of this type of cement dates from 1965. when Heidelberger produced 20% limestone cement in Germany [Schmidt 1992]. Later in Canada, up to 5% of limestone could be contained in Portland cement since 1983 [Barrett et al., 2013]. ASTM International allowed the same percentage of limestone in Portland cement in 2004, followed by AASHTO (American Association of State Highway and Transportation Officials) in 2007. These changes will result with reduction in energy consumption of 11.8 trillion Btu[1] and over 2.5 million tonnes of CO_2 per year [Tennis et al., 2011]. As response to growing pressure to reduce clinker content in cement, the Canadian Standards Association (CSA) introduced a new cement classification in 2008. in which Portland cement can have up to 15% limestone. Based on many studies and valid tests, portland limestone cement containing up to 15% limestone can make the same concrete as pure Portland cement [Barret et al., 2013; Tennis et al., 2011; Hooton et al., 2009]. This implies the same strength, durability and other features. Any increase in the amount of limestone usually reduces the clinker content by an additional 10%. When 40 to 50% supplementary cementitious materials is added - the effective reduction of clinker concentration in concrete exceeds 50%.

The technical benefits of applying SCM in concrete are as great as their impact on creating even better solutions that are one step ahead in green building. In most cases, mixed cements can be replaced, in 1:1 ratio, with classic Portland cement. Numerous organizations, including the American Concrete Institute (ACI) and the Cement Slag Association (SCA), offer detailed guidance and recommendations to construction companies that make concrete and use it during construction. Also, certification program as LEED (Leadership in Energy and Envirinmental Design) will continue to provide a major influence to develop and create even better, more innovative sustainable construction solutions.

Finding new ways to further reduce energy consumption and CO_2 emissions is a top priority for cement manufacturers. Thus, new solutions are constantly being created with result of reducing the amount of clinker while increasing the use of alternative materials. With these next-generation cements, consumers can use the same amounts of SCM in mixture, but also by adding up to 15% lime in clean Portland cement. All this is for the same purpose, which is to reduce carbon emissions in the construction sector.

Solar Thermal Electrochemical Procuced (STEP) cement

Concrete is the most widely used building material in the world, and large quantities of cement are required to obtain it. The production of cement, which accounts for 15% of the concrete mix, is responsible for up to 8% of the total carbon dioxide (CO_2) emitted into the atmosphere as a result of human activities. This is supported by the fact that for every 10kg of cement produced, 9kg of CO_2 is emitted into the atmosphere. The chemical reactions that take place during the production of cement emit large amounts of carbon dioxide, of which 60% of the emission is during the production of CaO from $CaCO_3$. Therefore, a great deal of research in the world has focused on addressing this problem and finding ways to obtain concrete components otherwise.

STEP – Solar Thermal Electrochemical Production, is advanced solar energy conversion with high efficiency through the use of the solar spectrum in order to generate energy rich chemicals. Researchers at The George Washington University, led by Dr. Stuart Licht, have developed a process called CO_2-free solar thermal electrochemical production of calcium oxide [Licht et al., 2012]. This is, in fact, a way of thermally decomposing limestone ($CaCO_3$) and obtaining CaO that goes into cement without emitting carbon dioxide. It is known that the solubility of $CaCO_3$ in water is $6x10^{-5}$ mol/kg of solution, while for calcium oxide this value is three times lower - $2x10^{-5}$ mol/kg, with calcium hydroxide as product of solubility. On the other hand, Licht explains that this situation

[1] British thermal unit

is reversed at high temperatures in molten carbonates, which allow endothermic, electrolytic synthesis and CaO deposition [Licht et al., 2012].
Figure 5 shows a new, solar, CaO process based on oxide solubility irregularities, without carbon dioxide emission.

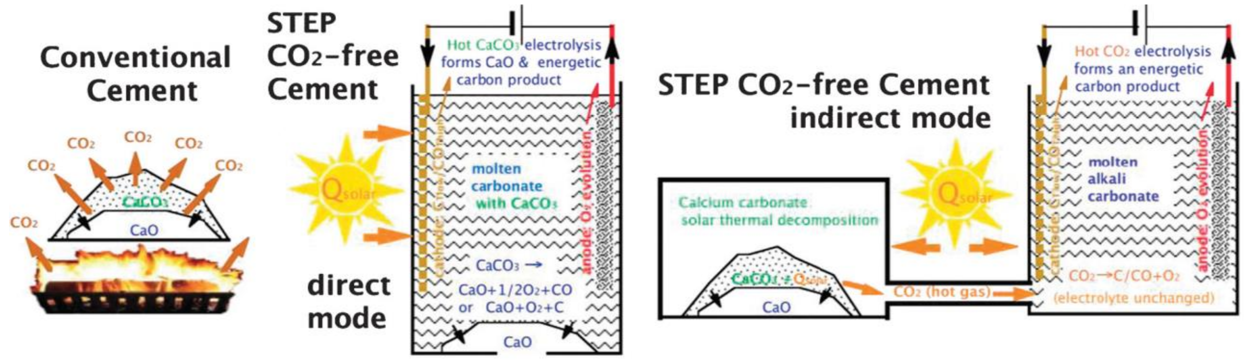

Fig. 5. Simplified solar production of CaO without CO_2 emission [Licht et al., 2012]

The contribution of the new solar process is that the electrolysis of molten carbonate forms oxides, which become calcium oxide when mixed with calcium carbonate. This avoids the formation of carbon dioxide and eliminates the fact that the production of cement has an impact on the formation of greenhouse gases.

Conclusion

Climate change caused by human activities is an exceptionally large problem that has a direct impact on the environment. One of those changes is the global warming of planet Earth caused by the increased release of greenhouse gases into the atmosphere. The greenhouse effect is a natural phenomenon that, by its presence, allows life on planet Earth to a certain extent. However, a big problem arises when one disrupts the natural processes in the direction of their intensification by their activities. Therefore, it is necessary to direct the production of individual materials towards alternative solutions, using components and processes that do not have a negative impact on the environment and intensify the greenhouse effect such as a new process for cement production.

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