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Usage of green concrete technology in civil engineering

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Abstract

It has been noticed, that concrete is second after sweat water product used by people on our planet. This is good and unfortunately bad information. Good because of fact, that thanks to concrete we are able to build solid and sustainable structures making our life easier and better. Bad because making a concrete is connected with huge energy cost and even bigger emission of greenhouse gasses.

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Keywords: green concrete, geopolymer, usage of ecological binders

1. Introduction

In this paper we are trying to bring closer implementation possibilities of new ecological geopolymer binders [1]. Noun ecological and green is not given here without a reason. Because of it we should be interested with using geopolymer concretes. Emission of greenhouse effect gasses is well known problem that makes our environment changed permanently. CO_2 is major gas just after steam causing this problem. Carbon dioxide is being produced from two main sources: natural and anthropogenic. The first one was here on earth from the beginning, but our planet was dealing with it very well. The anthropogenic one is being real problem. It is because the fact that people are working hard to make CO_2 grow. They are working on two fronts. Firstly they reducing the possibilities of

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absorption, secondly they using technologies which are highly cost and energy required. In 2013 due to Global Carbon Project data global CO_2 emission connected with fossil fuel use and cement production were 36 Gt. It is 61% higher than in 1990 according to Kyoto Protocol reference year. It is also 2.3% higher than in year 2012. Year 2014 will bring additional CO_2 emission growth in 2.5% increase due to year 2013 [2].

Traditional cement CO_2 emission is very high and in some cases can be equal to more than 1t per 1t of cement production [3]. Due to this fact ordinary cement, which is often called as Portland cement, unfortunately is being serious environment and atmospheric pollutant. This is happening because of fact that producing cement clinker involves very well-known reaction called calcination of calcium carbonate which can be written is this equation (1):

$$5CaCO_3 + 2SiO_2 \rightarrow (3CaO,SiO_2)(2CaO,SiO_2) + 5CO_2 \quad (1)$$

Because of this reaction 1t of cement production is generating about 0.55t of carbon dioxide. Additionally it requires to combust fossil fuels which emit an extra 0.40t of greenhouse gas. Huge cement industry which, especially in Europe, is forced to bring down level of CO_2 per 1t of cement, tries to make this possible. Restriction of carbon dioxide is not there where it should be. High developed countries like in Europe or North America are producing very less cement due to whole world production Fig. 1. Only there governments are regulating this incredible important ecological issue of cement industry.

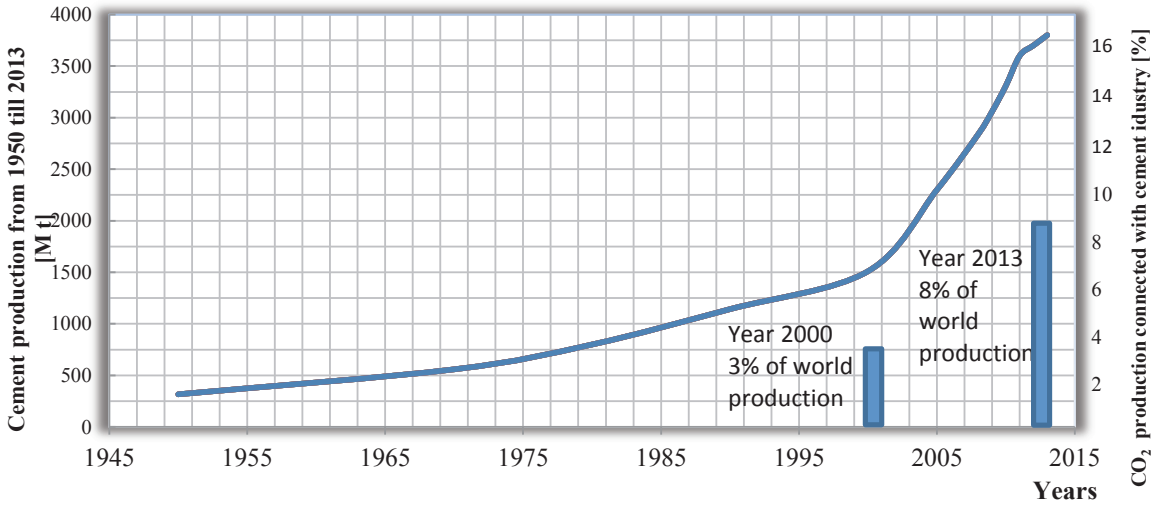

Fig. 1. Cement production and its share in total anthropogenic carbon dioxide emission across last 60 years [4].

Unfortunately there is no technology to reduce carbon dioxide emission of clean Portland cement. The exception of this is multicomponent cements which are produced with an addiction of by-products of fossil fuel combustion or metallurgy industry.

This are very the same products which can be used to producing geopolymer cements. The same cement, which according to data published in 1993 by founder of this technology, prof. Joseph Davidovits, is possible to reduce CO_2 emission from 40% to even 90% due to ordinary cement. This is possible because of fact, that geopolymer cement does not require calcium carbonate for binding.

2. Possibilities of carbon dioxide reduction

World industry is addicted to fossil fuels and cement industry, this two biggest issues making CO_2 growing. It is clear that in next decades we will not be independent from them. The only reasonable thing which should be done is attempt to reduce production of greenhouse gasses and make effort to find other replacement methods and products to produce “clean energy”. In civil engineering branch material engineers, designers and contractors should be more interested in usage of green concretes. It is not just because of simple carbon dioxide reduction which overall

amount could be connected only with production of concrete but general carbon footprint for whole structure or building in its lifecycle. In the simple comparison of Portland cement and geopolymer cement depending on obtaining method average CO_2 reduction is about 80% Fig 2. Looking forward additional benefits are possible to gain by using geopolymer concrete.

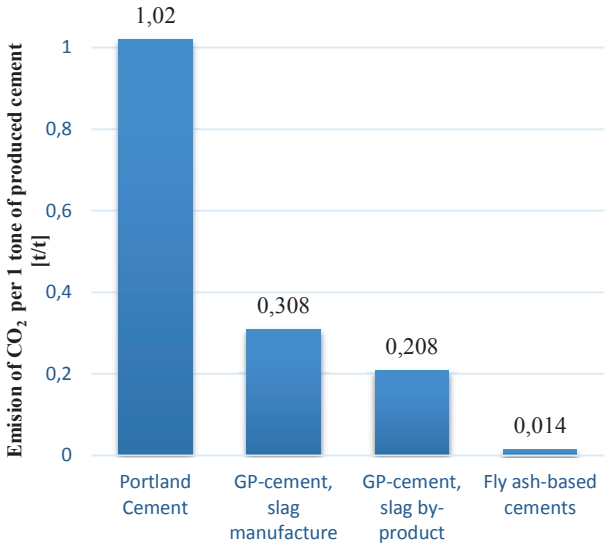

Fig. 2. Amount of carbon dioxide emission to atmosphere by one tone of produced cement according to US Portland Cement Association [4].

The most important factor describing ecologically of every material is carbon footprint. It is commonly described as the total sets of greenhouse gas emission caused by an organization, event, product or a person. Possibilities of calculating the total carbon footprint for types of cements and concretes is nearly impossible due to enormous amount of data which should be included to do it precisely. But there are huge possibilities to compare data and potentiality of carbon dioxide reduction due to whole lifetime of material, assuming that well known properties of geopolymer concretes are able to resist more time of the same corrosive expansion comparing to Portland concretes. Because of this the lifetime of structure in which green concrete is being used increase. Of course geopolymers are not only possibilities of lowering CO_2 footprint. The trend of prolonging the lifetime of materials, and their reuse when they have already been considered as waste is studied in many cases [5]. It is also very good idea of lowering the carbon dioxide footprint. With application of geopolymer cement and second life aggregate total amount of carbon dioxide footprint would be lowered multiplied times due to ordinary concrete.

3. Source of geopolymer cements

Nowadays only in European Union and United States every year there is being produced more than 100 million tons of fly ashes per year [6, 7]. According to European Coal Combustion Products Association and National Minerals Information Center there is remaining billions of tons of fly ashes. Unfortunately not all of them are proper to be used for green concretes. It is because of combusting temperature of coal which is not relevant to obtain products in required properties. Coal ashes are fortunately only one of many products which can give us geopolymer binder. They are in the middle of interest because plenty of material is available on fly ashes piles. Additionally they give biggest possibility of carbon dioxide reduction. The second most popular byproduct is blast furnace slag. Its properties are better than byproduct of coal combustion, but amount of it is also much smaller. Amount of fly ashes and blast fumes generated as by-products and possible to use for geopolymer concrete are high for countries well developed Table 1. In China and India, which are major producers of cements, this amounts is drop in the ocean of

demand [8]. The cleanest byproduct formed by nature is volcanic tuff which is by now best non-dedicated substratum.

Table 1. Amount of by products possible to use for geopolymer binders production [8]

Countries/Regions	**Amount of fly ashes [Mt]**	**Amount of blast fumes [Mt]**
USA	29	16
Canada	5	3
European Union	20	27
Other European Countries	11	4
Japan	4	15
Australia	2	1
China	62	20
India	16	4
Korea	3	7
S-W Asia	17	3
Post-Soviet Countries	15	13
Latin America	11	7
Africa	7	2
Near East Countries	3	1

Of course there are many possibilities to produce dedicated geopolymer cements. They relate to crushing and combustion of alumina-silicate minerals. Depending on ratio of this two components we are able to receive worst or better product able to use for geopolymer cement and concrete.

Despite this fact dedicated material, which were prepared only with view of producing geopolymer binders will always have better properties to this produced from byproducts. The main goal of researchers is to overcome present difference to the minimum.

4. Places and possibilities of implementation

Due to fact that many byproducts are pretending to being source of geopolymer concrete, implementation possibilities are enormously high.

Table 2. Products of coal combustion depends of combustion temperature [9]

Common coal minerals	**Temperatures of combustion**		
	850°C	*1500°C*	*1800°C*
Quartz	quartz	cristobalite	glass
Kaolinite	metakaolin	glass + mullite	glass
Illite	illite	glass + mullite	glass
Pyrite	iron sulphide	hematite / magnetite	glass
Calcite	lime	glass	glass

Furthermore in every place where ordinary concrete is being used there can be used geopolymer one. Very interested in new ecological material should be architects. Well properties of geopolymers give new possibilities in forming shapes and dimensioning. Additionally buildings and structures built with new material, comparing to ordinary one, will last longer. This could happened when we considering fine selected products. Here rises question, what to do with ones which are already available, but with worse properties. There are being held research which could answer this question. For now it is clear that coal is much better than the lignite. Byproduct rising from coal combusting is cleaner from unwanted minerals such as carbon and calcium. Very important is also temperature of combustion. The higher it is, the better byproduct we receive Table 2 [9].

5. Discussion

The issue of geopolymers opens new possibilities for environmental protection and comprehensive greening concrete industry. Ecologically problem of greenhouse effect will never be solved without legal regulation. It is because the fact, those large industrial potentates will be interested in environment protection only when they are forced to. More than twenty years ago there was published text by Joseph Davidovits in which were given speculation about global warming problem and future production of cement materials [10]. Author speculated that in next two decades worlds cement production will grow 3.5 times. From 1 billion of tones in year 1994 till 3.5 billion of tones in year 2014. This speculation was very close. Unfortunately growth was higher from speculated for about 14%. Efforts which were undertaken by European Union do not solved problem. Firstly because Portland cement lobby is truly not interested in new technologies. Secondly the science potential is too low even in well developed countries to undertake research on global industry field. Another problem which we are facing is fact that most of global production is being held in countries which are not obligated to European laws and restriction. Furthermore in China and India carbon footprint measured by one citizen is lower than in North America or even Europe Fig. 3, Fig. 4.

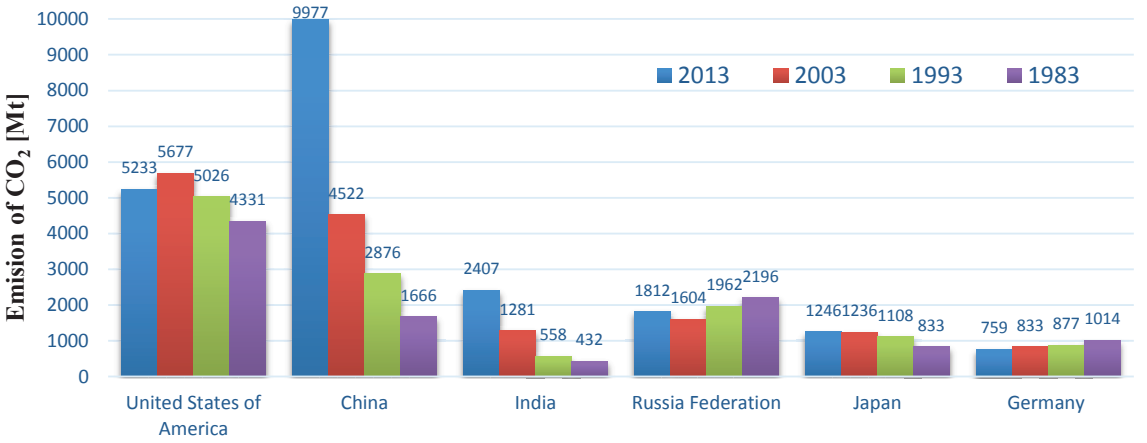

Fig. 3. Amount of total CO_2 emission in past years by countries of highest emission [2].

International communities' tries to fight with climate change. They are facing difficulties of reaching agreement on the regulation of greenhouse gases emission. Huge problem is measuring of relative contribution, which is given by First and Third World countries. Developing countries have contended that industrialized countries had caused the climate change problem, so now they should face the regulation of CO_2 and other greenhouse effect gases.

In case of civil engineering and architecture there should be elaborated guidelines which could faster possibility of geopolymer concrete apply. It will not happen today or even tomorrow. It lasted for decades and probably will take even more time, but can be done only if lots of work and plenty of researchers would work on it.

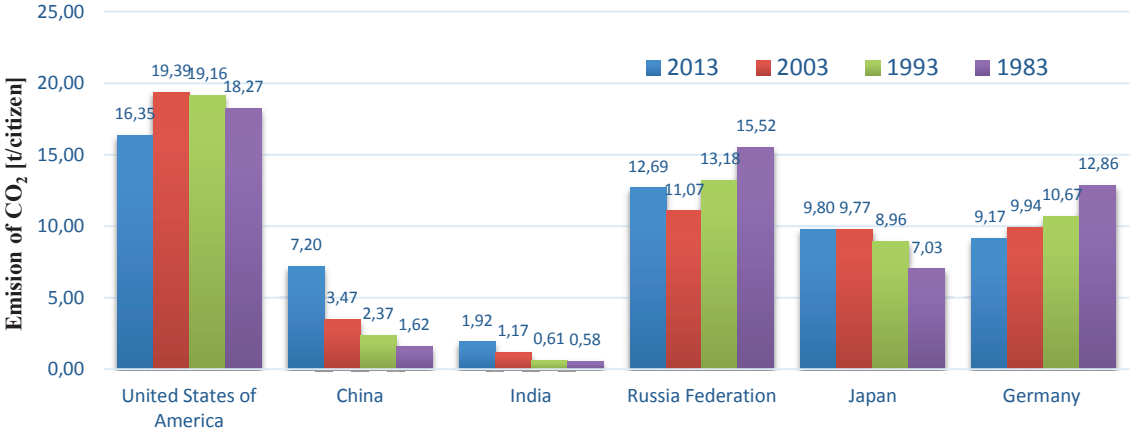

Fig. 4. Amount of CO_2 emission per citizen in past years by countries of highest emission [2].

Additional resources given by authorities and government on global, national and even local fields would really accelerate research which should be performing to implement new green binders. Till then we will need to believe that a lots of work that has been spent on environment awareness will spill in social effect [11].

References

[1] T. Błaszczyński, M. Król, Durability of Green-Concretes, Proceedings of 8th International Conference AMCM 2014, Wrocław, Poland, pp. 530-540, June 2014.

[2] Carbon Dioxide Information Analysis Center Global Carbon Budget 2014, , September 21, 2014.

[3] M. Król, T. Błaszczyński, Geopolymer Eco-concretes, Construction Materials, 11 (2013) 23-26.

[4] T. Błaszczyński, M. Król, Concrete and problem of carbon dioxide emission reduction, Isulations, 3 (2014), 28-30.

[5] J. Katzer, J. Kobaka, Harnessing Waste Fine Aggregate for Sustainable Production of Concrete Precast Elements, Annual Set - The Environment Protection, 12 (2010) 33-45.

[6] National Minerals Information Center, Coal combustion products, October 11, 2011.

[7] ECOBA, 2009 – Production and Utilisation of CCPs in 2007 in Europe (EU 15). Retrieved April 9, 2010.

[8] K. Humphreys, M. Mahasenan, Toward a Sustainable Cement Industry: Climate Change, World Business Council for Sustainable Development 2002.

[9] Geoplymer Webinar, Geopolymer Institiute 8-9 April 2014.

[10] J. Davidovits, Global Warming Impact on the Cement and Aggregates Industries, World Resource Review, 6 (194) 263-278.

[11] I. Piecuch, T. Piecuch, Environmental Education and Its Social Effects, Annual Set - The Environment Protection 46 (2013), 1561-1568.