ON THE POSSIBILITY OF RADICAL DECREASE OF CO2 EMISSIONS AND COST OF FUEL AT CEMENT PRODUCTION

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NANOCEMENT

Abstract

This article analyzes a new technology for modifying Portland cement into nano cement. This provides for a radical revision of the development strategy of the cement industry. It is possible to reduce by one half to three quarters CO2, NOX and SO2 emissions and fuel costs per ton of cement with minimal capital investments. At the same time saving energy, minimizing environmental footprint and producing cement of higher quality at a reduced cost.

A few years ago, the US government forecasted that the world emissions of carbon dioxide will increase by 75% by 2030. Energy Information Administration (the statistical department of the US Department of Energy made this conclusion in their annual forecast. According to the experts, the amount of CO2 emissions worldwide will increase from 29 billion tons in 2010 to 43.7 billion tons by 2030, unless additional measures are taken to reduce the emissions, Reuters Agency reported.

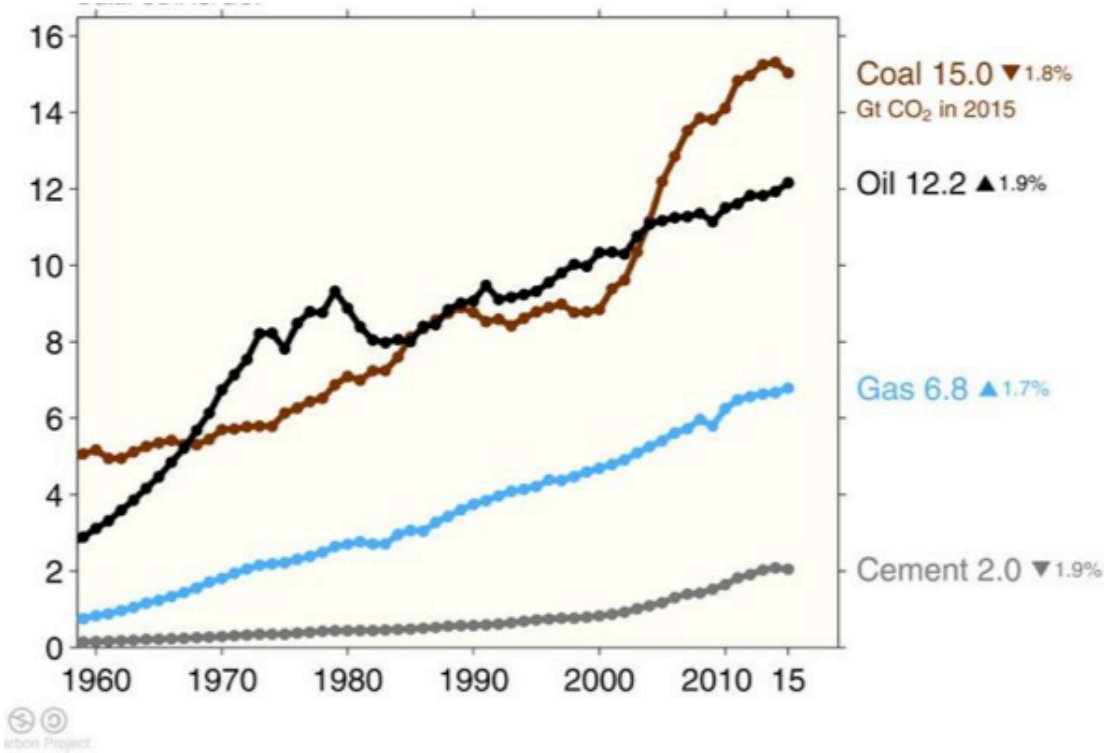

Figure 1. Increase in CO2 emissions when burning fuel and producing cement during the last half a century

Cement production, especially of significant volumes, requires burning hundreds of millions of tons of fuel annually and is accompanied by the release of significant amounts of heat, CO2, NOX and SO2, This contributes to climate change on the planet. While the annual production of cement has exceeded 4.5 billion tons, the volume of emissions into the atmosphere of CO2 by cement plants is about 1000 kg per ton of cement produced.

This amounts to billions of cubic meters of harmful gases annually (Fig. 1). On top of that, new plants are being build in China, India, Latin America and other developing countries, where CO2 emissions increase much faster proportionally to the increase in cement production, causing an overall increase in CO2 emissions from the cement industry. As it is well known worldwide, after the signing of the Paris Agreement on Climate Change, there is extreme pressure on reducing greenhouse gas emissions.

The established CO2 tax in British Columbia of $ 30 per tonne led to a sharp increase in cement imports and prompted the Canadian government last year to allocate $ 22 million to help cement enterprises.

Improvement of Portland cement technology is carried out today in two key ways to reduce fuel consumption and CO2, NOX and SO2 emissions: 1 - optimize the aggregate design of firing and the use of alternative fuels; 2 - the introduction of Portland cement with milling energy-saving mineral additives. In the first direction, the world's cement industry has achieved significant success - high-performance equipment, heat recovery systems, air purification systems, etc.. Machine builders produce complete technological lines with a capacity of 3 to 4 million tons of cement per year.

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The second direction, unfortunately, has practically stopped in development. The average number of mineral additives introduced into Portland cement in the world is about 15% of its mass. So the amount of mineral additives introduced in 2013 by cement plants in Russia amounted to about 8% of the mass, and significantly decreased over the past decades. At the same time, the world standard cement documents, which comply with the standards adopted in Europe (EN 197-1) and the USA (ASTM), provide for great opportunities for the introduction of mineral additives.

A significant decrease in the properties of cements with mineral additives explains why building organizations prefer to buy non-additive Portland cement.

Experts, nevertheless, suggest an increase in the amount of mineral additives used in cement: by 2020 - 26% by mass, by 2030 - by 27% by mass, and by 2050 - 28% by mass. The improvement of the construction and technical properties of Portland cement produced all over the world has long stopped developing, which for several decades already does not allow increasing the strength of cement above classes 42.5-52.5.

Cement factories around the world for decades produce almost the same product. Russian scientists have developed a technology for modifying Portland cement, which allows to radically increase its construction and technical properties, first of all, strength of cement up to 82.5 and higher, and also to increase the content of mineral additives up to 70%, at that providing for high construction and technical properties of cements (Table 1).

The new technology for modifying Portland cement into an energy-saving nanocement during the process of grinding clinker allows, for the first time in the world, to add mineral additives up to 70% by weight ensuring high quality of such nanocement of no less than 32.5 class with a reduction for each ton of cement of fuel costs up to threefold, from 200 kg to 60 kg, and actual CO2 emissions reduction from 1070 kg to 320 kg.
Nanocements allow for the addition of mineral additives up to 60-70% by weight with the provision of high quality cements and concretes on the basis of such cements. Using such cements in concrete results in, among other benefits, controlled workability and setting time, yielding additional economic benefits: it eliminates the use of expensive additives.

The essence of the new technology for modifying Portland cement into nanocement lays in the formation of a so-called nano shell on the surface of Portland cement grains during the process of mechanochemical activation taking place within the grinding stage. Nano shells appear to be a continuous capsules-shells of nanosize thickness consisting of a special modifier (Fig. 2), wrapped around cement grains. The scientific and regulatory basis for nanocements has been developed by the Russian scientists. The results of certification tests conducted in 2012-2016, in accordance with the existing GOST (Russian standardization system) standards demonstrated full compliance of nanocements with the Russian national pre standard PNST 19-2014: «Portland cement, nanomodified. Technical conditions». Consequent tests conducted in UAE, Canada and other countries demonstrated compliance of nanocements with the American standard ASTM C1157. For the first time in the world, nanocements were identified as nano-containing products of class B, the presence of nanoshells on cement grains was scientifically confirmed. The product was certified by the Russian Standard Authority and classified into following categories according to cement class: 82.5; 72.5; 62.5; 52.5; 42.5 and 32.5.

Considering the main parameters - rate of curing, compressive and flexural strength, all classes of nanocements surpass Portland cement in construction and technical properties. This method allows increasing the class of cement from 42.5-52.5 to 72.5-82.5.

The obtained characteristics of the rate of curing and the quality of nano-cement are the highest in the history of the world cement industry.
The new technology and nano encapsulation phenomenon significantly changes the concept of the potential of cement as a binding medium, improves efficiency of its application, allows to use finely dispersed mineral additives as an active agent for the formation of cement stone.

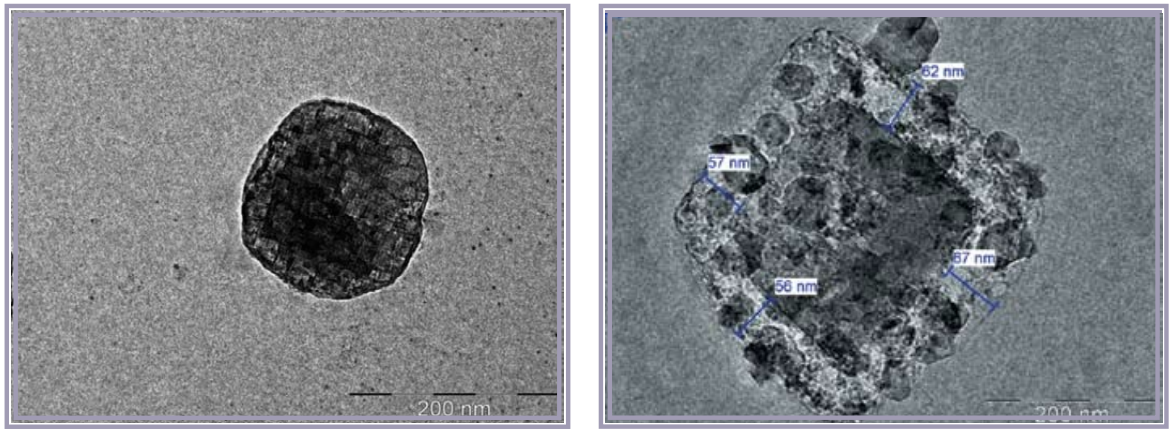
Table 1
Construction and technical characteristics of nano-cement tested for compliance with the national RF pre-standard 19-2014 "Portland cement, nanomodified. Technical conditions» in the State R&D Institute NIIMOSstroy, Moscow - Russia

Sample name	Strength MPa with normal hardening						Nano shell, width, nm	Unit parameters** per ton of cement, kg	
	age 2 days		age 7 days		age 28 days				
	Flexural	Compressive	Flexural	Compressive	Flexural	Compressive		Fuel consumption	CO2 emissions
Portland cement initial PC-500 D0-N "Oskolcement" lot No. 654	2.9	21.3	-	-	6.4	54.4	None	200	1070
NANOCEMENT 90* K 82,5	7.1	53.8	8.0	72.6	8.7	82.7	30-120	180	960
NANOCEMENT 75* K 72,5	6.9	54.7	8.0	68.5	8.5	77.8	30-115	150	802
NANOCEMENT 55* K 62,5	6.3	49.3	7.5	65.4	8.2	77.5	15-100	110	588
NANOCEMENT 45* K 52,5	4.8	39.9	6.7	57.4	7.9	68.1	18-95	90	481
NANOCEMENT 35* K 42,5	3.9	30.7	5.8	46.6	7.2	61.4	15-100	70	374
NANOCEMENT 30* K 32,5	3.0	20.4	5.6	46.4	7.6	52.1	14-85	60	321

** The figure hereinafter means the amount of the original Portland cement clinker in the nanocement, the rest is the fine-quartz quartz sand ground together with clinker*
*** The materials of mineral additives are considered dry for simplification of calculations, for the base cement the wet production method is considered*

Nano-cement technology and nanocements have been tested in the Russian Federation for many years, as well as in China, USA, Canada, UAE, Africa, Kazakhstan and other countries. The new technology was launched this year at the cement plant TURON ECO CEMENT GROUP in Kokand region of Uzbekistan, producing nanocement 45 with a reduction in specific fuel consumption and CO2 emissions by a factor of two by adding barkhan sand to clinker in the ratio of 1: 1, at that providing high quality cement.

In the forth quarter of this year, construction completion of two cement plants for producing nanocement is planned in Yelabuga, the Republic of Tatarstan and Astana, the Republic of Kazakhstan. The new technology can be implemented on any grinding line of any cement plant with virtually no capital investment.



a) b)

Figure 2. Typical electron microscopic images of grains of Portland cement (a) and nanocement (b). The blocky and mosaic microstructure of the nano cement grains is clearly visible. The dimensions of nano shell are specified on the grain of nano-modified Portland cement (b).

Conclusion

The phenomenon of nanoencapsulation of dispersed substances discovered and proved by Russian scientists gives the prospect of changing the strategy for the development of the world cement industry. It provides the possibility to drastically reduce fuel consumption and NOX, SO2, CO2 emissions per ton of cement by reducing the content of Portland cement clinker down to 30-35% by weight. It is then modified into a low-clinker nano-cement with preservation of high building and technical properties of the material with increased shelf life from 2 months for Portland cement to one year or more for nanocement. New technology also provides for reduction the cost of cement production by 20-25%.

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