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Construction binders and environmental indicators of their production

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Abstract. A comparative analysis of carbon dioxide emissions during the burning of Portland cement clinker, lime and gypsum was performed. The interrelation between energy indices and the emission of carbon dioxide is shown. The quantitative indices of atmospheric pollution in the manufacture of binders are given. Ecological expediency of production of gypsum and cement clinker in comparison with lime is shown. The article is made rough calculation of environmental pollution by carbon dioxide, which is produced and released into the atmosphere during the production of building binders. It was determined the directions of reducing the formation of gases during firing of the substances to reduce environmental pollution: decrease in endothermy of chemical transformations; reduction of the content of calcium and magnesium carbonates in the feedstock mixture; reduction of raw material moisture; reduction of fuel consumption for the process; increasing the technological efficiency of the process. It was determined the directions of reducing the formation of gases during firing of the substances to reduce environmental pollution. It is shown that carbon dioxide is released into the Earth's atmosphere in the amount of more than three billion metric tons per year by enterprises that produce cement, lime, and gypsum.

1 Introduction

Currently, environmental protection issues are addressed from industrial emissions, most often through the use of gas cleaning and dust removal technologies designed to reduce toxic emissions through their utilization or capture. Cleaning of exhaust gases from dust is carried out, mainly, by means of electric filters, fabric filters, scrubbers and cyclones. And reducing the emission of gaseous pollutants in the building materials industry is almost not drawn to attention.

The process of burning the building viscosity is accompanied by significant emissions of carbon dioxide, nitrogen oxides, water vapour, carbon monoxide, sulfur oxides and dust into the atmosphere [1]. The increase in the concentration of carbon dioxide in the atmosphere is a large-scale problem that can change the climate of the planet. Because carbon dioxide absorbs long-wave radiation reflected from the surface of the Earth, its

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presence in the atmosphere acts as a protective shield that reduces heat losses of the planet. This phenomenon is called the greenhouse effect, which is accompanied by an increase in temperature. According to the available estimates, the warming of the climate increases the rate of increase of the world ocean level by 5-25 times due to the melting of glaciers and the thermal expansion of sea water [2]. The problem of the climate on the Earth in the future is closely linked with the ecological balance between the two main factors - the concentration of aerosols and carbon dioxide in the atmosphere. In previous years, carbon dioxide emissions have not received sufficient attention. But the climate change, which began in recent years, indicates the importance of this problem.

2 Results and discussion

2.1 Theory of the question

Ecologists warn that if i Carbon dioxide during the firing of clinker is released in the decomposition of carbonates of calcium and magnesium and in the combustion of carbon-containing components of fuels. Therefore, reducing the content of calcium carbonate and magnesium carbonate in the raw material mixture at the clinker firing is one way to reduce carbon dioxide emissions into the atmosphere. The content of carbon dioxide in the composition of the exhaust gases also decreases with a smaller amount of combustible fuel.

The most common binders are cement, lime and gypsum. Cement raw materials are calcium and magnesium carbonates, as well as aluminosilicates. Lime is made only of carbonates. Therefore, the formation of carbon dioxide in the burning of lime is greater than that of the firing of cement clinker. Construction gypsum (calcium sulfate semihydrate) is formed as a result of the decomposition of dihydrogen gypsum (calcium sulphate dihydrate) on semi-water gypsum and water at certain temperatures. In other words, there is no carbon dioxide in the reaction products. As a result of the reaction, only water is released.

Total amount of gases released during roasting:

$$G = G_g \cdot F + G_m \cdot M_{CO_2}\left(\frac{CaCO_3}{M_{CaCO_3}} + \frac{MgCO_3}{M_{MgCO_3}}\right)\cdot 0.01 + \\ + \frac{G_m \cdot W}{100 - W} + G_m\left[\frac{n \cdot M_{H_2O} \cdot ASH}{M_{ASH}} + \frac{2 \cdot M_{H_2O}\left(CaSO_4 \cdot 2H_2O\right)}{M_{CaSO_4 \cdot 2H_2O}}\right]\cdot 0.01, \tag{1}$$

where $M_{CaCO_3}, M_{MgCO_3}, M_{H_2O}, M_{ASH}, M_{CaSO_4 \cdot 2H_2O}$ - the molecuflar weight of carbon dioxide, calcium carbonate, magnesium carbonate, water, aluminosilicate minerals and calcium sulfate dihydrate, kg, respectively,
n - the number of water molecules in the aluminosilicate,
G_g –volume of gases released during the combustion of fuel, m^3/m^3 of fuel,
$CaCO_3$, $MgCO_3$, ASH, $CaSO_4\ 2H_2O$ - amount of calcium carbonate, magnesium carbonate, aluminosilicate minerals and calcium sulfate dihydrate in the feed, % of the weight of the feed mixture,
G_m - consumption of dry raw materials, kg/kg of the binder,
W - the moisture content of the raw mix, % of the mass of the raw mix,
F - fuel consumption for the finished product.

$$F = \frac{q_{en} - q_{ex}}{\eta \cdot Q_r^n}, \tag{2}$$

where $q_{en,}$ q_{ex} – enthalpy of endothermic and exothermic reactions in the preparation of binders,

η - efficiency of the firing process,

Q_r^n - calorific value of the fuel.

In the formula, the first term shows the evolution of gases as a result of fuel combustion, the second - the release of carbon dioxide in the decomposition of carbonates, the third - the release of water vapour from the raw materials, the fourth - the liberation of hydrated moisture from aluminosilicates and calcium sulfate dihydrate.

As follows from the above formulas, an increase in the content of calcium and magnesium carbonates in the raw materials contributes to an increase in the formation of carbon dioxide and an increase in emissions into the atmosphere. Emissions of pollutants are also interrelated with energy costs [4-6]: the more fuel consumption for the firing process, the more the combustion products are released. When calcining cement clinker, the carbonate content in the raw material is approximately 80%. The starting materials for the production of lime are 100% carbonates. A building gypsum is obtained from calcium sulfate hemihydrate. From the dependence obtained, it is possible to determine the directions of reducing the formation of gases during firing of the substances to reduce environmental pollution:

- decrease in endothermy of chemical transformations;
- reduction of the content of calcium and magnesium carbonates in the feedstock mixture;
- reduction of raw material moisture;
- reduction of fuel consumption for the process;
- increasing the technological efficiency of the process.

And as a result of the reactions, only water is released.

2.2 Comparative indicators for the release of carbon dioxide in the manufacture of binders

It is easy to calculate the amount of carbon dioxide that enters the atmosphere only from the work of cement kilns.

If we take as a basis the heat engineering calculations of the rotary kiln for the firing of cement clinker wet production, the output of carbon dioxide from the raw material mixture-0.57 kg/kg of clinker, and the formation of carbon dioxide from fuel combustion - 0.6 kg/kg of clinker [3] . The total carbon dioxide emissions are $0.57 + 0.6 \approx 1.2$ kg/kg of clinker. With a dry method of production, this figure will be 0.8 kg/kg clinker. Comparative indicators of carbon dioxide release in the production of one ton of binders, tons of CO_2 / ton of binder, are shown in the diagram (Fig. 1). Global cement production is expected to increase from 3.27 billion metric tons in 2010 to 4.83 billion metric tons in 2030 [7]. In 2017, world cement production amounted to about 4.1 billion metric tons [8].

In total, approximately 350 million metric tons of lime and limestone were produced in 2015 [9]. In 2016, world total production of gypsum was estimated to be 263 million metric tons [10].

In the production of building binders, the annual emissions of carbon dioxide on the planet are approximately - for the production of cement $0.8 \cdot 0.8 \cdot 4.1 + 1.2 \cdot 0.35 + 0.06 \cdot 0.263 =$ $= 3.060$ billion metric tons. And this is only CO_2!

0.06 is the formation of carbon dioxide in the combustion of fuel consumed for the firing of gypsum. The figures speak for themselves. From the rotary kiln for burning cement clinker leaves 2-4 tons of gas per ton of clinker [11]. This figure varies depending on the moisture content of the source material, the amount of carbonates in the raw materials, the fuel consumption for firing and the type of fuel. Hence, all polluting gases are released into the environment two or more times more than the binder is produced.

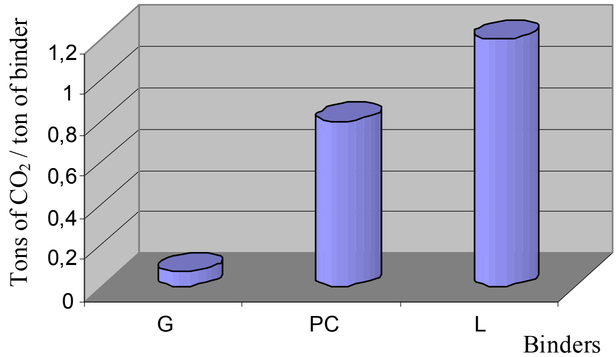

Fig. 1. Emissions of carbon dioxide in the production of gypsum (G), Portland cement clinker (PC) and lime (L)

The production of low-clinker and zero-clinker cements is noteworthy. They can be obtained from the waste [12-15] containing calcium oxides. The decarbonization process was realized in the previous production.

3 Conclusions

It is shown that approximately 3.06 billion metric tons of carbon dioxide is released annually into the atmosphere only from the production of binders: cement, lime, and gypsum. The formation of carbon dioxide in the production of construction binders may be reduced in the following areas: the use of raw materials with reduced carbonate content, the introduction of dry production methods and other economical technologies, the use of energy sources that do not contain carbon and its compounds. In addition, the urgency of this problem requires the creation of new and the introduction of known technologies for capturing carbon dioxide in the building materials industry.

References

1. Bruce Vigon with contributions from Tiffany Brunetti, Vinay Gadkari, Scott Butner, and Jill Engel-Cox. Toward a Sustainable Cement Industry. *Industrial Ecology in the Cement Industry* . **9 (9)**, 3-33 (2002).
2. IPCC. Technical summary. In: Climate Change 2013: The Physical Science Basis. Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (Stocker TF, et al., eds.). Cambridge, United Kingdom and New York, NY:Cambridge University Press (2014). Available: http://www.climatechange2013.org [accessed 21 May 2015]
3. KH.S. Vorob'yov, D.YA. Mazurov, *Teplotekhnicheskiye raschety tsementnykh pechey i apparatov* (Vysshaya shkola, Moskva, 1962)
4. V. Vinnichenko, A. Ryazanov, MATEC Web of Conferences **116**, 01020 (2017)
5. A. Ryazanov, V. Vinnichenko, A. Plugin, Proc. scientific. works, UkrSART, **138**, 77 (2013)

6. A. Plugin, V.Vinnichenko, O. Borzjak, Proc. scientific. works, UkrSART, **143**, 87 (2014)
7. Global cement production from 1990 to 2030. https://www.statista.com/statistics/373845/global-cement-production-forecast/
8. Cement production globally and in the U.S. from 2010 to 2017. https://www.statista.com/statistics/219343/cement-production-worldwide/
9. Lime and limestone production by country in 2015. https://www.statista.com/statistics/657049/production-of-lime-worldwide/
10. Prepared by Robert D. Crangle, Jr. GYPSUM. *U.S. Geological Survey*. 2 Mineral Commodity Summaries, 76-77 (January 2017) https://minerals.usgs.gov/minerals/pubs/commodity/gypsum/mcs-2017-gypsu.pdf
11. E. Hodorov, Uspekhi tsementnoy promyshlennosti**, 432** (1968)
12. Y.L. Wang, S.P. Cui, G.P. Tian, M.Z. Lan, Z.H. Wang. Materials Science Forum, **814**, 564-568 (2015)
13. Zur Strassen H. *Zement Kalk Gips*, **10**.1, 1-12 (1957)
14. W.C.Liu, Z.L.Wu, Y.J.Wang, Y.L. Zhao, Y.Yu. *Ind. Eng. Chem. Res.*, **52**, 13761-13767 (2013)
15. V. Vinnichenko, A. Ryazanov. *Ecology and industry*, **2,** 111 (2013)