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Research paper

Electricity costs for grinding of cement with expanding additives

Svetlana Samchenko, Dmitriy Zorin *

The Moscow State University of Civil Engineering, Moscow, Russia
**Corresponding author E-mail: dim-z@yandex.ru*

Abstract

The most popular building material, including on transport facilities, is cement. Cement production is associated with the electricity costs. The biggest cost item is the consumption for the cement clinker grinding. It is known that disperse characteristics of cements, such as fineness of grinding, specific surface, coarseness of grading, largely determine their hydraulic properties, and for expanding cements - the deformation ones. In the paper, the issues of electric power consumption were considered when grinding extender expanders: aluminous slag, sulfoaluminate, sulfoferrite and sulfoalumoferrite clinkers.

Keywords: *Expansive Cement, Grindability, Alumina Slag, Sulfoaluminate Clinker, Sulfoferrite Clinker, Sulfoalumoferrite Clinker.*

1. Introduction

Concrete and reinforced-concrete products with drying and hardening are reduced in volume and their shrinkage occurs. With prolonged shrinkage action and the presence of hard obstacles to volume reduction, for example, reinforcement or aggregate, holding-down gears, high tensile stresses arise in the cement stone, which can lead to the formation of cracks and destruction of concrete [1,2].
Reduction in shrinkage is usually achieved by constructive methods: increase in the number of reinforcement, breakdown of structures into separate blocks, increasing the frequency of shrinkage joints and other ways [3]. As a rule, all these measures increase construction costs and can shorten the life of structures.
Scientists and builders have always tried to find ways to compensate for shrinkage or to receive a positive expansion, so that it forever gives the right tension [4-6].
One way to reduce shrinkage is to use expanding cements [7]. At present, many different types of expanding cements are known [8]. The most common way to produce expanding cements is joint or separate grinding, followed by mixing of Portland cement clinker, gypsum and special additive [9,10].
Expanding cement upon hardening causes an increase in the volume of the cement stone, its compaction and self-stress. It is used in the construction of residential and industrial buildings, in the construction of chemical facilities, treatment facilities, as well as in the construction of tunnels and underground stations [11].
Among such additives, aluminous slag, sulfoaluminate, sulfoferrite and sulfoalumoferrite clinkers were widely used [12-15].
Recently, there has been a steady increase in electricity tariffs and much attention has been paid to energy and natural resource conservation. Studies were carried out to determine the specific consumption of electric power required on grinding of the expanders.
The aim of the work was to study the grindability of expanders to various dispersities and to determining the specific energy consumption spent on grinding. The aim of the work was to study the grindability of expanders to various dispersities and to determining the specific energy consumption spent on grinding.

2. Material and Methods

Portland cement clinker (PCC), aluminous slag (AS), sulfoaluminate (SAC), sulfoferrite (SFC) and sulfoalumoferrite (SAFC) clinkers were used as starting materials in the work.
The chemical composition and loss of ignition (L.O.I) of the materials is shown in Table 1.

Table 1: The chemical composition of the materials

	Portland cement clinker	Aluminous slag	Sulfoaluminate clinker	Sulfoferrite clinker	Sulfoalumoferrite clinker
SiO_2	20,1	10,5	12,77	12,23	14,76
Al_2O_3	4,56	47	14,73	3,09	10,87
Fe_2O_3	8,72	0,8	3,2	23,79	13,78
CaO	62,75	39,35	51,45	51,83	56,39
MgO	1,99	-	1,76	1,92	2,04
SO_3	0,57	-	10,45	5,19	2,39
R_2O	1,58	-	1,14	1,18	1,09
L.O.I.	0,92	0,12	2,7	0,11	0,51

The components were grinded in a laboratory mill to a specific surface area of 300 m^2/kg and 400 m^2/kg. Additives with a different specific surface area were then mixed with Portland cement and their deformation characteristics were studied.
The grindability of materials is characterized by the functional dependence of the fineness of the grinding on the specific energy consumption spent on grinding.
The specific energy consumption was calculated using the formula (1):

$$E_{ef} = \frac{0{,}28 \cdot 1000 \cdot n}{P \cdot 60 \cdot 48} \qquad (1)$$

Definition 1.1: *The specific energy consumption.* where *Eef – specific energy consumption (effective) expended during grinding for n rounds of the mill, kW·h/t; n is the number of rounds of the mill, counting from the beginning of grinding; P is the weight of the loaded material, kg; 48 – rotational speed of the mill rpm; 0.28 – is effective power of grinding bodies developed in one compartment of the mill at loading 55.0 kg of grinding bodies and material breakdown, kW.*

Specific production was calculated with the formula (2):

$$b = \frac{1000}{E_{ef}} \qquad (2)$$

Definition 1.2: *Specific production, kg/h/kW*

The processed data on the determination of grindability are presented in Table 2.

3. Results and discussion

From the presented results, the most energy-intensive one is the grinding of the sulfoaluminoferritic clinker. So, to achieve a specific surface area of S_{sp}=300 m^2/kg, 42 kW·h/t is required for the grinding of the sulfoaluminoferritic clinker, 37.3 kW·h/t - for the sulfoferritic clinker, 32.7 kW·h/t - for the Portland cement clinker. The most easily milled ones are aluminous slag and sulfoaluminate clinkers, to achieve S_{sp}=300 m^2/kg, upon grinding they require 23.3 kW·h/t and 9.3 kW·h/t, respectively.
To achieve a specific surface area of the studied materials of 400 m2/kg, specific energy consumption was 70 kW·h/t for the sulfoaluminoferritic clinker, 60.7 kW·h/t was for the sulfoferritic clinker, 60.7 kW·h/t was for Portland cement clinker, 37.3 kW·h/t was for the aluminous slag 18.7 kW·h/t was for the sulfoaluminate clinker. The graphical characteristic of grindability of the materials is shown in Fig.1 and Fig.2.

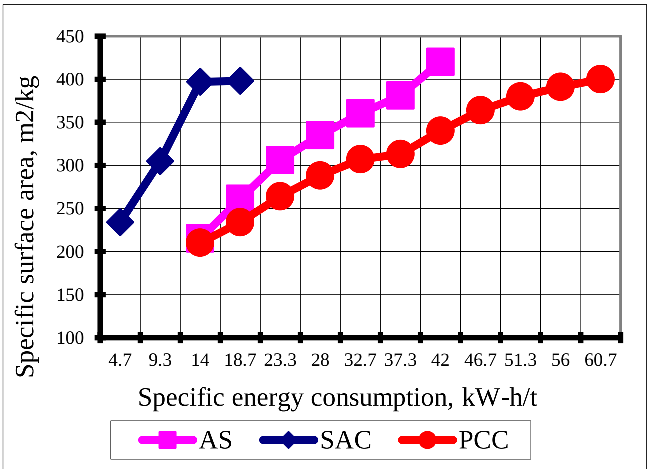

Fig. 1: Characteristic of grindability of the portland cement clinker, aluminous slag and sulfoaluminate clinker

Material	Total duration of milling, min	Specific energy consumption, kW-h/t	Specific production, kg/h/kW	Specific surface area, m^2/kg
1	2	3	4	5
PCC	30	14,0	71,4	210
	40	18,7	53,5	234
	50	23,3	42,9	264
	60	28,0	35,7	288
	70	32,7	30,6	307
	80	37,3	26,8	313
	90	42,0	23,8	340
	100	46,7	21,4	364
	110	51,3	19,5	380
	120	56,0	17,9	391
	130	60,7	16,5	400
AS	20	9,3	107,5	170
	30	14,0	71,4	215
	40	18,7	53,5	261
	50	23,3	42,9	306
	60	28,0	35,7	335
	70	32,7	30,6	360
	80	37,3	26,8	381
	90	42,0	23,8	420
SAC	10	4,7	214,1	234
	20	9,3	107,5	305
	30	14,0	71,4	397
	40	18,7	53,5	398
SFC	30	14,0	71,4	167
	40	18,7	53,5	196
	50	23,3	42,9	214
	60	28,0	35,7	240
	70	32,7	30,6	286
	80	37,3	26,8	304
	90	42,0	23,8	326
	100	46,7	21,4	363
	110	51,3	19,5	373
	120	56,0	17,9	380
	130	60,7	16,5	400
	140	65,3	15,3	404
SAFC	30	14,0	71,4	160
	40	18,7	53,5	196
	50	23,3	42,9	228
	60	28,0	35,7	252
	70	32,7	30,6	284
	80	37,3	26,8	290
	90	42,0	23,8	298
	100	46,7	21,4	325
	110	51,3	19,5	346
	120	56,0	17,9	369
	130	60,7	16,5	377
	140	65,3	15,3	383
	150	70,0	14,29	400
	160	74,7	13,4	411

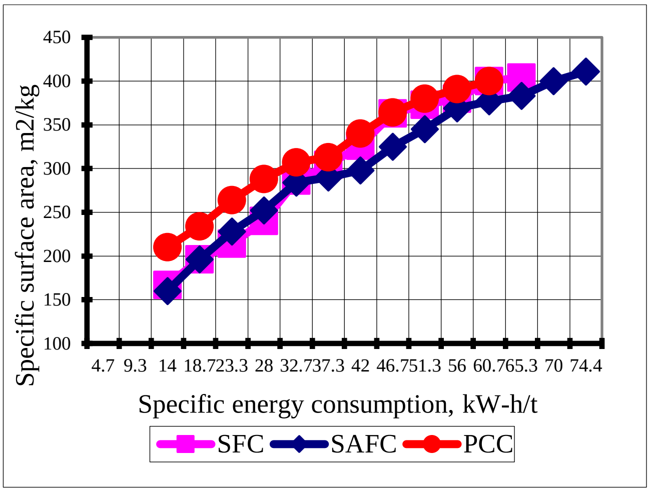

Fig. 2: Characteristic of grindability of the portland cement clinker, sulfoferrite and sulfoalumoferrite clinkers

4. Conclusion

It is seen from the above dependences that the fineness of the grinding of materials is different under identical grinding conditions, and this difference is primarily due to the crystalline structure of the minerals and their hardness.

Most of the time and electricity to achieve a specific surface of 300 m^2/kg and 400 m^2/kg is spent at the grinding of the sulfoaluminoferrite clinker, it is 90 minutes (1.5 hours) and 150 minutes (2.5 hours), respectively.

According to the results of the studies (Table. 3), the deformation characteristics and the construction and technical properties of cements based on aluminous slag and sulfoaluminate clinkers are good, and based on studies of electric energy costs for grinding, it is possible to recommend the use of these additives for the production of expanding cements.

Table 3: Expansion and strength of cements

№	Material	Specific surface area of expansive additives, m^2/kg	Expansion, %	Bending strength, MPa	Compressive strength, MPa
1	PPC+AS +gypsum	420	0,23	7,06	64,82
		306	0,31	7,12	61,40
2	PPC+SAC +gypsum	398	0,25	6,82	66,05
		305	0,30	7,50	62,04
3	PPC+SFC +gypsum	404	0,12	5,16	43,75
		304	0,08	6,86	41,64
4	PPC+SAFC +gypsum	400	0,15	5,39	56,55
		298	0,12	6,91	54,10

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