University of Belgrade
Technical Faculty in Bor and
Mining and Metallurgy Institute Bor

45th International October Conference on Mining and Metallurgy

IOC2013

PROCEEDINGS

Editors:
Nada Štrbac
Dragana Živković
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16 - 19 October 2013
Bor Lake, Bor, Serbia

CEMENT COMPOSITES MODELING USING AMORPHOUS KAOLIN

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Abstract

Cement based composites (concrete and mortar) are widely used in building industry, owing their popularity to huge production rate of cement. Nevertheless, cement production was found to have negative environmental impacts. This is the reason why more and more alternative binders, amorphous kaolin, are investigated and whenever possible implemented, with respect to the energy efficiency. Three series of mortars were made, with and without amorphous kaolin, and investigated both in fresh and in hardened state, as well. Positive impact of substitution of cement amorphous kaolin was detected, especially in fresh state (improvement of consistence).

Key words: *cement, amorphous kaolin, mortar, physical and mechanical properties*

1. INTRODUCTION

The increased production of cement for cement composites (concrete, mortar) contributes to the faster development of building industry, especially concrete structures, and vice versa, the growing industry gradually increases its need for cement and therefore puts more and more pressure on cement production facilities. As a result, cement production facilities develop fast and manage to keep up with the pace. Cement is undoubtedly indispensable raw material in all the branches of building industry: construction of residential, commercial and industrial structures, roads, tunnels and bridges, underground etc. Figure 1 represents the percentages of cement consumption in the construction of different types of structures in 2010.

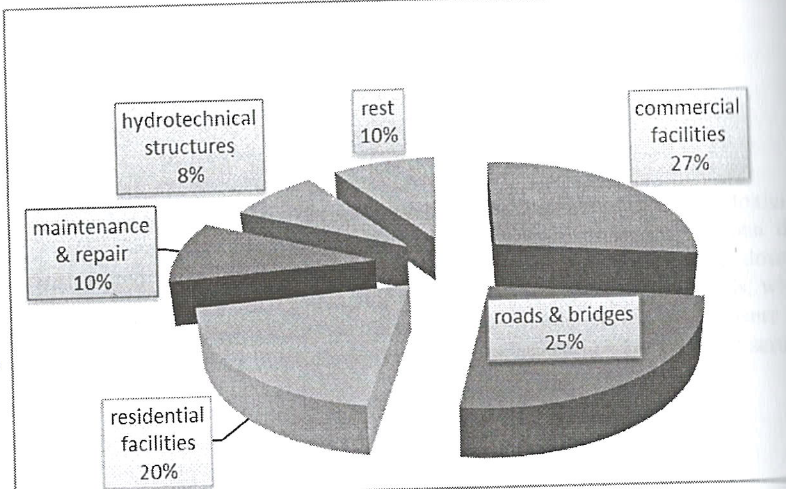

Figure 1 *– Percentages of cement consumption in different types of structures in 2010*

Annual production of cement in the world exceeds 2.7 billion tons and shows a tendency of growth. In the process of cement production, approximately 0.92 tons of CO_2 are produced, for every ton of cement clinker produced. This CO_2 emission is mostly a result of de-carbonation of limestone and the use of carbon based fuels.

In the field of building industry related scientific investigations, possibilities of applications of alternative binders are explored worldwide. These binders can substitute a part of the cement clinker in Portland cement, and thus reduce the energy consumption and emission of harmful gases, which cause the environmental pollution and influence the health of people. These new materials should comply with the requests of sustainable development, and their application should lead to the improvement of cement properties, and also the properties of mortars and concretes in which they are incorporated. Besides the common reactive additions regularly added to cement (slag, pozzolana, fly ash) alternative materials and their chemical reactions are being investigated, leading to the production of this type of materials.

EXPERIMENTAL

The aim of the experiments was:

- to explore the possibility of application of amorphous kaolin as a partial substitution of cement in the production of mortar, and
- to investigate the basic physical and mechanical properties (density, flow, compressive strength, tensile strength - athesion, flexural strength, water absorption and ultrasonic pulse velocity) of mortar.

In the scope of conducted investigation, contribution of amorphous kaolin varied, as a partial substitute for cement in quantities of 10% and 20% of the mass of cement. In other words, the amounts of water, sand and total amount of binder (cement or cement+kaolin) were held constant. Three mortar series were designed and made using laboratory mixer Rilem-CEM. Pure cement (with more then 95% of fine ground cement clinker) designated as CEM I, PC 42.5R „Lafarge" Beočin was used in these investigations. Compositions of these series are presented in the Table 1.

Table 1 – Mortar series compositions

Series	m_c (kg/m^3)	m_{ak} (kg/m^3)	m_v (kg/m^3)	m_a (kg/m^3)	ω
1	450.0	-	232.5	1350	0.517
2	405.0	45.0	232.5	1350	
3	360.0	90.0	232.5	1350	

Symbols used in this table: m_c – mass of cement, m_{ak} – amorphous kaolin, m_v – mass of water, m_a – mass of standard quartz sand i ω – water to powder ratio.

The used amorphous kaolin was produced by mechanical and chemical activation of kaolin based clay from „Garaši", Aranđelovac basin [1-3]. According to ASTM Standard C 618-98 ASTM C618 Specifications for Fly Ash and Raw or Calcined Natural Pozzolan for Use as Mineral Admixture in Portland Cement Concrete. total sum of oxides $SiO_2 + Al_2O_3 + Fe_2O_3$ must exceed 70% with the content of SO_2 of less then 4% and loss on ignition of less then 10%.

In comparison to these criteria, Serbian standard requires that the reactive SiO_2 content exceeds 25 %. Previous investigations showed that the used kaolin contains 33% of reactive SiO_2. Chemical composition of amorphous kaolin was determined with XRF method and shown (in mass percentages) in Table 2.

Table 2 – Chemical composition of amorphous kaolin

Component	SiO_2	Al_2O_3	K_2O	TiO_2	Fe_2O_3	CaO	MgO	Na_2O	Loss in ignition
Participation(%)	64.57	18.36	5.76	1.28	1.11	0.65	0.74	0.5	[illegible]

Pozzolanic activity was determined according to SRPS B.C1.018:2001. Compressive strength of 14 MPa was recorded, which complies with the quality requirements for class P10. Measured gravity of amorphous kaolin was 2.61 g/cm^3, specific area according to BET method: S_{BET}=[illegible] m^2/g.

3. RESULTS

Fresh mortar consistency (using flow-table method) and density testing were conducted according to standards ASTM C230 / C230M and *SRPS EN 1015-6:2008*, respectively. Hardened mortar mechanical properties, strength (compressive– $f_{p,28}$, flexural– $f_{zs,28}$, and tensile strength $f_{z,28}$), and physical properties – water absorption and ultrasonic pulse velocity were conducted on prism shaped 4×4×16cm specimens at 28 days. In order to investigate the further growth of strength, typical for the use of pozzolanic materials, compressive strength data were also collected for the age of 90 days ($f_{p,90}$). The obtained results of experimental investigations are shown in Table 3.

Table 3 – Results of mechanical properties investigations on hardened mortar

Series	Fresh mortar density (kg/m^3)	Flow (mm)	$f_{p,28}$ (MPa)	$f_{p,90}$ (MPa)	$f_{z,28}$ (MPa)	$f_{zs,28}$ (MPa)	Water absorption (%)	Ultrasonic pulse velocity (m/s)
"1"	2.158	110	52.0	67.1	3.3	9.25	8.4	[illegible]
"2"	2.158	120	48.2	60.1	3.2	8.17	8.9	[illegible]
"3"	2.139	125	42.5	57.4	3.0	7.33	9.3	[illegible]

4. CONCLUSION

The main advantage of mortars investigated in this paper lays in their ecological efficiency, in reduction of amount of energy, consumed in the process of production of cement. Also, in contrast to metakaolin (obtained by thermal activation of refined kaolin clays with high content of mineral kaolinite), the investigated amorphous kaolin is obtained by mechanical and chemical activation; a simpler production process, with less negative effects on environment (reduction of total CO_2 emission, needed for production of these kaoline based pozzolana).

Based on presented results, a conclusion can be made that the addition of amorphous kaolin has positive influence on properties of fresh mortar, mostly in terms of placeability and workability of mortar. On the other hand, the specimens made with the addition of amorphous kaolin partial substitution (10% and 20%) of cement showed, to some extend, lower compressive strengths. Namely, the decreased compressive strength of series with kaolin, in comparison to reference series, was 7.3 and 18.3% at 28 days, and 10.4% (with 10% replacement) and 14.5% (with 20% replacement) at the age of 90 days. It is also noticeable that the decrease in strength for the series with higher amount of amorphous kaolin decreases with time, and this trend is expected to extend for higher ages. Therefore, due to pozzolanic properties of amorphous kaolin, the difference in strength between reference and series with 20% of kaolin will decline in time.

For tensile strength, the differences from the reference are even smaller, and amount to 3.0% for series 2, and 9.1% for series 3. In both cases, tensile strengths are substantially higher then 1.5MPa, which is common requirement for constructive mortars.

The values of water absorption and ultrasonic pulse velocity indicate that porosity of series 2 and 3 are slightly higher than the reference, which directly influenced mechanical properties of investigated mortar series.

ACKNOWLEDGEMENT

The work reported in this paper is a part of the investigation within the research project TR 36017 "Utilization of by-products and recycled waste materials in concrete composites in the scope of sustainable construction development in Serbia: investigation and environmental assessment of possible applications", supported by the Ministry of Education, Science and Technological Development, Republic of Serbia. This support is gratefully acknowledged.

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