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Summary of the doctoral dissertation entitled:

„MATERIAL AND TECHNOLOGICAL CONDITIONS FOR THE USE OF GROUND GRANULATED BLAST FURNACE SLAG AS A TYPE II ADDITIVE IN CONCRETE COMPOSITION"

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Concrete, next to steel and wood, is the most commonly used engineering material of modern times. The policy of sustainable development, based on the reduction of the carbon footprint, protection of deposits of non-renewable natural resources and the use of industrial by-products, imposes the search for new solutions aimed at optimizing the content of Portland clinker in the composition of cement and concrete. During the production of 1 ton of Portland clinker, constituting approx. 95% of the CEM I Portland cement composition, approx. 1.7 tonnes of natural resources are used and approx. 780 ÷ 820 kg of CO_2 are emitted into the atmosphere (the amount depends on the technical level of the technological line).

Currently, from an economic and ecological point of view, components other than Portland clinker are more and more often used referred to in the provisions of the PN-EN 197-1: 2012 as main components, and in the concrete standard PN-EN 206 + A1: 2016-12 as additives of type I or II. These components include: siliceous and calcareous fly ash, ground granulated blast furnace slag and limestone. Siliceous fly ash and ground granulated blast furnace slag are the most widely used in industrial applications. Ground granulated blast furnace slag is a by-product of pig iron production in the blast furnace. In Poland, ground granulated blast furnace slag is commonly used as the main component in the production of CEM II/A,B-S Portland slag cement, Portland composite cement in a composition with other main components CEM II/A,B-M, slag cement CEM III/A, B, C, and composite cement CEM V/A,B. However, ground granulated blast furnace slag is not widely used as a type II additive in concrete composition. According to the author, this

situation is caused by the insufficient quantity of tests determining the influence of blast furnace slag on the properties of the concrete mix and hardened concrete, especially on the durability of the concrete composite.

The aim of this dissertation was to determine the material and technological conditions for the use of ground granulated blast furnace slag as a type II additive in the composition of concrete. Considering wider application potentials of the proposed solutions, the possibilities of simultaneous application of ground granulated blast furnace slag (ggbfs) and fly ash (FA) as type II additives in the composition of the ground concrete were also shown.

Doctoral dissertation includes:

1. A literature study describing:
   - types of additives used in the composition of concrete;
   - standard requirements and rules for using additives in the composition of concrete;
   - the properties of concrete mix hardened concrete containing ggbfs.
2. Own research including:
   - determination of ggbfs and FA properties for use as type II additives in concrete composition;
   - the influence of ggbfs properties and CEM I Portland cement on the activity index;
   - impact assessment of the w/s ratio (s = cement + ggbfs) on the development of the activity index:
   - determination of the effect of variable content of blast furnace slag and CEM I Portland cement on the level of the activity index;
   - the influence of the k-factor on the properties of concrete mix and hardened concrete, when using ggbfs as a type II additive in concrete composition;
   - assessment of the simultaneous use of ggbfs and FA as type II additives in the composition of concrete;
   - determination of the influence of the water-cement ratio on the properties of concrete mix and hardened concrete;
   - analysis of the environmental aspects when using ggbfs in concrete composition;
   - specification of material and technological conditions for the use of ground granulated blast furnace slag as an active type II additive in the composition of concrete.

Based on the literature review, it can be concluded that the determination of material and technological conditions for the use of ggbfs as a type II additive in the composition of concrete is not fully known. Research in this regard, especially in the country, is small. The publications that have been published so far have not fully illustrated the influence of ggbfs on the properties of concrete mix and hardened concrete. The commencement of further tests was triggered by the provisions in new editions of the EN 206 standard as well as the ecological and economic aspects related to the use of ggbfs as a type II additive in the composition of concrete.

In order to determine the material and technological conditions of the use of ggbfs as a type II additive in the concrete composition, the impact of factors influencing hydraulic activity ggbfs and the effect of properties and amounts of ggbfs characteristics on the properties of the concrete mix and hardened concrete were determined. The possibility of simultaneous application of ggbfs and FA in the composition of concrete was also assessed, which was used to verify the possible synergy effect of the components on the durability of cement composites. The environmental aspects of using ggbfs in hardened concretes are also presented.

The results of own research proved that the ggbfs, meets the requirements of the PN-EN 15167-1: 2007 standard and is characterized by high stability of physical properties, chemical and phase composition, is also of full value type II additive that can be used in the composition of concrete. The activity of the ggbfs depends on the degree of grinding (mechanical activation), chemical composition and the content of the glass phase.

The analysis of the obtained test results for the domestic ground granulated blast furnace slag showed that the value of the k-factor 0.6 recommended by the PN-EN 206 + A1: 2016-12 standard "Concrete - Requirements, properties, production and compliance" is too low. With a specific surface of the slag of approx. 4000 cm^2/g, the recommended value of the k-factor is 0.8. Moreover, it has been found that the ggbfs can be used along with the FA as a type II additive. In this case, it is recommended to take the value of the k factor at the level of 0.6.

Ground granulated blast furnace slag can be a component of concrete widely used in construction. The properties of the concrete mix and hardened concrete can be shaped by changing the amount of ggbfs in the concrete composition, selecting the appropriate w/s ratio as well as proper aeration (an action necessary in the case of the production of frost-resistant concrete). Reducing the w/s ratio allows the apply concretes containing ground granulated blast furnace slag in all areas of the construction industry, from prefabrication through the production of high-performance concretes, bridge and paving concretes, to massive structures (it is especially recommended to use with fly ash) and traditional ordinary concrete.

The use of ggbfs and FA as the type II additives in the composition of concrete, contributes to the strategy of sustainable development, as it allows the production of useful and durable concretes with low CO_2 emission (concretes with low Portland clinker content) and limitation of the extraction of non-renewable natural mineral resources.