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Determining the reactivity of concrete aggregates for Nuclear Power Plant concrete structures

Wyznaczanie reaktywności alkalicznej kruszywa do betonu przy budowie elektrowni jądrowej

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Abstract. The authors describe the additional requirements to ensure durability of concrete related to probability of corrosion due to alkali-silica reactivity of aggregates based on French Rules for Design and Construction of PWR nuclear civil works RCC-CW. Since these requirements are based both on European standards and the French experience they are not fully compatible with the conditions and requirements in other countries, including Poland. In the paper the RILEM methodology and assessment according to American ASTM standards are presented as well. The article is an introduction to the discussion on adapting to Polish conditions the guidelines for the reactivity assessment of aggregate for concrete resulting from RCC-CW.
Keywords: nuclear power plant, aggregates reactivity, internal corrosion of concrete.

Streszczenie. W artykule przedstawiono dodatkowe wymagania mające na celu zapewnienie trwałości betonu z uwagi na prawdopodobieństwo korozji wynikające z reaktywności alkalicznej kruszywa zgodnie z francuskimi wytycznymi do projektowania elektrowni jądrowej RCC-CW. W związku z tym, że wymagania te bazują zarówno na normach europejskich, jak i doświadczeniu francuskim, to nie są one całkowicie kompatybilne z warunkami i wymaganiami obowiązującymi w innych krajach, w tym w Polsce. W artykule przedstawiono także ocenę reaktywności zgodnie z RILEM oraz wg norm ASTM. Artykuł jest wstępem do dyskusji na temat dostosowania wytycznych dotyczących oceny reaktywności kruszyw do betonu wg RCC-CW do warunków polskich.
Słowa kluczowe: elektrownia jądrowa, reaktywność alkaliczna kruszywa, korozja wewnętrzna betonu.

Concerning durability of the NPP civil engineering concrete structures, according to RCC-CW [16], the main objectives are to:

- prevent internal disorders resulting from Alkali Silica Reaction (ASR) and Delayed Ettringite Formation (DEF);
- reduce and/or prevent cracking of concrete and corrosion of steel reinforcement and
- control creep of concrete.

Alkali-Aggregate Reactions (AAR) may involve siliceous aggregates (alkali-silica reactivity, ASR) or very rare carbonate aggregates (alkali-carbonate reactivity, ACR), and failure to take precautions may result in progressive deterioration of concrete structures. AAR are chemical reactions that occur between certain types of mineral in aggregates and the alkaline (Na+ and K+) and hydroxyl (OH-) ions present in the interstitial solution of cement paste in concrete. These dissolution reactions occur due to the high solubility in very alcaline solutions of certain amorphous, disordered or poorly crystallized forms of silica. This reaction leads to formation of a hygroscopic alkaline gel that absorbs water and expands, causing significant expansion and characteristic cracking of the concrete. The rate of expansion caused by AAR typically has been found to be 20 to 200 x 10^{-6} mm/mm per year [1], depending on the severity of the reaction and the degree of restraint. The expansion becomes detectable in about five to ten years after construction, and the most noticeable expansion may be detected in about 15 to 25 years.

The three prerequisites must be simultaneously fulfilled for AAR expansion to occur: high content of alkali in concrete (usually ≥ 3 kg/m^3), presence of reactive minerals in aggregate and sufficient moisture supply (at least 80%). If any one of these three conditions is not met, expansion due to AAR cannot occur. Other conditions, such as higher temperature, accelerate the speed of reaction. ASR involves a chemical reaction, and for the reaction to occur, the following components must be present: water, reactive silica, and a high concentration of hydroxyl ions – high pH [1]. Likewise, the concentration and distribution of these components and the ambient temperature have a significant influence on the rate and deleterious effect of the reaction. A concrete structure with ASR commonly exhibits widely differing signs of deterioration in different places. Concrete exposed to dry, interior environments without water normally does not develop cracking from ASR and the most vulnerable parts of a concrete structure are those exposed to a warm and humid environment [1].

In the absence of previous long-term experience EN 12620 [14] suggests to take one of the following precautions:

- limit the total alkali content of the concrete mix;
- use a cement with a low effective alkali content;
- use a non-reactive aggregate combination;
- limit the degree of saturation of the concrete with water.

When compliance with one of the above procedures is not possible the combination of aggregates and cement can be assessed using regulations applying at the place of use.

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