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A report on the fabrication of concrete pavement with the application of anionic bitumen emulsion

Michał Bołtryk [a], Krzysztof Falkowski [b], Edyta Pawluczuk [a,*]

[a] Faculty of Civil and Environmental Engineering, Białystok University of Technology, Wiejska 45E, 15-351 Białystok, Poland
[b] MARK-BUD Sp. z o.o. – Contractor Concrete Pavement of the Multimodal Reload Terminal, Białystok, Poland

HIGHLIGHTS

- Beneficial effect of bitumen emulsion on the concrete frost resistance was noticed.
- Bitumen emulsion enhances the concrete waterproofness.
- Anionic emulsion profitably changes the structure of concrete porosity.
- Concrete composition suitable for the most severe exposure classes was selected.
- Laboratory research results were verificated in practice.

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ABSTRACT

The problems of concrete degradation in pavements occur around the world, regardless of climatic zones, which is one of the chief factors in environmental corrosion. This article describes the final stage of Development Project No. 14 009 03 carried out by the Ministry of Science and Higher Education in Poland regarding the verification of laboratory research results with the construction of the Multimodal Reload Terminal within the Duty Free Zone in Małaszewicze, Poland. The Terminal concrete pavement was designed to expand and doweled in accordance with the national requirements and the paving layers was based on existing solutions. Concrete in the slab was modified with an anionic bitumen emulsion to reduce its water absorption and improve resistance to environmental aggression. To achieve the required consistency of the concrete mix superplasticizers were used. The use of bitumen emulsion allowed to achieve the concrete water absorbability to below 4% in comparison to reference concretes while at the same time retaining high F200 frost resistance. The technology of cement composites modified with anionic bitumen emulsion was successfully tested under real operating conditions with the creation of a concrete pavement capable of bearing high mechanical pressure in a corrosive environment.

1. Introduction

Concrete is a widely used composite material in the construction industry; however, due to its heterogeneous and porous structure, there are a number of problems related to maintaining its durability over a standard lifetime [1,2]. This is particularly true of structures exposed to corrosive conditions such as chlorides, cyclical freezing and thawing, corrosive chemicals and abrasion [3–6]. Numerous scientific facilities haves been researching how to improve concrete durability for many years. Many approaches have been applied including: different methods of thickening concrete [7], various curing methods [8], as well as protection of the surface layer [9–13]. Thus far, however, the use of chemical and mineral additives has played the most significant role in modifying the properties of concrete [14–17]. Different mathematical models have been developed to represent the relationship between strength and maturity of concrete. The linear relationship between double logarithmic strength and logarithmic maturity was implemented in practice to monitor the in-place strength gain and time of opening under variable temperature conditions [18].

One of the ways of minimizing the deficiencies of cement composites has been to produce high compression strength concrete: so called high performance concrete (HPC) or ultra-high performance concrete (UHPC). In modern engineering practice, cement composites with compression strengths in excess of 60 MPa are being used ever more frequently [19,20]. Unfortunately, high compressive strength does not always correspond to concrete in engi-

* Corresponding author.
E-mail address: e.pawluczuk@pb.edu.pl (E. Pawluczuk).

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neering structures with other equally outstanding properties. In particular, with an increase in strength it is not always possible to obtain the optimum resistance to a corrosive environment for a reinforced cement composite or adequate stiffness for thin-walled widely spaced engineering structures. The key challenge is to assure that concrete has durability in road surfaces, airport aprons and vehicle manoeuvring areas, which are exposed to significant mechanical loads as well as to corrosive environments. Some researchers analysed behaviour of concrete surrounding dowel bars what is a major problem in jointed plain concrete pavement. In some studies, using the finite-element method, a distribution of stresses around dowel bars was analyzed with special attention to compressive and tensile stresses, which are responsible for cracks initiation and propagation [21]. The cracks in concrete pavements are formed at early-age as consequence of internal stresses in the concrete. According to Pradena and Houben [22] the stress relaxation has an essential influence on the cracking process. The authors proposed a new equation of the relaxation factor, based on a theoretical and practical analysis of the transversal cracking in jointed plain concrete pavements. Can et al. [23] described the most appropriate method of rehabilitation of composite pavements and assessed the effect of various factors on the development of cracks in the composite pavement through survival analysis. Different mathematical models have been developed to represent the relationship between strength and maturity of concrete. The linear relationship between double logarithmic strength and logarithmic maturity was implemented in practice to monitor the in-place strength gain and time of opening under variable temperature conditions [18].

The aim of the study was determining the applicability of anionic bitumen emulsion in cement composites and establishing its effect on the properties of concretes exposed to an aggressive environment. In this article, the authors present research into optimizing the proportion of the ingredients for cement composites resistant to significant mechanical loads and corrosive environments as well as what has been learnt from the use of a cement composite in the construction of a concrete pavement for a 11,076 m^2 manoeuvre yard in Multimodal Reload Terminal within the Duty Free Zone in Małaszewicze near Terespol, Poland.

2. The research

The problems of concrete degradation in pavements occur around the world, regardless of climatic zones, which is one of the chief factors in environmental corrosion. In the example, Fig. 1, cracks in an airport apron can be seen caused by the insufficient stiffness of the concrete as well as the varying mechanical properties of the ground.

The next picture, Fig. 2, shows the loss of the upper layer of concrete after a 20-year usage period on a manoeuvring area on an industrial premises in Poland. The flaking of the concrete pavement is due to insufficient resistance to frost and the use of natural rounded aggregate.

The PN-EN 206:2014 standard [2] classifies levels of environmental corrosion including in regard to concrete pavements:

- XC – corrosion of the reinforcement caused by carbonization at the XC4 hazard level;
- XD – corrosion of the reinforcement caused by non-seawater chlorides at the XD2 hazard level;
- XF – damage caused by alternating freezing/thawing cycles together with de-icing agents at the XF4 hazard level;
- XA – chemical corrosion of concrete at the XA2 hazard level;
- XM – concrete erosion caused by abrasion at the XM1 hazard level.

In practice, the corrosion levels mentioned above occur with concrete structures in all Northern and Middle European countries, and in particular with concrete pavements.

The concrete pavement in the Multimodal Container & Reload Terminal in Terespol was designed to expand and doweled in accordance with the requirements specified by national and foreign regulations [24–26]. The design of the paving layers was based on a solution taken from a German catalogue [25]. The slab and substructure thicknesses were designed to accommodate the existing loads and comprised a concrete slab of 40 cm of at least C30/37 class modified with bitumen emulsion, a 20 cm layer of broken drainage aggregate, and ground stabilized with 15 cm of cement (Fig. 3).

In the underlying soil, some bearing grounds were present in the form of fine sand, and medium-condensed sand (resistant to frost and water). The soil was mixed and thickened with sand in order to obtain the following properties: $Is \geq 1.03$, $EV_1 \geq 60$ MPa, $EV_2 \geq 120$ MPa, $EV_2/EV_1 \leq 2.2$ [27]. Due to varying test results, the soil was stabilized with a 15 cm layer of cement of $f_{cm} = 1.5 \div 2.5$ MPa [28]. The main base course comprised broken aggregate stabilized mechanically. The primary and secondary deformation

Fig. 1. Cracks in an airport apron – Airport Santa Cruze de Tenerife (photo. K. Falkowski).

Fig. 2. The loss of the upper layer of concrete after a 20-year usage period (photo. K. Falkowski).