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The impact of using concrete of various density on the state of stresses in prestressed concrete flyovers over highways

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Abstract

A significant part of flyovers over highways and express roads in Poland is developed as two-span beam and frame structures. Due to the span length and economic conditions their superstructure are most often constructed as prestressed concrete ones. This paper presents the impact of some of the construction defects and imperfections not considered during the design stage on the stress state in the post-tensioned flyovers structures over highways. The results of the analyses concern three structures that were inspected in detail by the authors.

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Keywords: post-tensioned bridges; prestressed concrete; concrete density;

1. Introduction

In many of the existing or currently being under construction prestressed concrete bridge structures in Poland, the designers most often assume the density of concrete equal to 27 kN/m^3 (crushed stone basalt aggregate concrete [1]). However, it is presently more frequent to use in practice granite or granodiorite crushed stone aggregate in concrete to construct bridge structures. Such concrete is characterized by a lower density and lower modulus of elasticity then those made using basalt aggregate.

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According to [2] granite or granodiorite aggregate concrete is characterized by the density within 22.6 ÷ 23.2 kN/m^3. In design documentation (specification) the requirements concerning the control of density of concrete and its modulus of elasticity, are often not specified during the construction stage. This may lead to unintended work defects. While maintaining the design parameters of prestressed concrete structures designed with basalt aggregate concrete but constructed with the use of granite aggregate concrete, above defects may lead to undesired damages, for instance concrete cracks of unacceptable width.

The paper presents the results of the analyses concerning the impact of density of concrete on the state of normal stresses in the girders and a possibility of crack appearance in them inconsistent with the design assumptions. The analyses were carried out using the example of typical flyovers over highways [3,4], denoted below as WD-23, WD-14 and WD-28.

2. The description of construction solutions of the analyzed objects

The paper presents the results of the analysis of three two-span flyovers of girder type. The cross section of their superstructure constitute two monolithic trapezoid beams (main girders) joined with the deck slab. The beams are braced with cross beams over pillars and in some cases in spans. Exemplary geometric data of one of the structures is shown in Figures 1 and 2.

The superstructures were designed using prestressed (post-tensioned) concrete [1,5,6,7]. The following actions were taken into account: dead (self-weight) load, superimposed dead load, impact of prestressing, thermal effects, loads from unequal pier settlement and traffic (live) loads for load class B according to [1,7]. Basic parameters of the analyzed structures are presented in Table 1.

Table 1. Technical parameters of flyovers structure.

Specification / Flyover symbol	WD-23 [3]	WD-14 [3]	WD-28 [4]
Theoretical span l_t [m]	36.00+34.00	30.00+30.00	34.00+34.00
Overall width [m]	13.20	10.50	12.10
Sweep angle [°]	60.00	90.00	59.00
Construction height h_k [m]	1.76	1.46	1.67
Depth/span ratio h_k/l_t	1/20.42	1/20.62	1/20.36
Concrete class [10]	B45	B50	B50
Volume of concrete in structure [m^3]	715	426	565
Weight of reinforcing steel [kg]	94267	66770	84144
Prestressing steel	Y1860	Y1860	Y1860
Type of prestressing cables	22 L15.5	19 L15.7	19 L15.7
Number of cables [pieces]	2 x 7	2 x 6	2 x 6
Weight of prestressing steel [kg]	23950	16395	18480
Tensile strength of a single cable P_0 [kN]	4200.0	3684.2	4134.,8
The use of bearing capacity, σ_0/R_{vk} [%]	68.4	69.5	78.0
Load class [8]	B	B	B

Legend: * - non-usable width, i.e. barrier or balustrade fixing, distance between the barrier rail and the edge of the road

The superstructures of flyovers were designed using concrete B45 (~C35/45) or B50 (~C40/50), reinforcing steel A-IIIN (BSt500S) [5,8,9,10] and prestressing steel of the class Y1860 [5,11].

The prestressing system was composed by the prestressing tendons, system of anchorages, steel corrugated tendons sleeves and air vent injection pipes. Before concreting the superstructure, a precambering was introduced, reinforcement and prestressed elements were placed as well as filters and the elements of drainage system were installed [6,12]. The girders were supported on pot bearings, fixed bearings were placed on the intermediate pier.