ABSTRACT

Key-words: fibre reinforced polymers; FRP bars; FRP reinforced concrete members; fire resistance of FRP-RC beams; basalt FRP (BFRP); hybrid FRP (HFRP).

The main factors determining the choice of Fibre-Reinforced Polymer (FRP) bars are the expected environmental conditions and design assumptions. The fire resistance of FRP-based composites is currently one of the key research issues, arising from the need to ensure that these materials maintain their structural properties during elevated temperatures. Degradation of the matrix leads to a weakening of the interaction between fibres and consequently to a deterioration of the mechanical properties of FRP bars, such as flexural, tension, or shear strength. Therefore, the use of FRP reinforcement in load-bearing elements of concrete structures is currently limited to facilities where there is no fire hazard.

The thesis presents the results of original research that contribute to expanding the knowledge on hybrid-FRP (HFRP) bars and progress in their application. The "hybridization" process involved substituting some basalt fibres with carbon fibres to improve the physical and mechanical properties of the HFRP bars composed of them. The optimization of the choice of fibres was made considering two basic parameters:

(1) stiffness (carbon fibres have a five times higher modulus of elasticity than basalt fibres);
(2) cost of fibres (carbon fibres are currently several times more expensive than basalt fibres).

Hybridization allows for the production of a material with higher strength and stiffness compared to Basalt-FRP (BFRP) bars while being more cost-effective than Carbon-FRP (CFRP) bars. Additionally, carbon fibres are more resistant to high temperatures in oxygen-free environment, making HFRP bars potentially superior in terms of fire resistance compared to BFRP reinforcement.

In the first stage of the research, the optimization of the composition of HFRP bars was carried out. The optimization process involved the design of bars, considering parameters such as volume fractions and fibre location. To validate the theoretical optimization, HFRP bars were produced and subjected to extensive testing, including tensile, compressive, and shear strength tests. The results confirmed the optimization results and showed a significant improvement in the properties of HFRP bars compared to BFRP bars.

In the second part of the investigation, a comprehensive assessment of the fire resistance of concrete flexural members reinforced with innovative HFRP bars was conducted. Full-scale

beams were designed and constructed for the tests, which were conducted in two phases. In the first phase (initial), a limited number of elements with different BFRP and HFRP reinforcement were tested. In the second phase (main), tests were performed on an increased number of beams to confirm the repeatability of the research results. Two methods were used in the tests: the standard method and the residual method. The standard method involved simultaneous exposure of the tested beams to fire conditions and load. In contrast, in the residual method, unloaded beams were first exposed to fire, and then after cooling, a test was carried out to determine their residual capacity. This method aimed to provide a more realistic assessment of the capacity of beams in post-fire conditions.

In summary, the optimization of the composition of HFRP bars aimed to increase the stiffness of the reinforcement compared to traditional BFRP bars, resulting in a material with higher strength parameters, as confirmed by experimental tests on tensile, compressive, and shear strength. During fire resistance tests conducted on bending elements, it was observed that beams reinforced with HFRP bars had approximately twice as small deflections compared to those reinforced with BFRP bars, both in standard and residual tests. Moreover, in the main phase, most of HFRP-RC samples did not fail within the designated time and were subjected to a residual capacity test, unlike BFRP-reinforced beams, which lost their capacity due to the effect of high temperature. The conclusion from the results of the fire resistance tests indicates the potential possibility of using newly developed HFRP bars in load-bearing elements that may be exposed to elevated temperatures.