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# Investigation on Pull-Out-Behavior and Interface Critical Parameters of Polymeric Fibers Embedded in Concrete and Their Correlation with Particular Fiber Characteristics

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**Abstract :** Fiber reinforcement is a state of the art to enhance mechanical properties in plastics. For concrete and civil engineering, steel reinforcements are commonly used. Steel reinforcements show disadvantages in their chemical resistance and weight, whereas polymer fibers' major problems are in fiber-matrix adhesion and mechanical properties. In spite of these facts, longevity and easy handling, as well as chemical resistance motivate researches to develop a polymeric material for fiber reinforced concrete. Adhesion and interfacial mechanism in fiber-polymer-composites are already studied thoroughly. For polymer fibers used as concrete reinforcement, the bonding behavior still requires a deeper investigation. Therefore, several differing polymers (e.g., polypropylene (PP), polyamide 6 (PA6) and polyetheretherketone (PEEK)) were spun into fibers via single screw extrusion and monoaxial stretching. Fibers then were embedded in a concrete matrix, and Single-Fiber-Pull-Out-Tests (SFPT) were conducted to investigate bonding characteristics and microstructural interface of the composite. Differences in maximum pull-out-force, displacement and slope of the linear part of force vs displacement-function, which depicts the adhesion strength and the ductility of the interfacial bond were studied. In SFPT fiber, debonding is an inhomogeneous process, where the combination of interfacial bonding and friction mechanisms add up to a resulting value. Therefore, correlations between polymeric properties and pull-out-mechanisms have to be emphasized. To investigate these correlations, all fibers were introduced to a series of analysis such as differential scanning calorimetry (DSC), contact angle measurement, surface roughness and hardness analysis, tensile testing and scanning electron microscope (SEM). Of each polymer, smooth and abraded fibers were tested, first to simulate the abrasion and damage caused by a concrete mixing process and secondly to estimate the influence of mechanical anchoring of rough surfaces. In general, abraded fibers showed a significant increase in maximum pull-out-force due to better mechanical anchoring. Friction processes therefore play a major role to increase the maximum pull-out-force. The polymer hardness affects the tribological behavior and polymers with high hardness lead to lower surface roughness verified by SEM and surface roughness measurements. This concludes into a decreased maximum pull-out-force for hard polymers. High surface energy polymers show better interfacial bonding strength in general, which coincides with the conducted SFPT investigation. Polymers such as PEEK or PA6 show higher bonding strength in smooth and roughened fibers, revealed through high pull-out-force and concrete particles bonded on the fiber surface pictured via SEM analysis. The surface energy divides into dispersive and polar part, at which the slope is correlating with the polar part. Only polar polymers increase their SFPT-function slope due to better wetting abilities when showing a higher bonding area through rough surfaces. Hence, the maximum force and the bonding strength of an embedded fiber is a function of polarity, hardness, and consequently surface roughness. Other properties such as crystallinity or tensile strength do not affect bonding behavior. Through the conducted analysis, it is now feasible to understand and resolve different effects in pull-out-behavior step-by-step based on the polymer properties itself. This investigation developed a roadmap on how to engineer high adhering polymeric materials for fiber reinforcement of concrete.

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