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METHOD FOR PREDICTING CRACK PROPAGATION IN CONCRETE AND REINFORCED
CONCRETE ELEMENTS

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Relevance of the research. Damage and progressive deterioration of concrete and reinforced concrete structures due to crack initiation and propagation remain among the primary causes of reduced serviceability and catastrophic failure in civil infrastructure. Recent intensification of dynamic loads, environmental aggression and aging of constructions increase the likelihood of crack growth and subsequent loss of load-bearing capacity. Development of predictive methods for crack propagation is therefore essential for reliable assessment of residual life, planning of repair or strengthening works and ensuring safety of buildings and engineering structures [1-3].

The purpose of the work is to develop, substantiate, and validate a comprehensive and engineering-oriented method for predicting crack propagation in concrete and reinforced concrete elements subjected to operational, cyclic, and high-intensity dynamic loadings [4]. The research aims to create a unified predictive framework that identifies crack initiation thresholds, forecasts the trajectory and rate of crack growth, and quantifies crack criticality under varying mechanical and environmental conditions. The method is designed to integrate the mechanics of quasi-brittle fracture, nonlinear behavior of concrete and reinforcement, tension softening, damage accumulation, and bond-slip effects, ensuring adequate representation of the structural response prior to and during crack evolution.

Methodology and organization of the research. In this context, the identified nonuniform and structurally conditioned stress distribution was termed the Physically Verisimilar Stress (PVS) state. This concept serves as the theoretical foundation for the proposed PVS model, which describes the mechanical response of quasi-brittle materials such as concrete under conditions of progressive damage. The model is governed by three fundamental material parameters: the maximum attainable stress; the intrinsic structural length scale “a”, reflecting the characteristic size of the microstructural heterogeneities that influence crack initiation and localization; and the dimensionless coefficient “n”, which represents the degree of material ductility and the extent of the plastic zone preceding crack formation.

The results of the research. The research resulted in the development and validation of a comprehensive predictive method capable of accurately modeling crack initiation and propagation in concrete and reinforced concrete elements [4]. Numerical simulations incorporating the formulated damage-plasticity and cohesive fracture models demonstrated stable and mesh-independent predictions of crack trajectories under monotonic, cyclic, and dynamic loading regimes. The integration of Extended Finite Element Method crack tracing allowed the model to reproduce discontinuity evolution independently of element topology, ensuring consistency of predicted crack paths with experimentally observed behavior. The implementation of the PVS concept significantly improved the representation of stress redistribution in the fracture process zone. The experimentally determined PVS parameters – maximum stress, intrinsic microstructural length scale “a”, and ductility coefficient “n” – enabled the model to capture the transition from diffuse microcracking to localized macrocrack formation with high fidelity.

Conclusion. A method integrating fracture mechanics principles, advanced constitutive modelling and numerical techniques (Extended Finite Element Method / cohesive elements) was developed and validated for predicting crack propagation in concrete and reinforced concrete

elements. The method provides reliable forecasts for crack initiation and growth under a variety of loading conditions and can be used for structural assessment, planning of repair works and life-cycle management of concrete structures. Further work is recommended to expand the experimental database for different concrete classes and to integrate stochastic variability of material properties into probabilistic life predictions.

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STRENGTH INVESTIGATION OF ADGESIVE JOINTS BETWEEN CONCRETE AND STEEL

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Relevance of the research. The performance and reliability of composite concrete-steel structures are largely determined by the quality of adhesive joints between the materials. Failures in these joints can lead to localized cracking, detachment, or even catastrophic collapse, especially under dynamic or cyclic loads such as seismic events, wind, or repeated traffic vibrations. Modern engineering increasingly relies on composite structures for rehabilitation, retrofitting, and the construction of lightweight yet durable systems. Furthermore, the use of adhesives allows for more efficient load transfer, reduces stress concentrations, and enables innovative designs that traditional mechanical fastening cannot provide. Despite their advantages, the long-term behavior of adhesive joints under combined mechanical and environmental loads remains poorly understood. Therefore, the study of concrete-steel adhesive bonds is highly relevant for improving structural safety, optimizing material usage, and extending the service life of constructions [1-4].

The purpose of the work. The main objective of this research is to investigate the mechanical behavior, strength, and failure mechanisms of adhesive joints between concrete and steel. The study focuses on identifying the key factors that influence bond performance, including adhesive type, curing time, surface preparation, and joint geometry, and analyzing how these factors affect the response of the joints under tensile, shear, and combined loading conditions. The research also aims to establish correlations between experimental observations and predictive models for bond strength, providing practical guidance for structural engineers on the design and application of adhesive joints in concrete-steel composite systems. Ultimately, the work seeks to contribute to safer, more efficient, and durable solutions in modern civil engineering projects, enhancing the serviceability and longevity of structures [1, 2].