



Article

Punching Shear Behavior of Reinforced Concrete Slabs with Sustainable Cementitious Blends and Discrete Steel Fibers

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Abstract

Punching shear failure in reinforced concrete RC slabs is one of the most significant and detrimental failure modes due to its sudden nature and its dependence on a complex interaction between concrete strength, the reinforcement, and the loading conditions. In recent years, there has been increasing interest in utilizing sustainable cementitious materials and steel fibers as a way of enhancing structural performance and improving the durability of concrete. The study aims to assess the structural behavior of RC slabs utilizing a partial cement substitution with limestone powder (LP) and granulated blast-furnace slag (GBFS), with the addition of steel fibers. Twelve RC slabs were examined under uniform concentric loading to analyze cracking behavior, load–deflection relationship, stiffness variation, and ultimate punching shear strength. The results demonstrated that using limestone powder (LP) had a significant impact on the crack distribution pattern and resulted in a slight reduction in initial stiffness, with the load-bearing capacity decreasing to approximately 55.8% of the control mixture at high replacement ratios. Due to a slower hydraulic reaction than with other mixtures, increasing additional granulated blast-furnace slag resulted in a decrease in crack resistance and relative deformation. With a load-bearing capacity of approximately 92.9% of the control mixture, a tertiary mixture of limestone powder and granulated blast-furnace slag (GBFS) demonstrated a better balance in structural behavior, leading to improved crack control while maintaining a sufficient level of load-bearing capacity. The steel fibers also significantly contributed to enhanced post-cracking behavior by decreasing crack width and improving the stress redistribution mechanism within the RC slab. This led to increased punching shear resistance and enhanced energy absorption, with the ultimate load increased to 119 kN compared to the control mixture. Overall, the findings show that combining sustainable cementitious materials with steel fibers can effectively improve punching shear performance and enhance the efficiency and durability of reinforced concrete.

Keywords: punching shear; RC slabs; limestone powder; steel fiber; granulated blast-furnace slag



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1. Introduction

Incorporating focus on long-term viability into architecture is fundamental to a more sustainable environment and healthier [1]. The numerous ways sustainability principles may be incorporated into engineering practice lie in the selection of materials. Conventional