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Shear capacity evaluation of steel reinforced recycled concrete (RRC) beams

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ABSTRACT

The applicability of some major concrete design standards and other pertinent methods to calculate the concrete contribution to the shear resistance of reinforced recycled concrete (RRC) beams without stirrups is investigated. Results of a relatively comprehensive experimental program are used to compare the actual shear strength of the tested beams with their corresponding predicted values. The concrete mixes for the RRC beams were proportioned by the so-called Equivalent Mortar Volume (EMV) method. The method is predicated on the fact that recycled concrete aggregate (RCA) is a composite material, comprising mortar and natural aggregate, and the volumetric content and properties of each phase must be quantitatively accounted for when proportioning concrete mixes containing RCA. The test variables included in the test program are shear-span/depth ratio, beam size, RCA source, and coarse aggregate type. The results show that the shear capacity of a RRC beam is comparable, or sometimes superior, to that of a companion beam made of conventional concrete. The analyses performed in the current investigation show, contrary to previous findings, that existing shear design methods, such as the ACI and CSA codes methods, are applicable to RRC beams, provided the EMV method of mix design is used.

1. Introduction

Researchers in the past have reported that RCA-concrete, i.e. concrete containing recycled concrete aggregate (RCA), has some inherently inferior mechanical and physical properties compared to natural aggregate concrete (NAC), i.e. concrete containing only natural aggregate [1,2]. Following an extensive investigation, the writers hypothesized that the reason for the inferiorities reported by others is the application of conventional concrete mixture proportioning methods to RCA-concrete. To verify the preceding hypothesis, they proposed, and experimentally verified, a new mix design method. The new method was dubbed the "equivalent mortar volume" (EMV) method, which can be applied to proportion all concrete mixtures, with or without RCA. The method and its verification by extensive experimental data are presented by Fathifazl et al. [3]. The investigated properties include slump, fresh and hardened density, compressive strength, elastic modulus, and compressive stress–strain relationship. In addition, the freeze-thaw, carbonation and chloride penetration resistances of RCA-concrete designed by the EMV method were investigated and reported elsewhere [4]. Finally, large size beams were tested to study both the flexural and shear behavior of RCA-concrete members designed by the EMV method. In all cases, the RCA-concrete members were found to show equal or superior performance when compared with the companion NAC members when the RCA-concrete was designed by the EMV method [5–7]. On the contrary, when the RCA-concrete mixes were proportioned by the conventional method, the resulting concrete was in many cases of lower quality.

Since the application of conventional mix proportioning methods to RCA-concrete mixes generally results in lower quality concrete, members made of such concrete also exhibit lower flexural and shear strength compared to similar conventional concrete members [8–11]. Consequently, some investigators have reported that structural members made from RCA-concrete have lower diagonal cracking and ultimate shear strength values [9–11], as well as a smoother crack interface, less effective aggregate interlock mechanism and less ductile shear behavior [9]. This has led to the conclusion that the existing empirical equations for calculating the concrete contribution to the shear resistance of conventional reinforced concrete members do not apply to RCA-concrete members,

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