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Aggregate interlock in lightweight concrete continuous deep beams

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ABSTRACT

There are very few, if any, available experimental investigations on aggregate interlock capacity along diagonal cracks in lightweight concrete deep beams. As a result, the shear design provisions including the modification factor of ACI 318-08 and EC 2 for lightweight concrete continuous deep beams are generally developed and validated using normal weight simple deep beam specimens. This paper presents the testing of 12 continuous beams made of all-lightweight, sand-lightweight and normal weight concrete having maximum aggregate sizes of 4, 8, 13 and 19 mm. The load capacities of beams tested are compared with the predictions of strut-and-tie models recommended in ACI 318-08 and EC 2 provisions including the modification factor for lightweight concrete. The beam load capacity increased with the increase of maximum aggregate size, though the aggregate interlock contribution to the load capacity of lightweight concrete deep beams was less than that of normal weight concrete deep beams. It was also shown that the lightweight concrete modification factor in EC 2 is generally unconservative, while that in ACI 318-08 is conservative for all-lightweight concrete but turns to be unconservative for sand-lightweight concrete with a maximum aggregate size above 13 mm. The conservatism of the strut-and-tie models specified in ACI 318-08 and EC 2 decreased with the decrease of maximum aggregate size, and was less in lightweight concrete deep beams than in normal weight concrete deep beams.

1. Introduction

Shear is transferred in a cracked concrete slender beam without shear reinforcement in different ways including the dowel action of the main longitudinal reinforcement, aggregate interlock and shear in the uncracked concrete compression zone. However, deep beams can also transfer a large amount of applied loads through diagonal struts even after the occurrence of diagonal cracks [1–5]. Taylor [6] concluded that 50% of the applied shear force can be transferred by aggregate interlock in the slender beams tested. Fenwick and Paulay [7] also pointed out that the aggregate interlock contribution to the shear capacity of beams without shear reinforcement would increase with the decrease of shear span-to-depth ratio due to the steeper angle of diagonal cracks. However, very few [8], if any, investigations on aggregate interlock in deep beams are available in the literature, though aggregate interlock can play a significant role in load transfer of concrete struts with diagonal cracks.

The aggregate interlock contribution to the beam shear capacity is significantly dependent on the shape, size and strength of coarse aggregate as well as the concrete compressive strength [8]. The regression analysis carried out by Bažant and Sun [9] revealed that the shear capacity of slender beams without shear reinforcement increases with the increase of the maximum aggregate size. On the other hand, it was observed [10] that the aggregate interlock capacity decreased in beams with a smoother failure surface owing to cracks penetrating through coarse aggregate particles. As a result, the simplified modified compression field theory [11,12] neglects shear stresses transferred by aggregate interlock along cracks in beams having a concrete strength above 70 MPa and lightweight concrete beams. However, there is no apparent evidence for the reduced effect of aggregate interlock on the shear capacity of lightweight concrete beams.

The load capacity of deep beams predicted by strut-and-tie models (STMs) is significantly dependent on the effective strength of concrete struts [13,14]. Most design codes [1,2] propose a modification factor associated with the effective strength of concrete to account for the reduced friction properties of diagonal crack interfaces in lightweight concrete struts. A few comparative investigations [15–17] explored the conservatism of STMs specified in code provisions for normal weight concrete deep beams, yet acceptable conclusions for lightweight concrete deep beams is very rare. In particular, the modification factor of the effective strength of lightweight concrete struts in deep beams is fundamentally based on shear test results of slender beams and material properties such as splitting tensile strength.

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