Basrah Journal for Engineering Sciences
Basrah Journal for Engineering Sciences, Vol. 22, No. 1, (2022), 115-128

Original Article

Journal homepage: www.bjes.edu.iq
ISSN (Online): 23118385, ISSN (Print): 18146120

OPEN ACCESS

Shear Behavior of Two-Layer Beams Made of Normal and Lightweight Concrete Layers

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Received: 13 December 2021; Accepted: 16 January 2022; Published: 24 April 2022

Abstract

This study investigates the shear strength behavior of two-layer reinforced concrete beams consisting of two different types of concrete. One of the layers made of lightweight concrete (LWC) and the other was normal weight concrete (NWC). A total of 16 shear deficient reinforced concrete beams were fabricated and cast with NWC, LWC, and two-layer beam of both material with different configuration. All the beams were tested under four-point loading after 28 days. The variables of the experimental program include the ratio of thickness of the lightweight concrete layer to the overall depth of beam (h_{LW}/h), and concrete compressive strength. Experimental results which include load-deflection response curves along with failure modes for NWC, LWC and two-layer beams. The results showed that all beams failed in a similar mode, due to diagonal tension shear crack. Based on the experimental results it can be also concluded that the shear load is governed by compressive strength of lower layer of the concrete when the shear span to overall depth (a/h) of the beams is 2.75 or more. While for the a/h 2.375 and 2.00 the two-layer beam has a significant reduction in the shear capacity compared to the NWC beams and increasing compared to LWC beam. The ratio of experimental shear stress divided by the root square of concrete compressive strength $\left(vexp/\sqrt{f_c'}\right)$, which demonstrates the diagonally cracked concrete's ability to transfer strain and shear was maintained for all configurations greater than 0.17, which is the minimal value recommended by ACI318-19.

Keywords: Layered beams, Two-layer RC beams, LWAC beams, NWC beams.

http://dx.doi.org/10.33971/bjes.22.1.14

1. Introduction

Concrete has become one of the most widely used materials in the construction industry as a result of the rapid development of massive infrastructure throughout the world in recent decades. An estimated 31 billion tons of concrete have been used around the world which makes concrete one of the biggest consumers of natural resources [1]. Natural aggregates are primarily obtained from rock quarries and gravel pits. The extraction of coarse aggregates from a range of natural resources, on the other hand, has had a significant and perpetual environmental impact [2]. Numerous studies indicate that the United Kingdom and other developed countries consumed two hundred eight million tons of crushed aggregates extracted from the ground. As a result, natural aggregates are scarce in the majority of developed and developing countries worldwide [3]. Lightweight aggregate (LWA) was developed as a partial or complete replacement for natural normal weight aggregates in concrete mixtures as a result of a scarcity of natural aggregates [4]. LWA was developed by researchers and engineers using a variety of technologies and construction waste to address the scarcity of natural aggregates. The LWA is made from a variety of materials, including clay, shale, and palm oil, which results in concrete that is more porous and lighter in weight [5]. Because of the reduction in dead loads associated with structural design and foundations, a reduction in horizontal inertia actions associated with buildings in earthquake-prone areas is possible. Lightweight concrete (LWC) exhibits higher brittleness and lower stiffness when compared to normal weight concrete (NWC) [2], [6].

The lightweight aggregate is a popular alternative that alleviates the impacts of using typical coarse aggregates [7-10]. A popular alternative to using normal coarse aggregates is the lightweight aggregate, which is made artificially from a variety of sources. Low density, freeze-thaw resistance, thermal conductivity, smaller seismic demand, fire resistance, and a high strength-to-weight ratio make lightweight concrete (LWC) a viable alternative to conventional normal weight concrete (NWC) in the construction industry. Other advantages include lower cost, smaller cross-sections, and a higher strength-to-weight ratio. As a result, the use of LWC has increased significantly over conventional NWC due to the advantages and performance of structural members (such as beams, slabs, columns, walls, etc.). For this reason, the LWC has a wide range of properties and structural properties depending on the type of lightweight coarse aggregates that are incorporated into the concrete mix. [11-14].

LWC's mechanical properties, durability, and bond strength have been the subject of numerous studies previously. Yasar et al. [15] exploited basaltic volcanic pumice lightweight aggregate as a normal weight aggregate substitute, using 20 % fly ash as a cementitious replacement. Based on the results of the experiments, the researchers conclude that volcanic pumice aggregate can be utilized in structural applications. Korol and Sivakumaran [16] investigated the energy consumption of LWC slabs under extreme loading, the