Construction and Building Materials 174 (2018) 81–95

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Shear behavior of reinforced glazed hollow bead insulation concrete beams

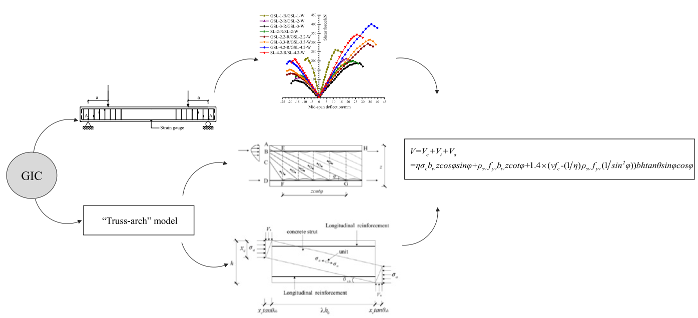
Yu Zhang [a], Gang Ma [b,*], Zhanfeng Wang [a], Zheng Niu [a], Yuanzhen Liu [a], Zhu Li [a]

[a] College of Architecture and Civil Engineering, Taiyuan University of Technology, Taiyuan, PR China
[b] College of Mechanics, Taiyuan University of Technology, Taiyuan, PR China

HIGHLIGHTS

- The effect of shear span ratio and reinforcement ratio on GIC beams is obvious.
- The stiffness of the GIC beams was always smaller than that of the normal concrete.
- The "truss-arch" model can be used in calculating the shear strength of GIC beams.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 3 November 2017
Received in revised form 29 March 2018
Accepted 9 April 2018

Keywords:
Glazed hollow bead
Lightweight concrete
Shear strength
"Truss-arch" model

ABSTRACT

The application of glazed hollow bead insulation concrete can improve the seismic performance of the structure, simultaneously ensuring characteristics such as structural durability, fire resistance, thermal insulation, antifreezing, and impermeability. However, with change in material's physical and mechanical properties, the shear resistance of vitrified microbead thermal insulation concrete members should be paid attention to. The literature search reveals only a few studies on the shear resistance of glazed hollow bead insulation concrete members. In this study, 14 glazed hollow bead insulation concrete beams and four ordinary concrete beams with C35 strength grade were tested. The mechanical failure process, failure form, failure mechanism, and the difference between vitrified microbead insulated concrete beam and ordinary concrete beam were compared. The effects of shear span ratio, hoop ratio and reinforcement ratio on the cracking load, ultimate load and failure mode were investigated. Combined with the "truss-arch" model, the shear bearing capacity of steel bar and concrete is described, and after considering the softening coefficient of glass microbead insulation concrete, based on the "truss-arch" model, a formula for calculating the shear capacity of inclined section of vitrified microbead insulated concrete beam was obtained. The results show that the shear failure test results of glazed hollow bead insulation concrete beams are similar to those of ordinary concrete beams; the shear bearing capacity of vitrified microbeads thermal insulation concrete beams is ~13% higher than that of ordinary concrete beams under the same conditions, and stiffness degradation is slow in the later stage. After the constitutive relation and softening coefficient are modified, the "truss-arch" calculation model can be used to calculate the shear capacity of vitrified microbead insulated concrete beams, and the results are in good agreement with the experimental results. The study of the shear behavior of glazed hollow bead insulation concrete beams can provide data and technical basis for engineering application and has important theoretical

* Corresponding author at: College of Mechanics, Taiyuan University of Technology, Taiyuan 030024, PR China.
E-mail addresses: zhangyu03@tyut.edu.cn (Y. Zhang), magang@tyut.edu.cn (G. Ma).

https://doi.org/10.1016/j.conbuildmat.2018.04.090

List of notation

GIC	glazed hollow bead insulation concrete
NC	normal concrete
LAC	lightweight aggregate concrete
P_{cr}	test value of load at cracking
λ	shear span ratio
h_0	effective depth of cross section
η	coefficient for the truss model
φ	angle of inclination of the concrete strut
a	distance between applied shear force and support
b_w	width of the concrete section
z	depth of the section
V_c	shear contribution of the diagonal compressive strut (of concrete) in the truss model
A_s	area of the compressive region of the compressive strut
A_{sv}	area of shear reinforcement
s	spacing of shear reinforcement
c	cover depth of concrete
σ_c	compressive stress in the compressive strut
φ	angle of inclination of concrete stress
V_a	shear force of the arch model
V_c	shear contribution of the diagonal compressive strut
V_t	shear capacity provided by stirrups in truss model
θ_{sh}	angle of inclination of the concrete oblique member in the arch model
σ_a	compressive stress in the concrete diagonal compression member in the arch model
σ_c	compressive stress in the compressive strut
f_c	maximum compressive stress
ν	softening coefficient of concrete
V_a	shear force of the arch model
θ	angle of inclination of the inclined concrete member
α	effective coefficient of the arch mechanism

significance and practical value to further understand the characteristics of this type of concrete structure, guiding engineering design, and promoting engineering application.

1. Introduction

With the growing economy and social needs, engineering structures often contain unprecedented size, height, and span. Requirements for seismic capacity and durability have pushed concrete towards becoming a multi-function material. One of the functional requirements of concrete has to meet is to be lightweight. Lightweight aggregate concrete (LAC) is prepared by using artificial lightweight aggregate, natural aggregate, cementing material, mineral admixture, and water. Its apparent density is not >1950 kg/m^3. LAC can significantly reduce the structural weight, foundation load, and basic engineering quantity. It can reduce seismic loads, obtain remarkable economic benefit, and guarantee improved structural performance in terms of durability, refractory, thermal insulation, frost resistance, and permeability.

Therefore, researchers have performed tests and theoretical analyses on the shear capacity of LAC containing different types of lightweight aggregate. Two approaches are generally considered in the calculation and design of shear force of an oblique section in an LAC beam. The first approach considers that compared to normal concrete, concrete area is discounted in the shear calculation of LAC, and a semi-empirical formula is derived for shear calculation. Mo et al. [1] carried out the shear performance tests of nine simple supported sand lightweight aggregate concrete beams with different shear span ratios and reinforcement ratios of longitudinal reinforcement with a strength of 37.0 MPa. The shear span ratio is 1.5, 2.3, and 4.0, and the reinforcement ratio of longitudinal reinforcement is 1.2%, 1.8%, and 3.2%, respectively, and four full lightweight aggregate concrete beams with a strength of 28.0 MPa were tested. The experimental results show that the bearing capacity of two types of lightweight aggregate concrete beams are obviously lower than those calculated by the code after the strength reduction, especially the bearing capacity of full lightweight aggregate concrete is lower; therefore, it is suggested to increase the strength reduction coefficient of concrete. In addition, the shear capacity of lightweight aggregate concrete beams is obviously lower than that of ordinary concrete beams of the same grade. Hanson et al. [2] tested the shear resistance of oblique sections of 57 lightweight concrete beams with different types of lightweight aggregates under concentrated loads. The experimental results show that the oblique section bearing capacity of lightweight aggregate concrete beams has a good correlation with the splitting tensile strength of concrete. Because the splitting tensile strength is related to the type of lightweight aggregate, the shear bearing capacity of lightweight aggregate concrete beam is closely related to the type of aggregate. In addition, he also proposed a formula for calculating the shear capacity based on the split strength. Ivey et al. [3] determined the shear test of 26 lightweight aggregate concrete beams without web tendons. The analysis of the test data revealed that the shear capacity of lightweight aggregate concrete beams without web tendons is mainly affected by the splitting tensile strength, shear span ratio, and reinforcement ratio of longitudinal reinforcement. To some extent, the rationality of Hanson formula is proved. Clarke et al. [4] evaluated the design of lightweight aggregate concrete beams by using the shear test data of the Eurocode 2 reduction 80% and found that the standard results were conservative. Ivey et al. determined the shear test of 26 lightweight aggregate concrete beams without web reinforcement. The analysis of the test data revealed that the shear capacity of lightweight aggregate concrete beams without web tendons is mainly affected by the splitting tensile strength, shear span ratio and reinforcement ratio of longitudinal bars. Ahmad et al. [5] compared and analyzed the load deflection of 15 ordinary concrete beams and lightweight aggregate concrete beams by means of rigid loading equipment, and the experimental results showed that no matter whether lightweight aggregate concrete beams have stirrups or not, the ductility coefficient decreases with increasing concrete strength, and the effect of stirrups improves the peak load of concrete. With increasing hoop ratio, the slope of the decreasing section of load deflection curve decreases, and with the increasing stirrups, the restraint effect of stirrups became better. The shear properties of 16 high strength slate lightweight aggregate concrete