Construction and Building Materials 169 (2018) 859–876

Contents lists available at ScienceDirect

Construction and Building Materials

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

Flexural response of basalt textile reinforced concrete with pre-tension and short fibers under low-velocity impact loads

Sai Liu [a], Deju Zhu [a,*], Gaosheng Li [a], Yiming Yao [b], Yunfu Ou [c], Caijun Shi [a], Yunxing Du [a]

[a] Key Laboratory for Green & Advanced Civil Engineering Materials and Application Technology of Hunan Province, College of Civil Engineering, Hunan University, Changsha 410082, China
[b] Key Laboratory of Concrete and Prestressed Concrete Structures of Ministry of Education, School of Civil Engineering, Southeast University, Nanjing 210096, China
[c] IMDEA Materials, C/ Eric Kandel, 2, Tecnogetafe, 28906 Getafe, Madrid, Spain

HIGHLIGHTS

- The flexural strength and toughness of BTRC increased with increasing impact velocity.
- Pre-tension led to an increase in flexural strength and bond properties.
- The failure patterns of BTRC depended on the short fiber type and impact velocities.
- The shape parameter values were related to the impact velocities and short fiber type.

ARTICLE INFO

Article history:
Received 21 September 2017
Received in revised form 4 February 2018
Accepted 21 February 2018

Keywords:
Three-point bending
BTRC
Short fibers
Rate sensitivity
Pre-tension
Flexural impact response

ABSTRACT

The flexural properties of basalt textile reinforced concrete (BTRC) specimens with pre-tension, short carbon, steel, and AR-glass fibers were investigated through three-point bending in a utilizing drop-weight impact setup. The flexural impact parameters, such as flexural strength, flexural modulus, ultimate strain, maximum strain, and energy absorption capacity, were determined under different impact velocities. The flexural strength and toughness of the BTRC specimens without pre-tension significantly increased when the impact velocity (1.0–3.0 m/s) and layers of basalt textiles were increased. By contrast, the flexural modulus initially increased and subsequently decreased with increasing impact velocity, whereas the loading rate exerted a marginal influence on the ultimate strain and the maximum strain. When the basalt textile had four reinforcement layers, the BTRC reinforced with 0.5 vol% of short carbon fiber or short steel fiber exhibited varied different flexural responses under different impact velocities (1.0–4.0 m/s); in particular, the BTRC reinforced with short steel fibers had a higher maximum strain. In addition, pre-tensioned BTRC with different short fibers were tested under an impact velocity of 1.0 m/s. The flexural strength decreased as the short carbon fiber and glass fiber contents increased. The highest flexural strength was observed in the pretensioned specimen with 0.5 vol% of short glass fiber and three layers of basalt textile. The addition of short fibers in cement matrix, the number of textile layer used as reinforcement, the pretension on textile, and the impact velocities used in the tests can significantly affect the flexural impact behavior of BTRC specimens. The Weibull parameters were analyzed to quantify the degree of variability in the flexural strength.

1. Introduction

In cement-based systems, textile reinforced concrete (TRC) is a new class of cement composite that contains bidirectional continuous fibers distributed within the cement matrix. Unlike with short fibers, textiles, when used as reinforcement materials in the cement matrix, can freely arrange fibers in accordance the specifications. The most prominent benefits of TRC include enhanced strength, ductility, and energy absorption capacities, which were due to multiple cracking mechanisms and which result in a strain hardening behavior under different loading conditions [1]. Most fibers for textiles application are in the form of multifilament bundles. The use of multifilament reinforcement for cement matrix has numerous advantages [2]. Basalt textile is a commonly used reinforcement in cement-based materials, such as corrosion resistance construction [3], in chemical and automotive industries,

* Corresponding author.
E-mail address: dzhu@hnu.edu.cn (D. Zhu).

https://doi.org/10.1016/j.conbuildmat.2018.02.168
0950-0618/

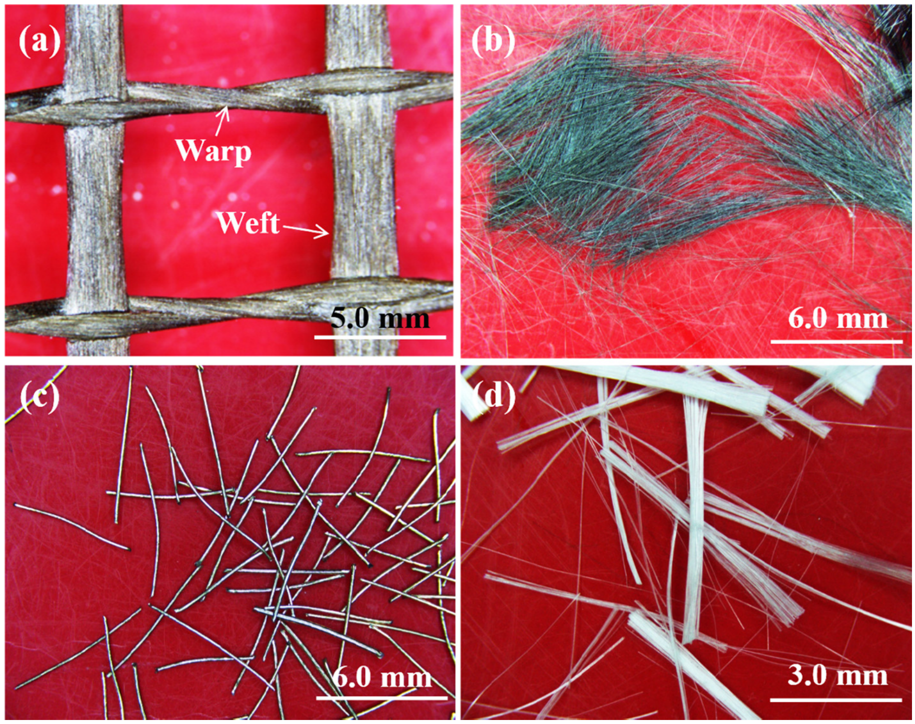

Fig. 1. (a) Leno weave structure of basalt textile, (b) short carbon fiber, (c) short steel fiber and (d) short alkali-resistant glass.

Table 1
Physical and mechanical properties of basalt textile and short fiber.

Materials	Length (mm)	Diameter (μm)	Aspect ratio	Tensile strength (MPa)	Elongation (%)	Young's modulus (GPa)	Density (g/cm^3)
[1]Filament of basalt textile	–	14	–	1650	1.7	83	2.8
[2]Single yarn of basalt	–	–	–	1233	2.4	49.4	–
[3]Three yarns of basalt textile	–	–	–	1191	2.2	54.2	–
Steel fiber	6	200	30	2860	3.5	210	7.8
Carbon fiber	6	7	857	3950	2.1	280	1.8
AR-Glass fiber	6	14	428	1700	3	72	2.68

Note: [1]the values from the manufactures, [2, 3]mechanical properties are obtained under quasi-static loading condition.

Table 2
Fine concrete mix design by weight.

The proportion of fine concrete (kg/m^3)								W/B
Portland cement	Fly ash	Silica fume	Sand (0–0.6 mm)	Water	Super-plasticizer (HSC)	Anti-foaming agent	Viscosity agent	
389	467	49	815	350	19.15	2.7	0.34	0.40

Note: W/B represents the water-to-binder ratio of the fine concrete.

and anti-low-speed impact loadings of automobiles [4]. The construction industry has given increasing attention to basalt fiber, which is produced from igneous rocks through high environmental melting processes with low pollution. The advantages of basalt fiber over carbon fiber include moderate cost, thermal stability, and elevated temperature resistance, whereas its advantage over glass fiber include competitive stiffness and strength [5,6], and it induces low poisonousness during manufacture process [5]. However, the low modulus of basalt fiber leads to a weak friction bond behavior [7]. To improve the mechanical properties of BTRC systems, the interface properties between the basalt textile and the cement matrix must be enhanced using different methods, such as adding short disperse fibers [8–14], impregnation epoxy [15], organic coatings with quartz sand [14], impregnation with nanoparticles [16], and pre-tension [1,11,17]. The increment of pre-tension lead to the increase of strength and stiffness of the textile reinforced concrete specimens, and pre-tensioned TRC can improve performance and improve load capacity at the use of stage as well as cracking force, providing a better utilization of the fabrics [18]. What's more, addition of short fibers in cement matrix can improve the stress transfer mechanics in concrete, result in more fine cracks. Overall, the increment of pre-tension load and the use of fibers in cement matrix lead to the increase of properties of tensile, flexural and interfacial bond of the BTRC specimens [11]. This work mainly focused on the effects of different short fibers, the number of textile layers and pre-tension on the flexural impact behavior of TRC specimens.

To design optimal TRC structural systems, the dynamic mechanical properties must be evaluated under realistic loading rates [19]. When TRC structural members suffer during impact