Construction and Building Materials 106 (2016) 575–583

Contents lists available at ScienceDirect

Construction and Building Materials

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

Improving performance of light weight concrete with brick chips using low cost steel wire fiber

Md. Abul Bashar Emon [a,*], Tanvir Manzur [a], Nur Yazdani [b]

[a] Department of Civil Engineering, Bangladesh University of Engineering & Technology, Dhaka, Bangladesh
[b] Department of Civil Engineering, University of Texas at Arlington, TX 76019, USA

HIGHLIGHTS

- GI wire fiber can be used as a low-cost alternative to steel fibers in concrete.
- Optimum GI fiber content is 2–2.5% by weight for conventional brick chip concrete.
- Considerable cost saving can be achieved by using GI fiber instead of steel fiber.

ARTICLE INFO

Article history:
Received 17 July 2015
Received in revised form 2 December 2015
Accepted 22 December 2015
Available online 30 December 2015

Keywords:
Light weight aggregate (LWA)
Brick chip aggregate
Galvanized iron fiber
Fiber reinforced concrete (FRC)
Low-cost
Ductility
Crack
Load-deflection

ABSTRACT

Brick chips, produced from burnt clay, are quite common in Bangladesh and other countries of the south-east region of Asia and have been used as coarse aggregate for many years. These brick chips are considered as light weight aggregate (LWA) because of their light weight and porous structure. Brick chips concrete is a form of light weight aggregate concrete (LWAC) and has lower mechanical properties and higher brittleness than conventional normal weight concrete. Improving this aspect of LWAC with brick chips is of great importance since brick chips are very popular in the country due to low cost and wide availability. Therefore, a comprehensive investigation has been made in this study on the improvement of strength and ductility of concrete having brick chips as coarse aggregate using locally produced low cost lightly galvanized mild steel wire fiber (commonly known as GI wire fiber in this region) as an alternative to conventional steel fibers. Steel fibers are not available in local markets in many countries of this region such as Bangladesh and importing is quite expensive. Compressive and splitting tensile strength of test cylinders as well as load–deflection and cracking behavior of test beams with variable fiber contents have been evaluated. Marked improvement has been noticed for compressive and tensile strength of concrete through GI wire fibers addition. Ultimate strength and toughness showed maximum increment up to thirty percent for a certain range of fiber content. Moreover, fiber inclusion has enhanced resistance against crack formation and propagation which is evident from crack width, crack spacing with respect to loads applied and crack patterns. Results of the experiments and cost comparison reveal that GI fiber can be adopted as a viable low cost alternative to steel fibers for performance enhancement of brick chips concrete.

1. Introduction

Concrete is the most widely used construction material throughout the globe. Especially in the developing regions of the world, construction of infrastructure constitutes the major share of the total development work. And concrete is an indispensible part of these development works in countries like Bangladesh as ingredients of concrete is inexpensive, readily available as well as concrete work is relatively simple to execute and maintenance free. However, the major limitation of concrete is the lack of ductility. In Bangladesh, this limitation is even more pronounced due to poor construction practice and lack of quality control. In addition to that, a vast region of the country falls in an active seismic zone which calls for the structures to be more resilient and ductile. Furthermore, extensive use of brick chips (crushed burnt clay bricks), which is a form of light weight aggregate (LWA), as coarse aggregate in concrete in this south-east region of Asia has posed some additional concerns to ponder; as light weight aggregate con-

* Corresponding author.
E-mail addresses: a.001.bashar@gmail.com (Md. Abul Bashar Emon), tmanzur.buet@gmail.com (T. Manzur), yazdani@uta.edu (N. Yazdani).

http://dx.doi.org/10.1016/j.conbuildmat.2015.12.165
0950-0618/

crete (LWAC) is expected to have higher brittleness and lower mechanical properties than normal weight concrete (NWC) [1]. Therefore, improving this aspect of LWAC with brick chips has the prime focus of the civil engineers and researchers.

Considerable number of studies have been carried out by incorporating various types of fibers such as steel fiber, glass fiber, fiber polymer, natural fiber, and nano-fiber within cement mortar and concrete [2–7]. Concrete with these fibers, generally known as FRC (fiber reinforced concrete), has improved ductility, better flexural performance and energy absorption capacity [8–10]. In the field of FRC, steel fiber is, by far, the front runner as a suitable reinforcing material [4,11]. Performance of steel fiber in concrete to improve mechanical properties, such as tensile strength, ductility, toughness, fatigue life, and impact resistance has been well established [8,9,12,13]. Majority of the previous researches in FRC have been conducted for concrete with normal weight aggregate like stone chips as coarse aggregate. A number of literatures are also available for fiber-reinforcing in various LWAC where pumice, oil palm shell etc. have been utilized as LWA [1,14,15]. However, a thorough literature review fails to reveal any significant study on FRC with brick chips aggregate. There are no authentic research results or database to comprehend the behavior of FRC produced from brick aggregate. However, in this region, brick chips are used massively in concrete works due to ease of availability and relative low cost. Therefore, performance enhancement of concrete made with brick chips needs an exclusive attention since use of brick chips as coarse aggregate is very popular particularly for construction of beams and slabs. Undoubtedly, use of steel fiber could be a promising solution to relative poor performance of brick chips concrete. Thus, a thorough investigation on performance of brick chips concrete reinforced with suitable fibers is of immense importance. A major constraint of using steel fiber in a country like Bangladesh is its relative high cost. Such additional cost for steel fibers can be an issue in popularizing them. In this context, fibers from locally manufactured lightly galvanized mild steel wire, popularly known as GI (Galvanized Iron) wire, can provide a viable low cost alternative to steel fibers, especially for Bangladesh and other developing countries [16]. Steel fiber for use in FRC is not available in local markets in many of these countries and importing can be quite expensive. Moreover, GI wire is locally produced and is available at a relatively low price.

GI wire fiber is different from conventional steel fiber in both shapes and properties. Steel fibers are available in various shapes and strengths, but GI wire fiber is normally straight cut from wires. GI fiber is relatively low in strength and more flexible as compared to typical steel fibers [16]. Research with GI wire as a suitable concrete reinforcing material is in the budding phase and behavior of GI Fiber Reinforced Concrete (GFRC) is yet to be properly investigated. With this as backdrop, experiments were conducted with GFRC with an aim to comparing performance of GI wire fiber as an alternative to steel fiber in concrete with brick chips as coarse aggregate. Concrete with crushed stone chips were also made for comparison. Compressive, splitting tensile and flexural strength of GFRC has been investigated. The experiments exhibited promising results when compared with steel fiber reinforced LWAC. A cost comparison also reveals that GI fiber can be a good option of cutting the cost of steel fiber in Bangladesh.

2. Background

It is now well established that adding discrete, randomly distributed steel fibers can improve concrete mechanical properties, such as tensile strength, toughness, durability, fatigue life, and impact resistance [9,15,17–22]. The composite material resulted from incorporation of steel fiber within concrete is commonly known as steel fiber reinforced concrete (SFRC). Because of its enhanced tensile strength and toughness in compression, SFRC has great potential for use in construction industries. The American Concrete Institute is also gradually promoting SFRC in building structural applications by including it in their Codes [23]. Fiber content and attributes usually do not have direct influence on compressive strength properties of fiber reinforced concrete; nonetheless, they can passively contribute to augmentation of compressive strength [18,19,24]. This phenomenon can be attributed to the confining effect of fibers and the countering effect to the lateral tension. Fibers aligned with tensile stresses may result in large increases in direct tensile strength, as high as 133% for 5% of smooth/straight steel fibers [25]. However, it has been observed that increase in tensile strength is quite variable since this enhancement depends on various factors like dispersion and alignment of fibers, fiber fraction, aggregate type, mix proportion etc. For randomly distributed fibers, the increase in strength can be much smaller. One major advantage of steel fibers is that steel fiber reinforcement can lead to significant increases in the post-cracking behavior or toughness of the composites [4,10,26]. Moreover, it has been found that fiber reinforcing reduces both potential of cracking and crack width, especially in early hydration stages [27,28]. As a result of reduced crack propagation, SFRC is known to have much better durability compared to concrete without fiber [29].

The history of research on modern SFRC stretches back to early 1960s [3]. Since initiation, majority of studies for many years were confined to the investigation of plain SFRC beams without main steel reinforcement. Investigation on the effects of fiber reinforcement on conventional reinforced concrete members eventually followed [30–32]. Oh [20] studied the mechanical behavior of reinforced concrete beams containing steel fibers. The steel fiber content varied from 0% to 2% by volume (0–7% by wt.). Generally, fiber reinforced composites are categorized according to fiber content into three classes such as low (below 1% vol. fraction), moderate (1–2% vol. fraction) and high (above 2% vol. fraction). The study by Oh [20] found marked increase in flexural strength and ductility and also reported significant improvement in crack control in SFRC when used alongside main reinforcement. It has also been shown that steel fibers effectively reduce the bursting pressures in the anchorage zones of post-tensioned concrete bridge members and reduce the need for secondary reinforcements, resulting in less steel congestion and improved constructability [33]. The ACI 318 Building Code has introduced steel fibers in shear design provisions, allowing the elimination of minimum shear reinforcement in SFRC (ACI [23]). Later on effect of steel fiber reinforcement has been investigated for various other types of concrete like concrete with different types of light weight aggregate (LWA), high performance concrete etc. Although researchers observed performance augmentation in most of the cases, the degree of enhancement has been found different for concrete having different types of LWA. For example, SFRC, with 0.5% volume fraction (1.7% by weight) of steel fiber and having oil palm shell, pumice and expanded clay as LWA, experienced compressive strength increment of 8% [34], 8% [35] and 18% [36], respectively. Again, with 1% volume content (3.4% by weight) of steel fiber for the same three types of aggregates, improvement in compressive strength was about 18% [34], 11% [35] and 27% [36], respectively. It is, therefore, evident that a comprehensive investigation is necessary before recommending fiber reinforcement for concrete having a new type of LWA. Since, fiber reinforcing technique is yet to be comprehensively applied on brick aggregate concrete as a LWAC, the present study can be considered as the initial progress in this context. Moreover, GI wire fiber as a substitute of conventional steel fiber is another aspect that makes this study distinctive.