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The confining effect of geo-grid on the mechanical properties of concrete specimens with steel fiber under compression and flexure

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HIGHLIGHTS

- This study examines the feasibility of geo-grid application in structural engineering.
- Geo-grid confined concrete under compression and split tension is investigated.
- Composite action of SFRC and geo grid enhanced the confinement and dissipation property.
- Geo grid provides an effective crack bridging mechanism.
- Flexural and compression behavior authenticates the feasibility of geo grid in structural work.

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ABSTRACT

An experimental investigation has been carried out for the use of geo-grid as a confinement in concrete specimens with steel fibers. This paper is focused on the confining effect of geo-grid on the mechanical properties of concrete under compression and flexure as well as to examine the bond between geo-grid and concrete. The effect of geo-grid with the steel fiber reinforced concrete (SFRC) has also been investigated. Experimental results indicate that geo-grid may be an effective alternative material to confine the concrete as compared to conventional confining techniques. The axial stress–strain behavior of concrete specimens confined with geo-grid is further improved by the use of SFRC. The performance of cylindrical specimens under split tension also proves the significance of geo-grid confinement with and without steel fibers. The flexure test on beam specimens reveal that the strength of geo-grid and its number of layers play a vital role in improving the load–deformation behavior as well as crack propagation. The stress transfer mechanism of geo-grid under flexure confirms that geo-grid may also be an alternative of tensile reinforcement in reinforced concrete specimens.

1. Introduction

Geo-grid is one of the constituent materials classified under geo-synthetics, manufactured from the polymers such as polypropylene, polyethylene and polyester. These geo-grids are classified as either uni-axial or bi-axial. Uni-axial geo-grids are principally used in grade separation applications such as retaining walls and steep slopes while bi-axial geo-grids are used mainly in roadway applications. The effective use of geo-grid as reinforcing material with plain cement concrete in thin sections where steel reinforcement is not possible is studied by Tang et al. [1], and Meski and Chehab [2]. The lack of conventional shear reinforcement in the concrete section with geo-grid may be compensated with the use of steel fibers. The use of discontinuous, randomly oriented fibers has long been recognized to provide post-cracking tensile resistance to concrete [3]. Dispersed fibers act as effective shear reinforcement and increases shear-friction strength of concrete. They are more effective to arrest crack propagation [4]. In steel fiber reinforced concrete (SFRC), the presence of randomly distributed steel fibers carries tensile stresses resulting from applied load and improves the tensile strength of concrete. Moreover, fibers also bridge tensile cracks and prevent the crack propagation [5]. It also significantly increases the concrete toughness and ductile behavior [6–8]. In particular, the improvement in ductility and energy absorption capacity resulting from the increase in fibers volume fraction are comparable to the improvements due to the effect of concrete confinement using transverse reinforcement. SFRC is now widely used in construction practices but an increase in the percentage of fibers and their non-uniform distribution may sometimes lead to fiber segregation creating more voids in the structure.

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Therefore, the complete reliance on concrete alone with steel fibers is not practical and reasonable solution for obtaining the composite strength [5]. Geo-grid with steel fiber may be a better choice for effective transfer of tensile stress and for enhance the composite action of SFRC. These strengthening materials may also impart better bonding behavior with concrete without practical difficulty.

In the present research work, an investigation has been carried out to study the effect of geo-grid with or without steel fibers in reinforced concrete structural applications as a tensile reinforcement. Twelve beam specimens have been tested under flexure and four cylindrical specimens have been tested under compression and split tension. The load–deflection, energy dissipation and stress–strain behavior with failure patterns of different specimens are compared with conventional specimen to examine the effect of geo-grid reinforcement. This study may open new alternatives and pave way to bring the geo-grid into structural concrete section with and without steel fibers.

2. Early studies

A number of experimental studies based on geo-synthetic materials were carried out in the past to improve the behavior of pavement design although the application of geo-grid in concrete in limited. The few main studies, carried out for the use of geo-grid as a reinforcing material in the construction industry, are briefly summarized.

Ling and Liu [9], and Khodaii et al. [10] studied the use of geo-synthetic materials for the reduction of reflection cracking in asphalt overlays. Shin and Das [11] studied improvement in the bearing capacity of a strip foundation on geo-grid reinforced sand. Raymond and Ismail [12] conducted experimental study on the effect of geo-grid reinforcement on unbound aggregates. Tang et al. [13] studied the effect of geo-grids for stabilizing weak pavement sub-grade. Tang et al. [1], and Meski and Chehab [2] conducted experimental tests to study the flexural behavior of geo-grid reinforced plain cement concrete beam under monotonic loading. Siva Chidambaram and Pankaj [14,15] conducted experimental study to examine the effect of geo-grid confined reinforced concrete beam under static and cyclic loading and observed enhanced ductile behavior.

3. Experimental investigations

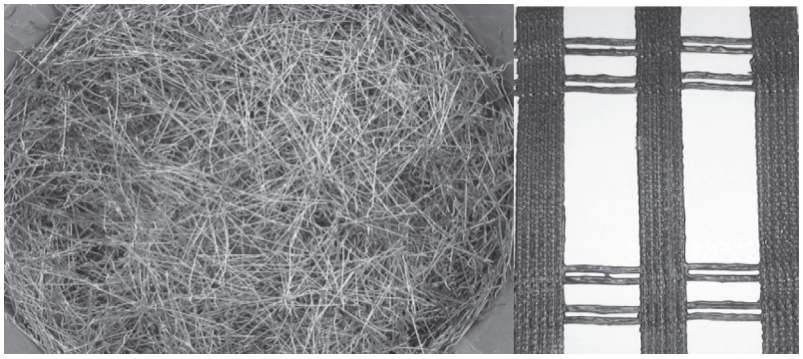
Compression and flexure tests have been conducted to study the effect of confinement with geo-grid in cylindrical specimens and as an alternative longitudinal reinforcement in beam specimens with and without steel fibers. The complete details of experiential programme along-with the instrumentation as well as material specifications used in preparation of tested specimens are summarized below.

3.1. Material specifications

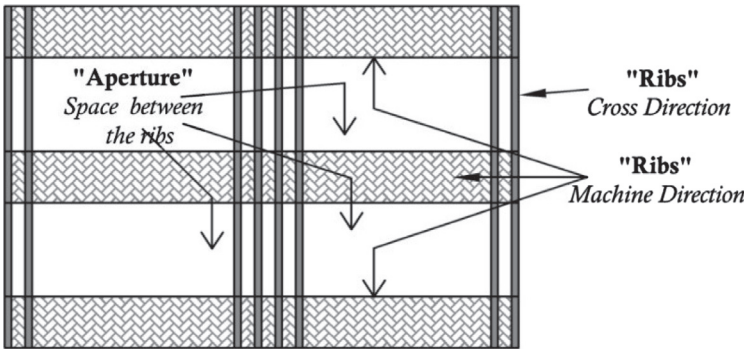
The concrete specimens have been prepared using a mix proportion of 1:1.45:2.25 in Ordinary Portland Cement (OPC) of Grade 43, locally available river sand as fine aggregate, and well graded crushed coarse aggregate having 20 mm maximum size. Hooked end steel fibers (Fig. 1a) with an aspect ratio (l_f/d_f) of 60 (length of fibers, l_f = 35 mm and diameter of fibers, d_f = 0.6 mm) has been used in two different volumes (V_f = 0.5%, 1% and 2%) to prepare SFRC specimens. In order to equate the density of conventional concrete a slight modified concrete mix proportion 1:1.40:2.20 have been used to prepare SFRC with 1% steel fiber. Uni-axial geo-grid (Fig. 1b), manufactured by using knitted polyester yarns having high molecular weight and tenacity with a proprietary coating are employed with three variable strengths (100 kN/m, 200 kN/m and 300 kN/m). The above mentioned geo-grid strengths are average tensile strengths in machine direction. The typical detail of geo-grid used in this study is shown in Fig. 1c.

3.2. Details of specimens for compression and flexure tests

Two sets of cylindrical specimens confined with geo-grid of size 150 mm × 300 mm are tested in direct compression and split tension. Table 1 summarizes the details of cylindrical specimens with different configurations. In geo-grid confined specimens, geo-grid is shaped into a tubular form as shown in Fig. 2 and inserted in the cylindrical mould before the concrete lay.



(a) Hooked End Steel Fiber **(b)** Uniaxial Geo-grid



(c) Geo-grid details

Fig. 1. Material used in preparation of compression and flexure specimens.