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Hybrid FRP–concrete–steel tubular columns: Concept and behavior

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Abstract

Hybrid FRP–concrete–steel double-skin tubular columns are a new form of hybrid columns recently proposed by the first author. The column consists of an outer tube made of fiber reinforced polymer (FRP) and an inner tube made of steel, with the space between filled with concrete. In this new hybrid column, the three constituent materials are optimally combined to achieve several advantages not available with existing columns. In this paper, the rationale for the new column form together with its expected advantages is first explained. A series of axial compression tests on stub columns are then presented to demonstrate some of the expected advantages. These test results confirm that the concrete in the new column is very effectively confined by the two tubes and the local buckling of the inner steel tube is either delayed or suppressed by the surrounding concrete, leading to a very ductile response. The application of the proposed hybrid section form in beams is also examined by presenting the results of a series of tests on beams with a hybrid section in which the inner steel tube is shifted towards the tension side. The test results also show that such beams have a very ductile response and that the GFRP tube in such beams enhances the structural behavior by providing both confinement to the concrete and additional shear resistance.

Introduction

In recent years, fibre reinforced polymer (FRP) composites have found increasingly wide applications in civil engineering, both in the retrofit of existing structures and in new construction. FRP composites possess several advantages over steel, including their high strength-to-weight ratio and good corrosion resistance. As a result, the use of FRP composites as externally bonded reinforcement for the retrofit of structures has become very popular in recent years [1], [2]. These same advantages can also be exploited in new construction, and indeed a large amount of research around the world is currently under way examining the performance of various forms of structures made of FRP composites alone (i.e. all FRP structures) or FRP composites in combination with other materials (i.e. hybrid structures). Examples include FRP bridge decks, concrete filled FRP tubes as columns and piles, and FRP cables.

Compared with the two primary traditional structural materials, namely steel and concrete, FRP composites also have some disadvantages. These include their relatively high cost, linear–elastic–brittle stress–strain behavior, low elastic modulus-to-strength ratio, and poor fire resistance. In retrofit applications, cost savings arise from a number of aspects that offset the higher material cost, but this is harder to achieve in new construction at the present. The low elastic modulus-to-strength ratio is not critical in retrofit applications as the FRP is generally used to resist tension. The poor fire performance is also not an acute problem in retrofit applications either because the structure is in the open space (e.g. bridges) or because the FRP is not required to make any contribution to structural resistance during a fire. When FRP composites are deployed in new construction, the consequences of their weaknesses need to be minimized as in retrofit applications. Based on these considerations, it may be concluded that the successful application of FRP composites in new construction requires the following three criteria to be met: (a) cost effectiveness at least in terms of a life-cycle cost assessment; (b) FRP to be used in areas subject to tension as much as possible; (c) fire resistance to be non-critical. It should be noted that criterion (c) is easily met for bridge structures and other outdoor structures, while the first two requirements very often mean that FRP composites should be used in combination with other materials to form hybrid structures.

Based on the above discussion, it is apparent that the area of hybrid structures should be a major research focus in the use of FRP composites in new construction. Within the area of hybrid structures, the aim shall be to optimally combine FRP with traditional structural materials such as steel and concrete to create innovative structural forms that are cost-effective and of high-performance. To this end, simple duplications of existing structural systems are often inadequate. This paper presents the idea of a new form of columns, namely FRP–concrete–steel hybrid double-skin tubular columns (DSTCs), proposed by the first author of the paper, as well as test results to evaluate their axial and flexural behavior.

Section snippets

New hybrid column

Concrete-filled steel tubes have been a common form of columns. The simplest form of concrete-filled steel tubes consists of a single hollow steel tube filled with concrete with or without internal steel reinforcing bars. A variation of this simple system is the double-skin tubular column, consisting of two generally concentric steel tubes with the space between filled with concrete. To the best of the authors' knowledge, such double-skin tubes were first reported in late 1980s [3]. Since then,…

General

Obviously, for the new hybrid column to be accepted in practical applications, a great deal of research is required to develop knowledge of its structural behavior and reliable design methods. As a first step, a series of stub column tests on this new DSTC were conducted. In parallel, tests were conducted on corresponding FRP-confined concrete (FCC) cylinders for comparison, so as to reach a better understanding of the axial compressive behavior of this new member. Details of the test specimens …

General

A series of four-point bending tests were conducted to demonstrate the application of this new hybrid section as a beam and to provide a preliminary evaluation of the flexural behavior of such beams. In these beams, the inner steel tube was shifted towards the tension side to leave more concrete in the compression zone and to move more of the steel tube to the tension zone. Details of the test specimens and the test results are presented in this section.…

Specimens

In total, three specimens were prepared…

Conclusions

The details of a newly proposed hybrid FRP–concrete–steel double-skin tubular column have been introduced in this paper. The new column consists of an inner steel tube and an outer FRP tube, with the space between them filled with concrete. The new column possesses many advantages over existing columns including double-skin FRP–concrete columns and double-skin steel–concrete columns. These advantages include good ductility, corrosion resistance and ease for construction. In addition, fire…

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