Behavior of Compound Concrete Filled Reinforced PVC Tubes Under Compression

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Abstract - *The reuse of coarsely crushed demolished concrete lumps (DCLs) with fresh concrete (FC) in compound concrete (i.e. concrete composed of DCLs and FC) provides a viable option to recycled concrete aggregates for recycling concrete waste. Compound concrete-filled steel tubular (CCFST) columns further improve the efficiency with which DCLs are used due to the advantages of concrete-filled steel tubular columns, such as improved strength and ductility. The use of PVC to encase cementitious composite materials like concrete is reviewed. This paper also discuss on the experimental study of the compressive behavior of compound concrete filled reinforced PVC tubes compared to PVC tubes without reinforcement.*

Key Words: Concrete filled tubes, Demolished concrete lumps, PVC tubes, Compressive strength, Displacement

1. INTRODUCTION

Concrete-filled tubular (CFT) columns are widely used as columns in many structural systems. Concrete-filled tube columns combine the advantages of ductility, generally associated with steel structures, with the stiffness of a concrete structural system. The advantages of the concrete-filled tube column over other composite systems include: The tube provides formwork for the concrete, the concrete prolongs local buckling of the tube wall, the tube prohibits excessive concrete spalling, and composite columns add significant stiffness to a frame. While many advantages exist, the use of CFTs in building construction has been limited, in part, to a lack of construction experience, a lack of understanding of the design provisions and the complexity of connection detailing. Consequently, a joint was needed that could utilize the favorable strength and stiffness characteristics of the concrete-filled tube column yet be constructible.

Durability and protection of new reinforced concrete structures in service aggressive environments are of particular concern for practicing and design engineers. One possible method of protection is the utilization of plastic tube for encasing concrete and its steel reinforcement. In PVC tube encased concrete, the tube has several roles including preventing any moisture loss necessary for the setting and hydration of fresh concrete, eliminating the time consuming and costly curing process, protecting concrete from thermal changes, and making column impermeable by closing the surface pores, in addition to confining concrete core and displaying considerable plastic deformation. As a permanent form-work for fresh concrete, the tube can confer a protective cover to concrete, preventing the cover spalling, in substructures in contact with soil (pile), marine environment (bridge columns and piers); and in several light structural applications and constructions, such as houses, residential, agricultural and industrial buildings.

The recycling and reuse of Construction and Demolished (C&D) concrete waste have great significance due to the obvious social and environmental merits: reducing the demand for natural resources for construction materials and saving space in landfills. A typical method of reusing C&D concrete waste is to break it into Recycled Concrete Aggregates (RCAs) and use them in Recycled Aggregate Concrete (RAC). However, because RCAs have weak interfacial transition zones and damage/porosity, RAC has a number of limitations compared with natural aggregate concrete. In the past few decades, extensive studies worldwide have been carried out to enhance the performance of RAC; nevertheless, its use has been limited to nonstructural applications, mainly due to the limitations mentioned above. Compared with the reuse of C&D concrete waste as RCAs in RAC, the direct use of coarsely-crushed Demolished Concrete Lumps (DCLs) with Fresh Concrete (FC) in structural members to form compound concrete (i.e. concrete composed of DCLs and FC), provides another viable option for recycling of concrete waste. In addition to reducing the cost, energy, and time required to produce RCAs from C &D concrete waste, the use of DCLs also avoids significant further damage to the parent concrete (i.e. the C&D concrete waste) caused by a crusher or other tools during the production of RCAs and minimizes the amount of useless debris/ash it creates. Furthermore, by reusing C&D concrete waste in the form of DCLs that are distinctly larger (e.g. 50–300 mm) than RCAs (e.g. normally<50 mm) in structural members, considerable amounts of cement, water, and energy can be saved, thus reducing the emission of carbon dioxide. As a result, reusing C&D concrete waste in the form of DCLs is greener than reusing RCAs in RAC. Given these advantages, studies on recycling C&D concrete waste as DCLs or large RCAs have increased in the past decade, and the authors' research group has carried out systematic studies on compound concrete and/or composite structures that incorporate DCLs.

Previous studies on compound concrete have shown that the DCLs and the FC bond well regardless of whether the strength of the FC is similar to or significantly higher than that of the DCLs, implying the feasibility and reliability of using DCLs in structural members.

Although the presence of DCLs may have some detrimental effects, such as a reduced compressive strength, a decreased modulus of elasticity and a slightly stronger size effect in the strength of compound concrete, these unfavorable effects can be controlled by limiting the replacement ratio of the DCLs (the mass ratio of DCLs to compound concrete).

2. EXPERIMENTAL PROGRAM

2.1 Test Specimens

Compression tests were conducted on 10 CCFPT (Compound Concrete Filled PVC Tube) specimens. Of these two tubes were filled with compound concrete alone. For other eight, two each tube were reinforced with internal stirrups of different spacing respectively and filled with compound concrete. The details of the specimens are listed in Table 1. For reinforcement, round plain bars with a diameter of 6mm were used for the circular stirrups, which were to three axial steel bars (round plain bar) with a diameter of 6mm for fixing. Typical photograph of internal stirrups are shown in Figure 1. All the specimens were of length 560mm and external diameter of 250mm.

The main parameter tested was the effect of internal stirrups in the PVC tube. The specimens are labelled individually as: CCFPT-nil, where 'CCFPT' stands for Compound Concrete Filled PVC Tube and 'nil' stands for no reinforcement. Also, for CCFPT-150, CCFPT-130, CCFPT-110, CCFPT-90, '150, 130, 110, 90' stands for the centre to centre spacing of internal stirrups.

Fig -1: Typical Photograph of Internal Stirrups

Table -1: Details of Specimens

Specimen ID	Thickness (mm)	Length (mm)	Diameter (mm)	Spacing (mm)
CCFPT-nil	2.5	560	250	-
CCFPT-150	2.5	560	250	150
CCFPT-130	2.5	560	250	130
CCFPT-110	2.5	560	250	110
CCFPT-90	2.5	560	250	90

2.2 Material Properties

A concrete mix of M20 was used in this study. All the properties of materials tested were within the codal limits. The mix design for quantity required for 1m^3 volume of concrete is shown in Table 2.

Table -2: Mix Design

Materials	Quantity
Cement	358.47 kg
Fine Aggregate	709.20 kg
Coarse Aggregate	1148.57 kg
Water	197.16 *l*
Mix Proportion: (1:1.97: 3.2)0.5	

The characteristic dimensions of DCLs are in the range of about 100-150mm. The replacement ratio for DCLs was kept less than 20% of mass of concrete. The water absorption rate was obtained as 4.08% and an aggregate crushing value of 37.2%.

2.3 Specimen Preparation

The old concrete members used to produce the DCLs were taken from construction site in local area. The old members were broken to DCLs of required size (100-150mm).

Before casting the concrete, the circular steel stirrups were positioned in the PVC tubes with the aid of three axial bars and the DCLs were wetted with water to reach a condition close to saturated-surface dry. The first layer of FC was poured into the ready PVC tube, followed by a layer of DCLs thrown into the tube with enough vibration (using needle vibrator) to ensure compaction between the FC and the DCLs; this layer-by-layer procedure was repeated until the casting of compound concrete was complete. During concrete casting, it should be noted that when the upper layer of FC was cast, the vibration process should not disturb the lower layer of FC to prevent the DCLs from settling.

After the compound concrete casting was complete, the specimens were by a hemp bag to maintain relative humidity of over 90% at room temperature for 28 days

2.4 Test Setup

All the specimens were tested in the structural laboratory using a compression testing machine with a loading capacity of 5000kN. Dial gauges were installed to obtain the displacement values. The test setup is shown in Fig. 2.

Fig -2: Test Setup

3. RESULTS AND DISCUSSIONS

3.1 Load Deflection Response

Chart 1 shows the load deflection response of the compound concrete filled PVC tubes. The graph shows the influence of internal stirrups in different spacings i.e, 150mm, 130mm, 110mm and 90mm. Of which the closest spacing (90mm) shows higher ultimate load with least deformation. Also graph clearly shows the effect of internal stirrups by comparing with the PVC tube without reinforcement (CCFPT-nil).

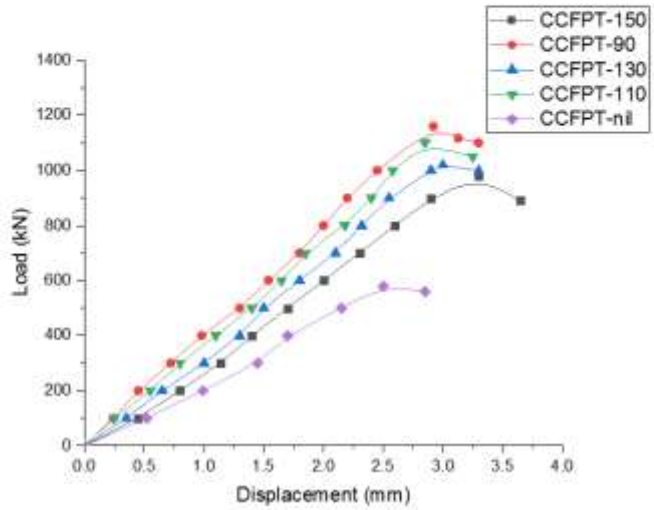

Chart -1: Load- Displacement Graph

3.2 Compressive Strength

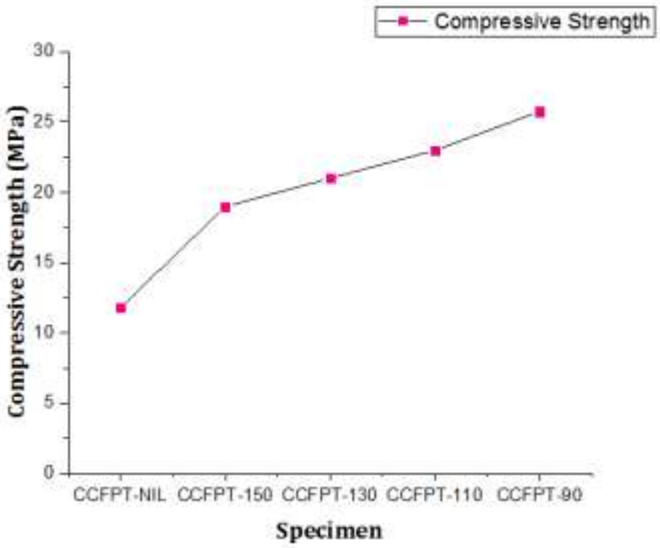

Chart -2: Compressive Strength of PVC Specimens

Chart 2 shows the compressive strength of PVC specimens. The compressive strength increases with the decrease in spacing between internal stirrups. i.e, closest spaced reinforcement provides more compressive strength. The graph also shows the effect of internal stirrups compared PVC specimen without reinforcement.

3. CONCLUSIONS

The compressive behavior of compound concrete filled PVC tubes with and without reinforcement was studied. The following conclusions are drawn from the experimental results.

- The use of internal stirrups improves the compressive performance of the compound concrete filled tubes. Compared to PVC specimen without reinforcement, effect of stirrups increases the load carrying capacity of the CCFTs.

- As the centre to centre spacing of internal stirrups decreases, the compressive strength increases.

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