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Enhancing Filled-tube Properties by Using Fiber Polymers in Filling Matrix

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Abstract: In dealing with filled steel pipe columns, the column strength is governed by the composite action of both steel and concrete. Furthermore, the steel pipe will produce a confinement to the concrete core due to the hoop stresses in the pipe material. This study presents the effect of both composite and confinement of concrete for filled steel pipes. The lab results of several specimens at different aspect ratios and various ratio of steel to concrete areas are investigated. The results of this study has an important significant in understanding the behavior of filled steel pipes.

Key words: Fiber Reinforced Polymers (FRP), composite material, concrete confinement, filled steel pipes

INTRODUCTION

The aim of this study was to reveal and enhance the properties of concrete in compressive strength, flexural strength, tensile strength and heat resistance by adding a cheap fiber polymers.

It is well known, that concrete is a perfect building material. It is cheap, durable and easy to use. However, it's bad behavior in tension arise the necessity of finding a new technique to overcome and enhance concrete characteristics. Thinking of using composite material to enhance and overcome the bad behavior was of an interest to many researchers nowadays. Studies show that the presence of fiber polymers in concrete mass acts as crack arresters, resisting the development of crack and transferring a brittle matrix into strong composite with better ductility[1-3].

The Fiber Reinforced Concrete (FRC)[2] as a composite material, essentially consisting of concrete reinforced by random placement of short, discontinuous and discrete fine fibers of specific geometry. Fibre Reinforced Polymers (FRP) may provide a more economical technically superior alternative to the traditional techniques in many situations. The FRP is lighter, more durable, fire resisting and higher strength to weight ratio compared to traditional reinforcing materials such as steel[2-5].

As early as 1906, Considere[2] and Talbot[3] considered the beneficial effects of concrete confinement on the strength and deformation capacity. Since then, further research has made generally accepted the fact that, when uniaxially loaded concrete is restrained from dilating laterally, it exhibits increased strength and axial deformation capacity. The existence of steel confining affects the dilation of concrete due to the uniaxial load. Such studies have regarded concrete confined by steel tubular columns[4,6-10].

The ultimate compression strain of unconfined concrete is inadequate to allow a component to reach the required ductility without extensive spalling of cover concrete. Members subjected to compressive loads are of critical importance for the safety of a structure, due to the increase in the carried loads, to inadequacy to withstand exceptional loads (seismic loads, impact, etc).

The use of Fiber-reinforced Concrete (FRC) has been gaining increasing popularity in the civil engineering community. The favorable properties possessed by these materials successfully exploited for strengthening and/or rehabilitation of concrete as well as masonry structures.

The confined concrete either cracks or crumbles, depending on the level of confinement pressure provided by steel tube. High confinement level is often characterized by column strengthening purposes, while; low confinement level normally represents the repairing of columns that undergo concrete spalling. The associated concrete core behavior and failure modes need to be developed and quantified as far as possible.

Now a days, the provision of adequate ductility in concrete structures attracts the attention of several researchers[7,8]. Repair and retrofitting of existing structures have become a major part of the construction activity in many countries[7]. This can be attributed to aging of the infra structure and increased environmental awareness in societies.

The aim of this work was to investigate the enhancement of concrete properties in compressive, flexural and tensile strength, by applying a significant amount of confinement pressure and/or adding cheap fiber polymers.

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MATERIALS AND METHODS

Test setup: The test is divided into two main sets. The first set uses fiber reinforced concrete as a filling material while the second one uses plain concrete as a filling material. Each set consists of three main separate groups with respect to the confinement effect namely: fully confined, partially confined and un-confined. For fully confined specimens, confinement is assured by using a thick wall steel cylinder. Partially confined specimens are made of the same steel pipes cylinder but with a vertical pass cut through the wall. are Low-pressure plastic tubes where used to caste the unconfined concrete specimens to have a uniform specimen cross-section. The confinement due to plastic cover is assumed to be neglected. On the other hand, different specimen lengths were used in this test to figure out the effect of specimen length on specimen strength. All specimens are cylindrical in shape, with a diameter of 89 mm. Five specimen lengths were used; 100, 150, 200, 250 and 300 mm. A lean concrete mix (strength = 15 N/mm^2 MPa) was used in this test.

The axial load is applied directly to a thick steel disk that is smaller in diameter than the steel pipe to assure that the load is applied to the concrete core and the steel cover is subjected to a confined hoop stresses only.

As the concrete expands laterally under uni-axial compression load, the steel cylinder is affected by hoop tension, which will provide a continuous confining load around the circumference of the enclosed concrete. This confinement will drive the concrete core to a tri-axial stress state rather than uni-axial stress state.

Design mix: The following design mix proportions were used to produce the fresh concrete[11]:

- Coarse aggregate, passing sieve size (19 mm) and retained on sieve size (13.2 mm) Weight: 28.5 kg
- Medium aggregate, passing sieve size (12.5 mm) and retained on sieve size (9.5 mm) size weight: 28.5 kg
- Fine aggregate, passing sieve No. 8 (2 mm) weight: 38 kg
- Cement by weight: 14.0 kg
- Free water of 11.75 L
- Fibre to concrete ratio by weight: 0.8%

RESULTS AND DISCUSSION

The results of Table 1 show the variation of the maximum carried load with respect to the specimen length for plain concrete set. As specimen length decreases the carried load increases. An increase in the carried load of 50% for confined samples is noticed due to a decrease in the specimen length from 300 to 100 mm, while, this ratio is 27% for partially confined samples. More over, this ratio is almost the same for unconfined samples. The carried load of the confined specimens is about 7 times of that of the unconfined ones. The effect of partially confinement is about 10 to 15% more than that of the un-confined specimens.

Table 1: The test results of the first set (i.e., without fiber reinforcement)

Specimen length (mm)	Applied load (N) Confined	Partially	Un-confined
300	420,000	59,000	58,000
250	480,000	65,000	59,000
200	520,000	72,000	60,000
250	580,000	72,000	62,000
100	640,000	75,000	62,000

Table 2: The test results of the second set (i.e., fiber reinforced concrete)

Specimen length (mm)	Applied load (N) Confined	Partially	Un-confined
300	480,000	74,000	60,000
250	520,000	79,000	62,000
200	580,000	82,000	67,000
250	620,000	82,000	69,000
100	720,000	85,000	70,000

The results of Table 2 show the variation of the maximum carried load with respect to the specimen length for fiber reinforced concrete set. As specimen length decreases the carried load increases. An increase in the carried load of 56% for confined samples is noticed due to a decrease in the specimen length from 300 to 100 mm, while, this ratio is about 15% for partially confined samples as well as unconfined samples. The carried load of the confined specimens is in the range of 8 to 10 times that of the unconfined ones. As noticed, the effect of partially confinement is about 20% more than that of the unconfined specimens.

Table 1 and 2, show clearly that the use of fiber reinforcement do increase the maximum carried load for all samples. This increase is about 13%.

For un-confined samples, using fiber reinforced concrete shows an increase in the carried load due to the existence of fibers, which will reduce the initiation of shear cracks as a result of the increase in the ability of carrying splitting stresses.

Figure 1 shows the failure pattern and the deformation of the tested specimen under loading for both confined and partially confined samples.

Table 1 and 2 shows the effect of using fiber reinforced concrete in compare with plain concrete for confined, partially confined and un-confined concrete, respectively.

(a)

(b)

Fig. 1: Failure pattern and the deformation of the tested specimen under loading: (a) Confined samples: (b) Partially confined samples

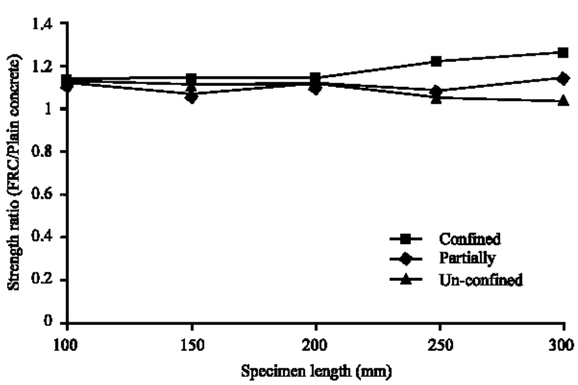

Fig. 2: Comparison between the strength of FRC and plain concrete for different confinement situations

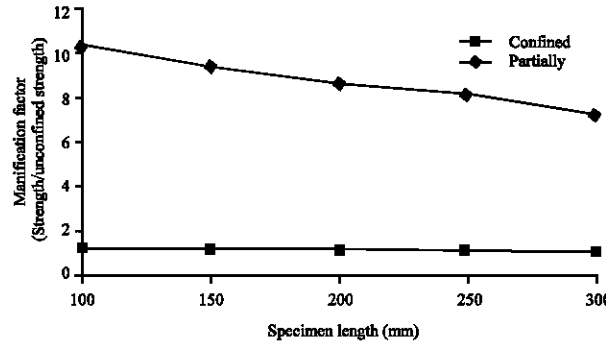

Fig. 3: Comparison effect of using FRC on the strength of unconfined concrete cylinders for different specimen lengths

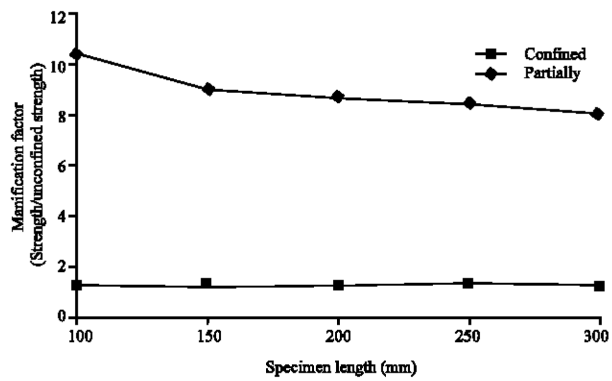

Fig. 4: Comparison effect of using FRC on the strength of unconfined concrete cylinders for different specimen lengths

Figure 2 shows that, the strength of fiber-reinforced samples is higher than that of plain concrete. This ratio is in the range of 13% increase.

Figure 3 shows the normalized strength of confined plain concrete samples with respect to the unconfined sample. This Fig. 3 shows a ratio of 8 to 10 times for confined concrete.

Figure 4 shows the normalized strength of confined fiber reinforced concrete samples with respect to the unconfined sample. Figure 4 shows a ratio of 8 to 10 times for confined concrete.

CONCLUSION

The performance of confined concrete is investigated in this study using both, plain concrete and fiber reinforced concrete. The increase in ductility of confined concrete is related to the stiffness properties of the confining device. As the concrete expands under uniaxial compression load, the steel cylinder is affected by hoop tension, which will provide a continuous confining load around the circumference of the enclosed concrete. Thus, confinement increases the strength of concrete. The use of fiber reinforcement does increase the maximum carried load for all samples. The aspect ratio (i.e., length to diameter ratio) also affects the strength. An increase in the aspect ratio will decreases the strength of confined samples.

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