EFFECT OF REINFORCING STEEL FIBER LENGTH ON COMPRESSIVE STRENGTH OF CONCRETE USING RECYCLED COARSE AGGREGATES

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ABSTRACT

This paper presents an experimental results to evaluate the compressive strength of concrete using recycled coarse aggregate, reinforced with steel fibers. The steel wire lengths used are 5 mm, 10 mm and 13 mm, with bending at both ends. Concrete using recycled raw aggregates is designed to have a strength grade of B15. The content of steel fiber used includes 0,5% and 1%. Samples were 15x15x15 cm in size and were compressed at 28 days of age. Compressive strength of concrete using 10% recycled aggregate increases with increasing fiber length. This growth is linear. Compared with the value of compressive strength of concrete when using 5 mm steel fiber, the result recorded an average increase of 9.5% when using 10 mm steel fiber and 12.92% when using 13 mm steel fiber. The obtained results are also consistent with the results published by some authors when studying the compressive strength of UHPFRC when increasing the fiber length.

ẢNH HƯỞNG CỦA CHIỀU DÀI SỢI THÉP GIA CƯỜNG TỚI CƯỜNG ĐỘ CHỊU NÉN CỦA BÊ TÔNG SỬ DỤNG CỐT LIỆU THÔ TÁI CHẾ

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TỪ KHÓA

Cốt liệu tái chế
Cường độ chịu nén
Bê tông gia cường sợi thép
Chiều dài sợi
Chất thải rắn

TÓM TẮT

Bài báo đánh giá cường độ chịu nén của bê tông dùng cốt liệu thô tái chế, gia cường bằng sợi thép. Sợi thép sử dụng có các chiều dài khác nhau, gồm 5 mm, 10 mm và 13 mm, uốn ở hai đầu. Bê tông thiết kế có cấp độ bền B15. Hàm lượng sợi thép được sử dụng bao gồm 0,5% và 1%. Mẫu kích thước 15x15x15 cm được nén ở 28 ngày tuổi. Cường độ chịu nén của bê tông dùng 10% cốt liệu thô tái chế tăng khi chiều dài sợi thép tăng. Sự tăng này là tuyến tính. So với khi sử dụng sợi thép có chiều dài 5 mm, kết quả thí nghiệm ghi nhận mức tăng trung bình 9,5% khi sử dụng sợi thép 10 mm và 12,92% khi sử dụng sợi thép 13 mm. Kết quả này cũng đồng nhất với một số công bố về cường độ chịu nén của UHPFRC gia cường sợi thép.

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1. Introduction

Currently, there have been many studies on the use of aggregates from construction solid waste in new concrete [1] – [5]. Similarly in Vietnam, there have been some related publications [6]-[9]. However, it is still necessary to fully investigate the impact of recycled coarse aggregates in the short and long term. According to the research results of the authors, the strength reduction of concrete is about 10-30% when using recycled aggregate [7], [8]. To compensate for that reduction, using steel fiber reinforcement is a common solution. The rate of using recycled coarse aggregate is 10%, according to the research results of [7], in which recycled coarse aggregate has been used at the rates of 10%, 20% and 30%. The results show that the compressive strength of concrete when using 10% recycled aggregate is only slightly reduced compared to conventional concrete. At larger proportions, this drop is relatively significant.

It is appropriate to use steel fiber reinforcement for concrete. However, it is necessary to further evaluate the effect of steel fibers on concrete using recycled coarse aggregates such as diameter, length of fibers, arrangement of fibers in concrete, etc.

There have been a number of studies on the influence of steel fiber length on the properties of concrete. Among them, Juhong *et al.* in 2019 investigated the effect of fiber length and maximum size of coarse aggregate on mechanical properties of concrete. The results show that fiber length has a greater influence on the mechanical properties of concrete than the maximum size of coarse aggregate [4].

Hasan S.A. in 2016 investigated the effect of steel fiber length on the mechanical properties of ultra-high-performance fiber-reinforced concrete UHPFRC, in which 3 types of fibers of length 8 mm, 13 mm and 16 mm with hooks at both ends as shown in Figure 1, were used [3]. The results show that the compressive strength of concrete increases as the fiber length increases, and the increase is almost linear (Figure 2). However, with UHPFRC concrete, this increase is not large, recorded from Hasan's experiment shows that this increase is about 8%. Yoo *et al.* [5] reported the same when investigating the compressive strength of UHPFRC when increasing the length of the fiber.

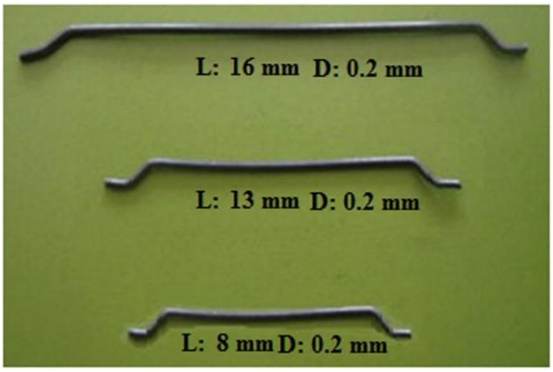

Figure 1. *Steel fibers used in research on ultra-high-performance fiber-reinforced concrete UHPFRC [3]*

Figure 2 shows the published results of Hasan S.A. *et al.*, in which, at 28 days of age, the concrete strength increased from 152 Mpa when using steel fiber with a length of 8 mm to 164 MPa when using steel fiber with a length of 16 mm, equivalent to an increase of 8% [3].

In this study, straight steel fibers will be used to compensate for the loss of strength of concrete when using recycled aggregate. Through the compressive strength of concrete when using steel fibers with different fiber lengths, the effect of steel fiber length on the compressive strength of concrete using recycled aggregate will be evaluated.

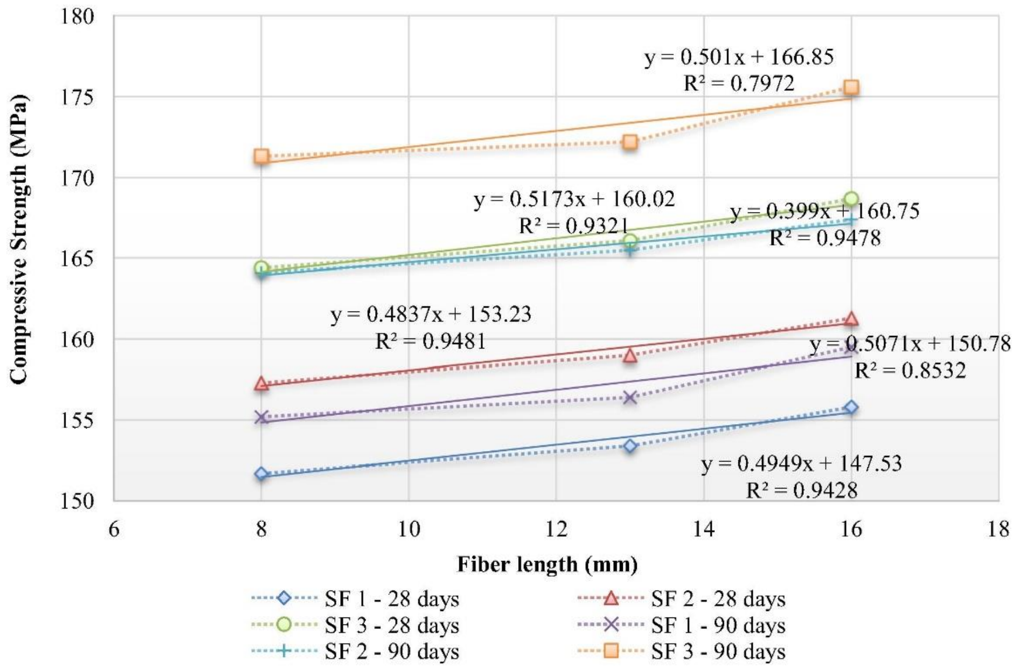

Figure 2. *Effect of steel fiber length on compressive strength of UHPFRC* [3]

2. Experimental set-up

2.1. Preparation of recycled aggregate

Construction waste was collected from demolition works in Vinh city, which is concrete waste. After being cleaned to remove dust and coarse impurities, the collected waste will be pounded, crushed manually combined with a compressor in the laboratory. After crushing, waste concrete is sieved through sieves of 5 mm, 10 mm, 20 mm, 40 mm, 70 mm, 100 mm. The composition of recycled coarse aggregates is mixed according to Table 1 to ensure compliance with TCVN 7572-2:2006. Recycled coarse aggregate will be soaked in water until saturated, then taken out to drain under normal conditions to avoid affecting the slump.

Table 1. *Granular composition of recycled coarse aggregate*

Sieve size	Quantity on sieve (g)	Separate residual amount (%)	Accumulated residual amount (%)	Accumulated residual amount according to TCVN 7572:2006
40 mm	0	0	0	0
20 mm	780	7.8	7.8	0-10
10 mm	4930	49.3	57.1	40-70
5 mm	3740	37.4	94.5	90-100
<5 mm	550	-	-	-

2.2. Concrete mix design

Concrete is designed with durability grade B15, design slump is SN = 8 cm and factor of safety γ_b = 1.1. PCB40 cement is used, with density γ = 3100 kg/m^3. The sand used has a module of magnitude Mdl = 2.5; density γ_a = 2650 kg/m^3, volumetric density γ_o = 1660 kg/m^3. Crushed stone (recycled from concrete) has Dmax = 20 mm; volumetric weight γ_o = 1430 kg/m^3 and density γ_a = 2610 kg/m^3.

Concrete mix proportions are represented in Table 2. Thus, the total weight of coarse aggregate is 1216.3 kg corresponding to 1 m^3 of concrete, which includes 10% recycled coarse aggregate respectively 121.63 kg and 90% natural coarse aggregate respectively 1094.67 kg. Steel fibers are added to the mix at the rate of 0.5% and 1% of the total dry weight of the concrete mix.

Table 2. *Mix compositions for 1 m^3 of concrete*

Component	Cement (kg)	Sand (kg)	Aggregates (kg)	Water (kg)
Quantity	292.5	648.3	1216.3	195.0

2.3. Steel fiber

Figure 3. *Steel fiber RS65/13*

Straight steel fiber was used (Figure 3), which has physical properties as shown in Table 3. The steel fibers used in the research are commercial products of Shanghai Micro Steel company.

Table 3. *Physical properties of steel fibers*

No.	Appellation	Value		
1	Notation	RS65/13	RS65/10	RS65/05
2	Length	L = 13 mm	L = 10 mm	L = 5 mm
3	Diameter		d= 0.2 mm	
4	l/d	65	50	25
5	Tensile strength		≥ 2000 MPa	
6	Number of fibers per unit weight (gram)	311	405	810

3. Results and Discussion

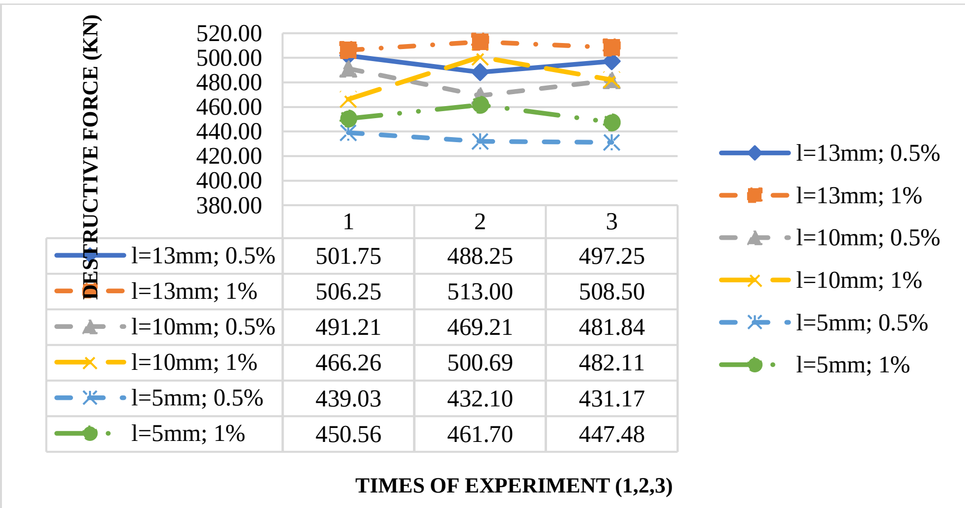

Figure 4. *The resulting sample destruction force*

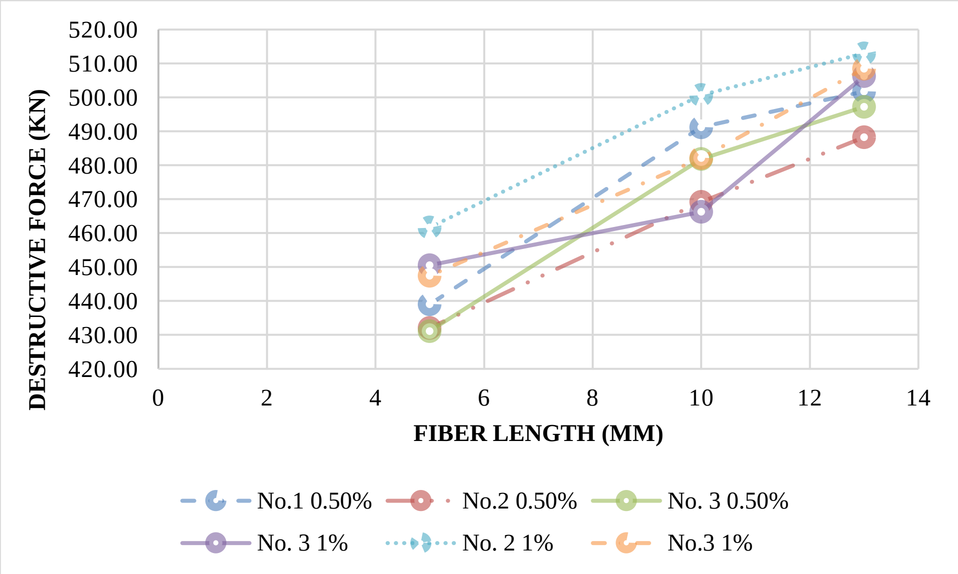

Figure 5. *Recorded destructive forces vs. fiber lengths*

Before casting the sample, the slump of the concrete is measured. From there, water and cement are added according to the design ratio to ensure the design slump before casting the sample. The samples were compressed at 28 days of age. The results are shown in Figures 4 and 5.

From Figure 4, it can be seen that the results do not differ much between the experiments, proving that the process of molding and compressing the samples ensures uniformity. The recorded destructive forces versus fiber lengths are represented in Figure 5. The results indicate that the length of steel fiber does not have much influence on the compressive strength of concrete. Compared to the value at 5 mm fiber length, the destructive force increased by an average of 10.7% with 10 mm long fibers and 14.2% compared with 13 mm long fibers. This can be explained because the fibers used in the experiment are short fibers (l<30 mm), so the effect of the fiber length, if changed in the short length region, will not have much effect on the properties of the concrete, especially the compressive strength (Fiber is mainly used to improve bending resistance).

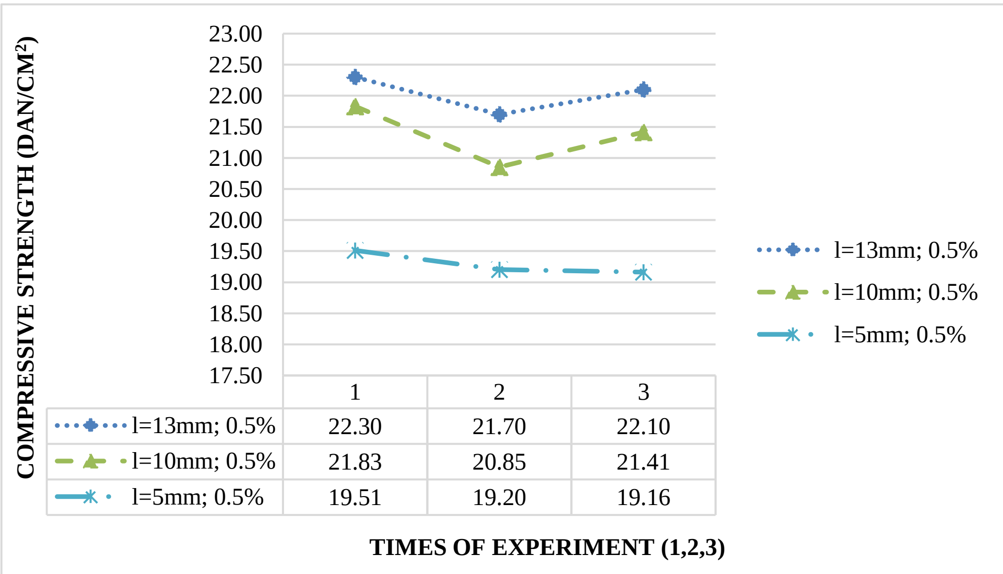

Figure 6. *Compressive strength of concrete when using 0.5% steel fiber*

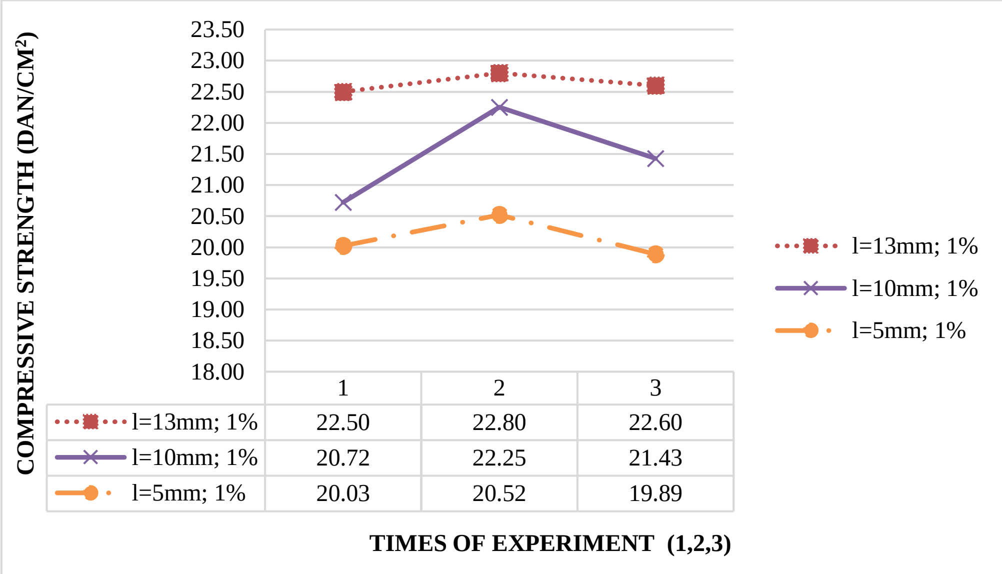

Figure 7. *Compressive strength of concrete when using 1% steel fiber*

The compressive strength obtained at each test corresponding to the fiber length is shown in Figure 6 at the rate of 0.5%, and Figure 7 at the rate of 1%. There is a clear partition between the fiber lengths and the results show that the compressive strength when using 13 mm fiber is the largest, the lowest is 5 mm fiber respectively. In addition, the difference between the compressive strength obtained using 13 mm and 10 mm fibers is negligible.

Calculated compressive strength is represented in relation to the fiber length as in Figure 8 corresponding to the content of 0.5% and Figure 9 corresponds to 1% content.

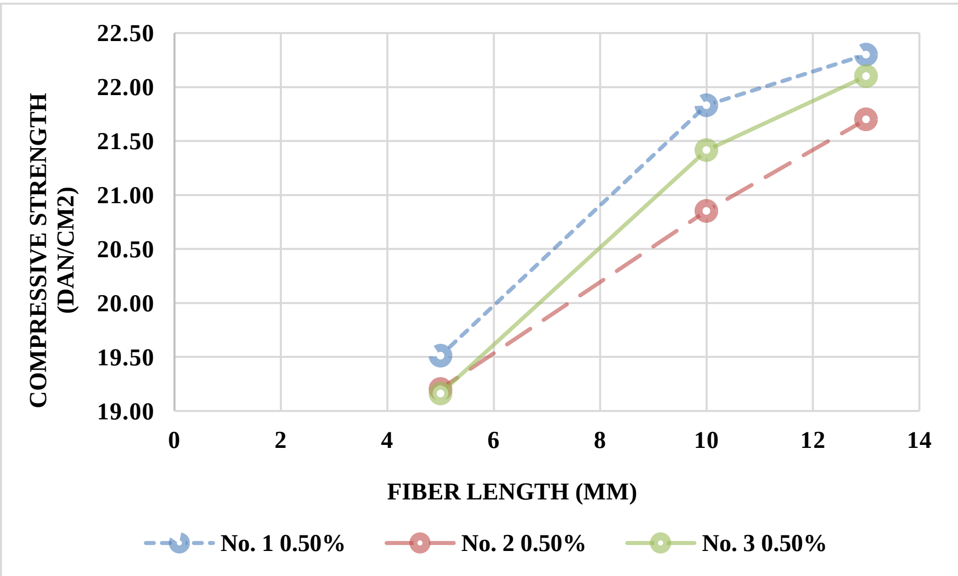

Figure 8. *Compressive strength of concrete with fiber length (content 0.5%)*

The graph shows that the compressive strength of concrete increases as the fiber length increases. Compared to when using 5 mm steel fiber, an average increase was recorded of 9.5% when using 10 mm length steel fiber and 12.92% for 13 mm length steel fiber (Figure 10). This result shows the similarity with that published by Hasan S.A. in 2016 on the influence of steel fiber length on the mechanical properties of UHPFRC [3]. In which, when using short fibers of less than 30 mm, the compressive strength increases as the length of steel increases. Figure 6 and Figure 7 also show that this increase is linear.

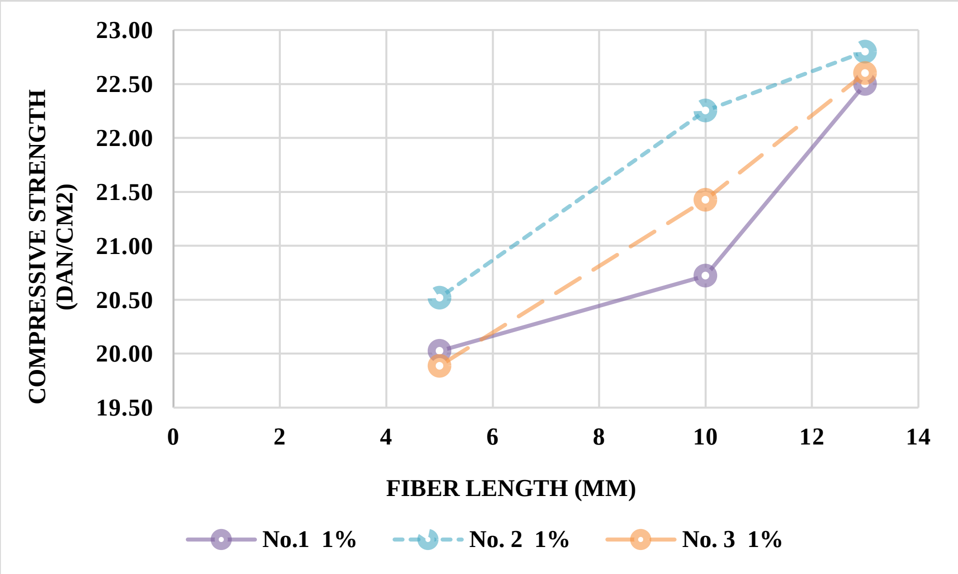

Figure 9. *Compressive strength of concrete with fiber length (content 1%)*

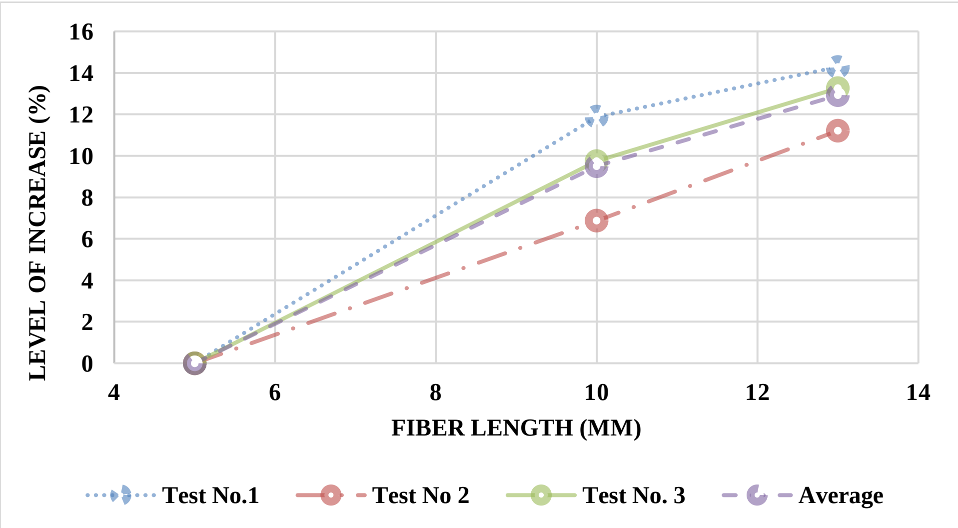

Figure 10. *The increase in compressive strength of concrete (compared to concrete using 5 mm steel fiber)*

4. Conclusions

The compressive strength of concrete using 10% recycled coarse aggregate, reinforced with steel fibers with lengths of 5 mm, 10 mm and 13 mm has been studied, analyzed and evaluated. Concrete designed with durability grade B15. The fiber content was used at two values, 0.5% and 1%. The test specimen has dimensions of 15x15x15 cm, after molding, it is cured at room temperature and tested at 28 days of age. Experimental results show that: The compressive strength of concrete using 10% recycled coarse aggregate linearly increases with increasing fiber length. Compared to when using 5 mm steel fiber, an average increase was recorded of 9.5% when using 10 mm length steel fiber and 12.92% for 13 mm length steel fiber. Thus, using steel fiber can completely compensate for the loss of strength of concrete when using recycled coarse aggregate.

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