Available online www.jsaer.com

Journal of Scientific and Engineering Research, 2016, 3(6):454-459

Research Article

ISSN: 2394-2630
CODEN(USA): JSERBR

Study on effect of fiber content to slump and compressive strength of concrete

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Abstract By using method of laboratory experiments, this study evaluates the effect of fiber content to slump index and compressive strength of concrete. The polypropylene fiber content of sampling concrete groups are inturn: 1,0kg/m^3; 1,3kg/m^3; 1,6kg/m^3; 1,9kg/m^3 và 2,2kg/m^3. The results show that the influence of fiber content to slump very clear; affect the compressive strength is not great, but affects the rate of formation is relatively clear intensity. At a certain limit, while fiber content increases, the slump of the mixture will decrease and the strength of concrete will increase. Proposed reasonable fiber content of should be 1.6 - 1,9kg /m^3.

Keywords Slump index, Compressive strength, fiber content.

Introduction

There have been many studied on the world on concrete using fiber reinforced with fibers such as steel fiber, glass fiber, mineral fiber, lignin fiber and polyester fiber. These studies often focus on the effect of fiber in concrete components, affect level to the features of the concrete mixture and concrete, selection of suitable fiber for use, or determining the optimal fiber content.

By studying on concrete using basalt fiber, Jongsung Sim [1] concluded that tensile strength of this mixture is 1.5 ÷ 2 times greater than conventional concrete and elongation can be reach 4 ÷ 6 times higher.

Dias D P, Thaumaturgo C et al., [2] showed that: comparing to conventional concrete, when reinforced basalt fiber content is 2,65kg/m^3, compressive strength and cracking tensile strength (pull when pressed split) increased 26.4%, respectively and 12%; bending tensile strength increased to 45.8%. Several studies in China indicated that the influence of polyester fiber to the compressive strength and cracking resistance of concrete is clearer than glass fiber [3]; basalt fibers have great impact in improving the properties of concrete, proposed reasonable fiber content is 0.2 ÷ 0.3% of mixture volume [4]; when using basalt fiber for concrete level of 30, with fiber contents in turn are 0%, 0.1%, 0.2% and 0.3%, the 28-day compressive strength always increases and the largest value is of 31.5%; as for concrete level of 50, compressive strength increases and decreases more slowly increases with the amount of increase or decrease is not significant [5]; as the fiber content improves some features of the concrete also improve markedly, in which compressive strength, tensile strength and bending tensile strength are the most prominent [6-7]. In Vietnam, there were several studies such as Doan Thi Thu [8] researched to improve the features of composite jute/ Polypropylene plastic; Nguyen Hung Phong [9] experimentally studied of shear reinforcement for concrete beams reinforced with fiberglass panels; Dang Van Thanh [10] studied the effects of fiber and factors affecting the properties of SMA.

By studying the results of previous studies shows: the conclusions are provided from the scientific experimental results, however, the number of experiments, systematic, and comprehensive are still limited; with the same study problem, the same influencing factors but the results are not completely identical, even are contradictory results; the number of studies on concrete using polypropylene fiber are not many, furthermore, there is no study on the influence of polypropylene fiber content to the basic features of the concrete .

In this paper, we use laboratory experimental methods, through indicators to slump and compressive strength, for studying the influence of polypropylene fiber content to the workability and strength of concrete mixture.

Material and Methods

Materials

Binder: Using Portland cement with technical properties are shown in Table 1.

Table 1. Typical properties of cement

N^o	Test	Request
1	Compressive strength	
	- 3 days (± 45 minutes)	≥ 21 N/mm^2
	- 28 days (± 8 hours)	≥ 40 N/mm^2
2	Setting time	
	- Intial	≥ 45m
	- Final	≤ 375m
3	Fineness:	
	- The amount of 0,09mm sieve	≤ 10 %
	- Blain rate	≥ 2800 cm^2/g

Aggregate: Using fine aggregate which is according to ASTM C331.

Fiber reinforced: using Polypropylene fiber. Photos of this fiber and some specific technical characteristics are shown in Figure 1 and Table 2.

Figure 1: Polypropylene fiber

Table 2: Properties of Polypropylene fiber

Name of properties	Value
Proportion	0,91 g/cm^3
Extreme elongation	15%
Fiber diameter	18 ÷ 48µm
Fiber length	6 ÷ 19mm
Melting temperature	160 ÷ 170^0
Tensile strength	≥ 460MPa
Acid and alkali resistance	Strong
Elastic modulus	≥ 3,5GPa
Water absorption	None
Safety	No toxic material

Ingredient of concrete: the selected level of concrete durability design is B15 (compressive strength of 20MPa average); ingredients of concrete are designed by experiment and theoretical method. The result is showed in Table 3.

Table 3: Selected ingredient of concrete

Stone – D (kg/m^3)	**Sand – C** (kg/m^3)	**Cement – X** (kg/m^3)	**Water – N** (litre)
1197	747	300	210

Test program

To assess effect of fiber content (symbol: P) to slump and compressive strength of concrete. We use 05 samples of concrete with the number of Polypropylene fiber contents are 1,0kg/m^3; 1,3kg/m^3; 1,6kg/m^3; 1,9kg/m^3 and 2,2kg/m^3. The other compositions (stone - D, sand - C, cement - X and water - N) are determined according to design (showed in table 3).

The slump and compressive strength of concrete are determined according to ASTM C143 [11] and ASTM C1314 [12].

Results and Discussion

The effect of fiber content to slump of mixture

The slump of mixture after 01-minute and 30-minute finishing kneading are showed in Table 4.

Table 4: The effect of fiber content to slump

Slump of mixture (cm)							
01 minute - S_1				**30 minutes - S_{30}**			
N_1	**N_2**	**N_3**	**Av**	**N_1**	**N_2**	**N_3**	**Av**
8.5	8.5	8.0	8.3	7.0	6.5	6.0	6.5
8.0	8.3	8.0	8.1	6.5	6.3	5.5	6.1
8.0	7.5	6.0	7.2	6.3	6.0	5.5	5.9
7.0	7.0	6.5	6.8	6.0	6.0	4.5	5.5
6.5	6.0	5.0	5.8	4.5	4.5	4.0	4.3

From the result, we illustrate the relationship between fiber content and slump in figure 2.

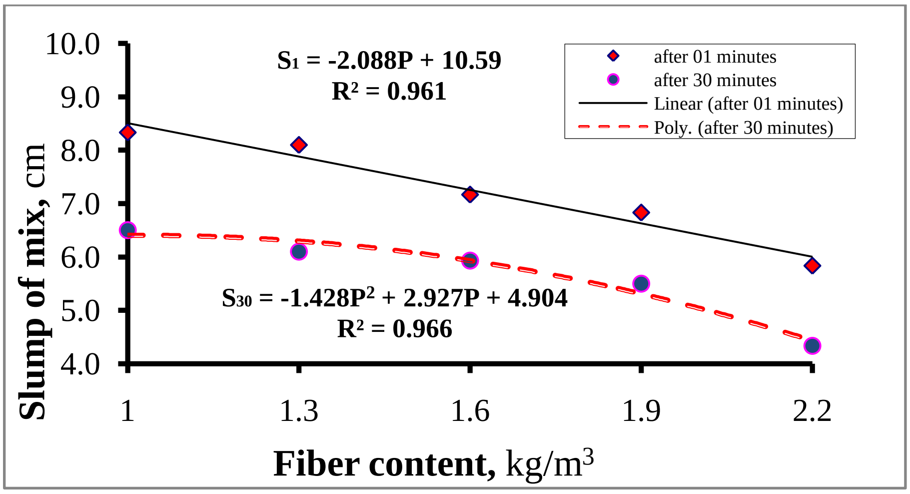

***Figure 2:** Relationship between fiber content and slump*

From the experimental results in Table 4 and Figure 2 show that: the slump of concrete mixture decreases as reinforced fiber content increases: when reinforced fiber content is 1kg/m^3, initial slump (S_1) is 8.3cm and the slump after 30 minutes (S_{30}) is 6.5cm; when the reinforced fiber content is 2.2kg/m^3, initial slump is 5.8cm and slump after 30 minutes is 4,5cm; the decreases are in turn 30% and 33.3%.

This shows the effect of fiber content to slump of the concrete mixture is very clear. In concrete mixtures fiber is distributed uniformly throughout respective positions with different dimensions, creating a connecting space network and holding aggregate particles; furthermore, fiber is also capable of resisting lubricating and holding cement mixture (cement and water) on the surface to create the adhesion between fiber and other components; thus this creates huge internally linking force inside the mixture, making flexibility of the aggregate reduces, slump of concrete mixture reduces.

Comparison between the initial slump and slump after 30 minutes showing that, the slump after 30 minutes of the mixture is also significantly reduced: when the reinforced fiber content is 1 kg/m^3, the initial slump is 8.3cm and after 30 minutes it is 6.5cm (decrease 22%); when reinforced fiber content is 2.2kg/m^3, the initial slump is 5.8 cm and 4.3 cm after 30 minutes (decrease 25.7%)

This shows that, while reinforced fiber content increases the time holding slump of mixture decreases. This can be derived from several reasons: reinforced fiber as well as a catalyst to further accelerate the curing process of mixture. The uniform distribution of fiber to all positions and under different dimensions in the mixture makes cement mixture is uniformly distributed over the thinner thickness, thereby the hardening speed, crystallizing to form compressive strength will be faster. Therefore, the concrete mixture has greater fiber content, the workability (slump) of the mixture decreases sharply over time. From on this characteristic, the concrete construction using reinforced fiber, to ensure quality and slump, it is necessary to use increased plasticizing additives, pay attention to accelerate the construction process and to ensure the construction schedule.

Within the scope of the study, equation 1 and 2 as follows can be used to evaluate the relationship between fiber content and slump of the concrete mixture after 1 minute and after 30 minutes:

$$\mathbf{S_1 = -2.088P + 10.59} \quad (1)$$

$$\mathbf{S_{30} = -1.428P^2 + 2.927P + 4.904} \quad (2)$$

The effect of fiber content to compressive strength

The experimental result of compressive strength of concrete samples at 7 days (R_{b7}) and 28 days (R_{b28}) are showed in Table 5.

Table 5: The effect of fiber content to compressive strength

P (kg/m^3)	**Compressive strength** (MPa)							
	07 days – R_7				**28 days – R_{28}**			
	N_1	**N_2**	**N_3**	**Av**	**N_1**	**N_2**	**N_3**	**Av**
1.0	17.5	17.4	17.9	17.6	22.3	22.0	22.7	22.3
1.3	18.2	18.0	18.5	18.2	22.8	22.5	23.1	22.8
1.6	18.8	18.6	18.7	18.7	22.8	23.0	23.1	23.0
1.9	18.9	19.3	19.4	19.2	23.1	23.0	23.2	23.1
2.2	19.0	19.0	18.3	18.8	22.6	22.5	22.0	22.4

From the result, we construct the relationships between fiber content and compressive strength of concrete. They are showed in figure 3.

From Table 5 and Figure 3 shows that the concrete strength changes when reinforced fiber content changes, however, this change is not so big. When the fiber content varies from 1.0kg/m^3 to 1,9kg/m^3, compressive strength of the 28-day concrete sample tends to gradually increase: the lowest is 22,3MPa as fiber content is 1,0kg/m^3, the highest is 23.1MPa as fiber content is 1,9kg/m^3. When the fiber content exceeds 1,9kg/m^3 to 2.2kg/m^3, compressive strength of the concrete samples tend to decrease.

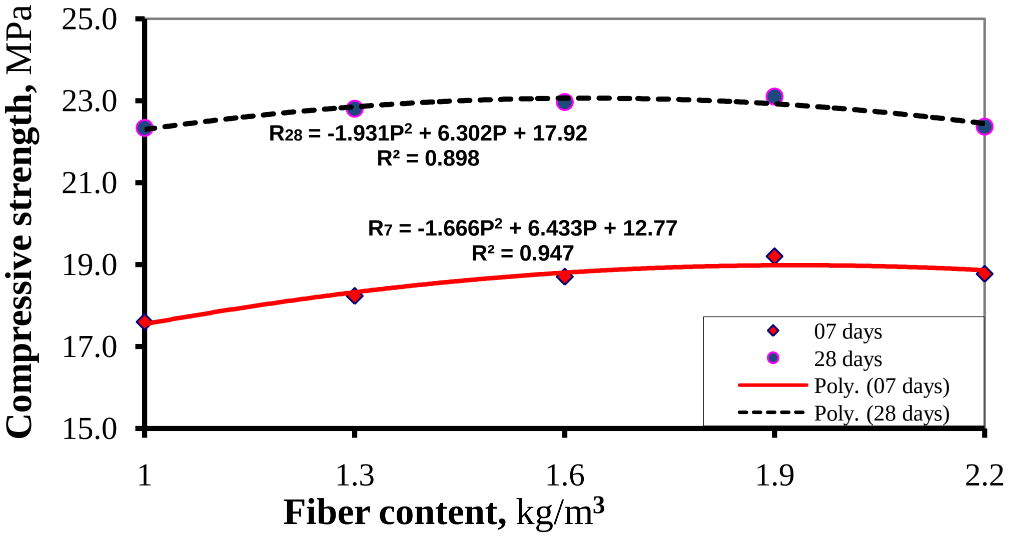

Figure 3: Relationships between fiber content and compressive strength

It can be concluded that, effect of reinforced fiber content to the compressive strength is not so great; increase or decrease the fiber content in a determined range will not make compressive strength of concrete change very much.

With the fiber content varies from 1.0kg/m^3 to 1.9 kg/m^3, compressive strength of the 28 day concrete sample tends to gradually increase. This is due to, in concrete mixture, fiber is capable of uniformly distributing throughout the positions with the different dimensions creating a connecting space network and holding the aggregate particles; furthermore, fiber is also capable of resisting lubricating and holding cement mixture (cement and water) on the surface to create the adhesion between fiber and other components; thus this creates a bigger bond forces linking within mixture contributing to increase of the bearing strength of concrete.

When the fiber content in the interval of 1,9kg/m^3 to 2.2kg/m^3, compressive strength of the concrete samples tend to decrease. This can be explained due to 3 major reasons:

Firstly, as there is a large amount of reinforced fiber in mixture, it inevitably needs a large amount of cement paste for lubricating and coating the fiber surface, while the amount of cement paste made of samples is fixed, therefore to a certain extent in the mixture will lack cement paste. The layer of cement paste for coating and lubricating surface will be thin or lacked in several positions of aggregates. This reduces the connectivity among concrete components, thereby making to reduce the strength of concrete.

Secondly, due to physical characteristics and mechanical properties of fiber: compressive strength of fiber is smaller than that of aggregate, as the fiber content in the mixture is significantly (exceed a certain limit), total volume of fiber will occupy a significant space leading to a formation of mixed "weakness space" and widely distributing within the internal concrete. At a certain level, those "weakness space" will reduce the total compressive strength of concrete samples.

Thirdly, when amount of fiber in the mixture is abundant it can lead to an uneven distribution, fiber mixed up into bundles causing local weak; this not only adversely affects the quality of concrete but also causes fiber wastefully.

From experimental results, the other side shows that: in the early days of the maintenance period, the development of concrete strength using reinforced fiber is faster than that of normal concrete; the strength of the concrete samples increases faster as reinforced fiber content increases; if the strength of 28-day concrete is considered as a standard, as reinforced fiber content increasse, strength of 7 day concrete tends to reach nearly the strength of 28 day concrete, when the fiber content is 1.0; 1,3; 1,6; 1,9 và 2,2kg/m^3, compressive strength of the 7-day concrete samples are: 78.8; 79.97; 81.42; 83.12 and 83.90%, respectively.

This shows the influence of fiber content to development speed of concrete strength is also relatively clearly. In concrete mixture, fiber is capable of distributing evenly throughout every positions with different dimensions;

due to small size, using reinforced fiber can lead to the total surface area of the component materials per a unit volume of concrete greater than that os conventional concrete, this makes cement paste (cement and water) is spreaded more evenly distribution with a thinner thickness; therefore it enables the cement hydration process happens faster so that the hardening process and strenght formation process are also faster.

Within the scope of the study, the relationship between fiber content and compressive strength of concrete at 7 days and 28 days are described in equations 3 and 4.

$$\mathbf{R_7 = -1.666P^2 + 6.433P + 12.77} \quad (3)$$

$$\mathbf{R_{28} = -\ 1.931P^2 + 6.302P + 17.92} \quad (4)$$

Conclusion

The reinforced fiber content influences significantly to the slump of concrete mixture: slump decrease gradually as fiber content increases; the more fiber content increases, the more time for keeping slump decreases.

Reinforced fiber content affects the compressive strength of concrete not so much: at a certain limit, compressive strength increases when fiber content increases; however, as the fiber content exceeds the range of 1.6 ÷ 1.9 kg/m^3 concrete strength tends to decrease; nevertheless, the increase or decrease in strength are small (less than 5%).

With the concretes equivalent to the concrete level of B15, using similar materials, the influence degree between Polypropylene fiber content to slump and compressive strength can be assessed by the equations 1 to 4 with a high confidence level.

Through the experimental results and analysis, synthesis of the influence of fiber content to slump and compressive strength, we propose that reinforced Polypropylene fiber content in the reasonable range of 1.6 ÷ 1,9kg/m^3, and plasticizing additives should be used in order to ensure the workability of construction.

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